INTERNATIONAL HYPOTHERMIA CONFERENCE AND WORKSHOP

University of Rhode Island, Narragansett, Rhode Island 02882
Division of Marine Resources, (401) 792-6211
Marine Advisory Service, Coastal Resources Center

INTERNATIONAL CONFERENCE ON HYPOTHERMIA

January 23-25, 1980, Kingston, Rhode Island, U.S.A.

Hypothermia is the condition of lowered internal body temperature, caused by exposure to cold air or water which can result in death. Recent statistics seem to indicate that hypothermia is the major contributing factor in approximately one-third of all drownings in the United States. In fact, the Royal Navy estimated that two-thirds of their World War II fatalities were from drowning and hypothermia. The rise in heating fuel costs may increase hypothermia-related deaths among the elderly and children in urban areas. Cold exposure has long been recognized as a major killer among outdoor and maritime workers and recreators.

While cold has always been a killer of man, the science of hypothermia and survival/treatment techniques is only an emerging technology. Consequently, this first International Conference on Hypothermia brought together many of the world's leading medical researchers and experts to present technical reports and papers on all aspects of accidental hypothermia, including prevention, treatment, and survival in urban, field, and aquatic environments.

This notebook contains the papers presented to the conference as well as supplemental articles and information distributed. These will be edited into a conference proceeding to be published later by URI. The notebook is organized into two parts: technical papers (alphabetically arranged by author) followed by miscellaneous articles (listed in the table of contents).

Hypothermia is preventable and survivable if properly identified in time. During the conference, the 1970's were labeled the decade of development of survival equipment; all hoped that the 1980's will be called the decade of development of treatment. We can see what is needed, now let us all work together to keep warm and alive.

Neil W. Ross
Conference Chairman

NWR/mmm

HYPOTHERMIA CONFERENCE NOTEBOOK
TABLE OF CONTENTS

Acknowledgements
Schedule of Conference
List of Speakers
Papers and Abstracts Presented

Baker, E.	A Study of Immersion Hypothermia
Bowman, W.	Prevention and First Aid of Accidental Hypothermia
Bradley, N.	Personal Flotation Devices for the Handicapped
Eggleton, R.	Non-Invasive Temperature Determination for the Hypothermia Victim under Field Conditions
Franz, D.	"Cold-induced vasodilation"
Goldman, R.	Publications List
Hamilton, R.	"Pressurized diving bell survival"
Hamlet, M.	Resuscitation of Accidental Hypothermia Victims
Harnett, R.	A Study of Immersion Hypothermia Part II: An Experimental Comparison of Methods for Rewarming from Deep Hypothermia in the Field
Hayward, J.	"Cardiac temperature during rewarming from hypothermia"
Hiscock, R.	Development of Exposure Suits by the Liaison Committee for Emergency Rescue Equipment
Keatinge, W.	Hypothermia - Past and Future
Kreider, M.	Cross Acclimation Between Severe Cold Exposure Producing Hypothermia and Exhaustive Exercise in Rats
Lloyd, E.	Airway Warming as a Method of Treatment for Accidental Hypothermia
Low, A.	Current Status of Hypothermia Therapy and Prophylaxis in Germany
McAniff, J.	The Incidence of Hypothermia in Scuba Diving Fatalities
Miller, J.	Application of Hypothermia
Miller, Jon	Accidental Hypothermia: 103 Cases
Mills, W.	Accidental Hypothermia
Nicodemus, H.	Inotropes During Hypothermia and Rapid Rewarming
Nixon, D.	Legal Aspects of Hypothermia Training
O'Brien, E.	A Study of Immersion Hypothermia
Oksenhold, E.	Hypothermia Protocol
Pozos, R.	Influence of Breathing Hot Humidified Air on the Amplitude of Shiver
Richardson, N.	Hypothermia: Brochure for Girl Scouts of USA
Smith, D.	Drowning Facts & Myths, Part II
Steinman, A.	Airway Rewarming & Afterdrop Panel Report
Suess, S.	The Breath Heater and Humidifier for Breathing Apparatus
Wittmers, L.	Effect of Alcohol on the Diving Reflex

Miscellaneous - Publications

Golden, F.	Immersion: Some Advice on First Aid and the Nature of the Problem
Johanson, D.	Physiological Responses of Human Subjects Wearing Thermal Protective Clothing Assemblies in Varying Environments
Belanger, R.	Hypothermia Wrap
US Dept. of Transportation	Resuscitation from Hypothermia: A Literature Review
USCG Newsletter	10 Swim at Pt. Judith and Emerge Warm, Dry

USCG	A Closer Look
US Dept. of Commerce	Cold Water "Drownings" Need Not be Fatal
URI	Polar Bears Warned: Keep Away from Alcohol
Sea Grant	Hypothermia and Survival
Keiffer, E.	Survival Techniques in Cold Water
Prov. Journal	10 Swim at Pt. Judith and Emerge Warm, Dry
Pratt, R.	Summary of Cold Water Survival Courses
Maime Commercial Fisheries	Survival Training Saves Sidelinger
Johnston Fire Dept.	Water & Ice Rescue
Armstrong, B.	Living Aboard
Dempewolff, R.	If You're Drowning...Here are brand-new ways to save your life!
Red Cross	Hypothermia by Exposure to Cold
Krupa, G.	Body-temperature Drop is Cited in Woman's Underwater Survival
Cooke, R.	The Water Was so Cold It Helped Save Her Life
Bangs, C.	Survival in Winter
DeLapp, T.	Taking the Bite Out of Frostbite and Other Cold-Weather Injuries
Altman, L.	Unnoticed Loss of Body Heat Can Kill
National Safety Council	Leading Causes of all Deaths

ACKNOWLEDGMENTS

The 1980 INTERNATIONAL HYPOTHERMIA CONFERENCE AND WORKSHOP acknowledges with appreciation the generous funding and services from the following organizations.

1. U. S. COAST GUARD
2. UNIVERSITY OF RHODE ISLAND
   - MARINE ADVISORY SERVICE/SEA GRANT
   - DEPARTMENT OF PHYSICAL EDUCATION
   - COLLEGE OF NURSING
   - BAY CAMPUS DIVING PROGRAM
3. NATIONAL SEA GRANT, NOAA
4. UNDERSEA MEDICAL SOCIETY, INC.
5. MOBIL OIL CORPORATION
6. RHODE ISLAND BOATING COUNCIL, INC.
7. AMERICAN RED CROSS
8. OUTDOOR EMPIRE PUBLISHING CO.
9. RHODE ISLAND DEPT. ENVIRONMENTAL MANAGEMENT
10. NEW ENGLAND MARINE ADVISORY SERVICE

INTERNATIONAL HYPOTHERMIA CONFERENCE AND WORKSHOP

INTERNATIONAL HYPOTHERMIA CONFERENCE

SCHEDULE

Wednesday, January 23, 1980 University of Rhode Island (White Hall Lobby)

8:00 am - 8:30 am Registration

8:30 am - 8:45 am Opening (Auditorium)
Neil W. Ross, Conference and Workshop Chairman
University of Rhode Island Marine Advisory Service, Sea Grant

8:45 am - 9:30 am Welcome: Frank Newman, President, University of Rhode Island
Keynote Address (Auditorium)
Dr. William R. Keatinge, "Hypothermia: its past and future"
London Hospital Medical College, London, England

9:40 am - 12:30 am Concurrent presentations

I. Hypothermia Treatment (Auditorium)

Moderator: Dr. James Palker, USN Submarine Research Laboratory, Connecticut, USA

Bangs, Cameron. "Current Management of Hypothermia," Oregon, USA

Eggleton, R.C. "Non-invasive Temperature Determination for the Hypothermia Victim Under Field Conditions." Indiana University School of Medicine, Indiana, USA

Harnett, R.M., et al. "An Experimental Evaluation of Methods for Treatment of Profound Accidental Hypothermia." Clemson University, South Carolina, USA

Hamlet, Murray. "Resusitation of Accidental Hypothermia Victims." U.S. Army Research Institute of Environmental Medicine, Massachusetts, USA

II. Hypothermia Physiology (Room 204)

Moderator: Dr. Charles Shilling, Undersea Medical Society, Washington, D.C., USA

Hayward, John. "Cardiac Temperature During Rewarming for Hypothermia." University of Victoria, British Columbia, Canada

Nicodemus, H.F. "Inotropes During Hypothermia and Rapid Rewarming." Naval Medical Research Institute, Maryland, USA

Wittmers, Lorentz. "Effects of Alcohol on the Diving Reflex." University of Minnesota, USA

Pozos, Robert S. "Effects of the Temperature of Inspired Air on the Amplitude of Shiver." University of Minnesota-Duluth, Minnesota, USA

12:30 pm - 2:00 pm Luncheon (Butterfield Cafeteria)

2:00 pm - 4:30 pm   Concurrent panel discussions (White Hall)

Clinical Diagnosis and Monitoring Hypothermia (Room 206)
*Dr. William Keatinge, London Hospital Medical College, London, England
Dr. Reginald Eggleton, Indiana University School of Medicine, Indiana

Field Recognition and Management of Frostbite and Hypothermia (Room 204)
*Dr. Cameron Bangs, mountain rescue specialist, Oregon
Dr. John Hayward, University of Victoria, Vancouver, Canada

Urban Hypothermia of Elderly, Children, Alcoholics and Handicapped (Room 110)
*Dr. Robert Pozos, University of Minnesota, Minnesota
Nancy Bradley, University of Minnesota, Minnesota
Dr. Jon Miller, University of Louisville, Kentucky
Dr. Daniel Danzl, University of Louisville, Kentucky

Training Applications of Hypothermia Technology (Room 202)
*Nancy Richardson, Girl Scouts of USA, New York
Fay Ainsworth, Outdoor Empire Publishing, Inc., Washington
C.P. Dail, American National Red Cross, Washington, D.C.
Robert Pratt, University of Maine, Sea Grant, Maine
David Smith, United States Coast Guard, Missouri

*Moderator

4:30 pm - 5:00 pm   "Mamalian diving reflex" (Auditorium)
Edward Rupert, International Association of Dive Rescue Specialists, Colorado
Dr. Alan Steinman, U.S. Coast Guard, Washington, D.C.

5:00 pm - 7:00 pm   Return to motels

7:15 pm - 10:00 pm   Buffet Dinner and Cabaret Show (Memorial Union Ballroom) (cash bar)

Thursday, January 24, 1980

8:30 am - 12:30 am   Concurrent presentations (Auditorium)

III. Hypothermia Case Studies

Moderator: Dr. Barbara Tate, College of Nursing, University of Rhode Island, Rhode Island

Lloyd, Evan. "Inhalation Rewarming." Royal Infirmatory, Edinburgh, Scotland

McAniff, John J. "The Incidence of Hypothermia in Scuba Diving Facilities." University of Rhode Island, Rhode Island, USA

Smith, David S. "Drowning Facts & Myths, Part II." U.S. Coast Guard, Second District Missouri, USA

Bowman, Warren. "Prevention and First Aid of Accidental Hypothermia." National Ski Patrol System, Inc., Montana, USA

Bradley, Nancy. "Multiple Factors that Influence the Safety of Physically Handicapped People in Cold Water." University of Minnesota-Duluth, Minnesota, USA

Mills, Evan. "Accidental Hypothermia in 50 Alaskan Case Studies." Alaska, USA

Thursday, continued

- Hypothermia Protection Equipment (White Hall, Room 204)

Moderator: John Bernhartsen, United States Coast Guard Headquarters, Washington, D.C.

Hiscock, Richard. "Lisison Committee on Emergency Rescue Equipment Studies of Exposure Suits (1943)." Massachusetts, USA

O'Brien, E.M. "Experimental Evaluation of the Effectiveness of Hypothermia Protection Equipment." Clemson University, South Carolina, USA

Goldman, Ralph. "Insulation Against Heat Loss in Air and Water Environments." U.S. Army Research Institute of Environmental Medicine, Massachusetts, USA

Baker, E. "Simulation of Immersion Hypothermia Protective Devices." Clemson University, South Carolina, USA

Suess, Stephen E. "The Breath Heater and Humidifier for Breathing Apparatus for Divers." University of California, California, USA

12:30 pm - 2:00 pm Luncheon (Butterfield Cafeteria)

2:00 pm - 4:30 pm Concurrent panel discussions (White Hall)

Airway Rewarming and Afterdrop (Room 110)
*Dr. Alan Steinman, United States Coast Guard, Washington, D.C.
Dr. R. Michael Harnett, Clemson University, South Carolina
Dr. Lorentz Wittmers, University of Minnesota, Minnesota
Dr. Erling J. Oksenholt, Oregon
Dr. Evan Lloyd, Royal Infirmatory, Edinburgh, Scotland

Hypothermia Nomenclature (Room 225)
*Dr. Murray Hamlet, U.S. Army Research Institute of Environmental Medicine, Massachusetts
Dr. Reginald C. Eggleton, Indiana University School of Medicine, Indiana

Preventing Hypothermia: Protective Clothing and Survival Equipment (Room 206)
*Dr. John Hayward, University of Victoria, Vancouver, Canada
Dr. Robert Pozos, University of Minnesota, Minnesota
Dr. Ralph Goldman, U.S. Army Research Institute of Environmental Medicine, Massachusetts
Dr. Edward O'Brien, Clemson University, South Carolina

4:30 pm - 5:00 pm Open session for abstracts (Auditorium)

5:00 pm - 7:30 pm Dinner on own in town (car pooling encouraged)

7:30 pm - 10:00 pm Cold Water Survival (Tootell Pool Building)

a. Manufacturers' exhibits on survival equipment (East Gym)

b. Cold-water survival demonstration (pool)
Cmdr. David Smith, U.S. Coast Guard (street shoes not allowed on pool
Dr. Alan Steinman, U.S. Coast Guard deck; tennis shoes or bare feet)

c. Rhode Island Boating Council will host a cocktail reception starting at 9:00 pm (East Gym)

Friday, January 25, 1980

8:30 am - 10:30 am	Reports from afternoon panel discussions (White Hall Auditorium) (15 minutes from each panel)
10:30 am - 10:45 am	Coffee break
10:45 am - 11:30 am	Report from Training Standards Committee Dr. Robert Pozos, University of Minnesota
11:30 am - 12:00 noon	Conference summary and evaluation Neil Ross, Chairman
12:00 noon - 1:30 pm	Luncheon (Butterfield Cafeteria)
1:30 pm - 2:30 pm	Special post-conference workshop to identify needs (Optional) (White Hall Room 110)

INTERNATIONAL HYPOTHERMIA WORKSHOP — Kingston, Rhode Island

SCHEDULE

Friday, January 25, 1980

1:30 pm - 2:00 pm	Workshop welcome, program orientation (White Hall auditorium) Neil W. Ross, Conference & Workshop Chairman University of Rhode Island Marine Advisory Service
2:00 pm - 2:45 pm	Conference Report Dr. Robert Pozos, University of Minnesota
2:45 pm - 3:00 pm	Break
3:00 pm - 3:40 pm	Legal Aspects of Hypothermia Training Dr. Dennis Nixon, attorney, University of Rhode Island
3:40 pm - 4:00 pm	Accidental Hypothermia: an Overview of Urban, Field and Aquatic Environments. Dr. Murray Hamlet, U.S. Army Research Institute of Environmental Medicine
4:00 pm - 5:00 pm	Hypothermia Experts Reaction Panel Moderator: John Bernhartsen, U.S. Coast Guard (possible members include: Keatinge, Mills, Lloyd, Hiscock, MacInnis)
5:00 - 8:00 pm	Dinner on own in town (please carpool)
8:00 - 9:30 pm	Public Lecture: Ten Years Beneath the Artic Ice (Chafee, Room 271) Dr. Joseph MacInnis, Undersea Research Ltd., Toronto (adults $1.00, children 50¢, workshop participants free)

Saturday, January 26, 1980 (Tootell Pool Building)

Hypothermia 1

8:30 am - 12:00 noon Rotating Workshop Sessions (one hour each)

1. Outdoor Exposure Hypothermia (West Gym)
   Dr. Joseph MacInnis, Undersea Research Ltd.
   Dr. Warren Bowman, National Ski Patrol System
   Dr. Cameron Bangs, Oregon

2. Urban Hypothermia (Room 123)
   Dr. Richard Pozos, University of Minnesota

3. Hypothermia Education (Room 122)
   Fay Ainsworth, Outdoor Empire Publishing, Inc.
   Robert Pratt, University of Maine Sea Grant
   Frank Pia, Water Safety Films, Inc.

Hypothermia 2

8:30 am - 9:30 am — Immersion Hypothermia (Room 100)
Dr. John Hayward, University of Victoria
David Nagle, Coastal Rescue Training Center
Dr. Alan Steinman, U.S. Coast Guard

9:30 am - 11:30 am — Cold Water Survival Equipment & Rescue (Pools - bare feet only)
Cmdr. David Smith, U.S. Coast Guard
and Hayward, Nagle, Steinman

10:00 am - 4:00 pm — Public program (free)
a. Observe pool sessions (Gallery)
b. Visit exhibits (East Gym)
c. Survival Movie Theatre (East Gym)
d. Outdoor pond demonstrations at noon (Tootell Pond)

12:00 noon - 1:30 pm — Hot soup and bag lunches Participants only. (Room 100)

12:00 noon - 1:00 pm — Cold Water Survival Suit Demonstration (outdoor Tootell Pond)
by Hypothermia 2 volunteers
Public and Hypothermia 1 may watch

12:20 pm - 12:40 pm — Ice Rescue Demonstration (outdoor Tootell Pond if iced over)
by Johnston (R.I.) Fire Department - Vincent Monti & staff

Hypothermia 1

1:30 pm - 2:30 pm — Immersion Hypothermia (West Gym)
2:30 pm - 5:00 pm — Cold Water Survival Equipment & Rescue (Pools - bare feet only)

Hypothermia 2

1:30 pm - 2:30 pm — Outdoor Exposure Hypothermia (Room 122)

2:30 pm - 3:30 pm — Urban Hypothermia (Room 122)

3:30 pm - 3:45 pm — Break (Room 100)

3:45 pm - 5:00 pm — Hypothermia Education (Room 122)

5:00 pm - 6:30 pm — Return to motels

6:30 pm - 7:00 pm — Car pool to Jamestown Island in Narragansett Bay

7:00 pm - 9:30 pm — Hypothermia Banquet (Bay Voyage Inn)

Speaker: Dr. Cameron Bangs, Oregon
"Mountain Rescues Survived"

Sunday, January 27, 1980 (Tootell Pool Building)

8:30 am - 9:30 am — Hypothermia Workshops - Self Selection for further discussion, dialog, sharing and practice in sessions of choice.

1. Outdoor Exposure: (Room 122)
Bowman, MacInnis, Bangs

Sunday (continued)

	2. Urban environments (Room 123)
	3. Education, Hypothermia Handbook, A/V Aids (Room 100) Ainsworth, Pratt, Pia
	4. Aquatic Rescue, Unconcious Victim, HELP, Huddle (Shallow Pool) Harold Anderson, Gerald Dworkin, Mike Angell
	5. Cold Water Immersion Physiology, MDR (West Gym) Hayward, Steinman
	6. Immersion Survival Equipment (Diving Pool) Smith
9:30 am - 10:00 am	Coffee Break (Room 100)
10:00 am - 11:00 am	Self selected Workshops continue 1 - 6 repeat and continue, plus this new session: 7. Scuba Rescue and Hypothermia Issues (East Gym) McAniff
11:00 am - 12:00 noon	Great Survival Equipment Pool Race (Diving Pool) Competition between participant teams; team members only on pool deck, all others to gallery seats. Race Director: Robert Pratt, U. Maine Judges: Harold Anderson, Red Cross John O'Leary, URI
12:00 noon - 1:15 pm	Buffet Lunch (Room 100) Free Swimming - time permitting (Pools)
1:30 pm - 2:45 pm	Hypothermia Program Planning Workshops (White Hall) An opportunity for organizations and programs to begin planning own hypothermia training. Groups of 8 or more (including Red Cross, Sea Grant, military), will be assigned rooms. Smaller groups use space as available. Each group should appoint a spokesperson/leader.
2:45 pm - 3:oo pm	Break
3:00 pm - 3:45 pm	Planning Reports from Organizations/Groups (Auditorium) Moderator: Chris Duerr, Conference/Workshop publicity, URI Sea Grant
3:45 pm - 4:30 pm	Questions & Answers from Hypothermia Experts
4:30 pm - 5:00 pm	Workshop Wrap-up: Feedback and adjournment Neil Ross, Workshop Chairman, URI

Dr. E. R. Baker, M.D.
Systems Engineering Program
Clemson University
Clemson, SC 29631

~~. Cameron C. Bangs, M.D.
1400 Division Street, Suite 5
Oregon City, OR 97045

Dr. Warren D. Bowman Jr., M.D.
National Medical Advisor
National Ski Patrol System
Billings Clinic, Box 2555
Billings, MT 59103

Ms. Nancy Bradley
Hypo & Water Safety Institute
University of Minnesota
School of Medicine
2205 East Fifth Street
Duluth, MN 55812

C.P. Dail, Jr.
National Director First Aid Program
American Red Cross
17 & D Streets, NW
Washington, D.C. 20006

Dr. Reginald C. Eggleton, M.D.
Professor of Surgical Research
School of Medicine, Indiana Univ.
1100 W. Michigan Street
Indianapolis, IN 46202

Dr. Ralph F. Goldman, M.D.
Director, Military Ergonomics
ARIEM
Natick, MA 01760

Dr. Murray P. Hamlet, D.V.M.
Director, Exper. Pathology Div.
ARIEM
Natick, MA 01760

Dr. R. Michael Harnett, M.D.
systems Engineering Program
Clemson University
Clemson, SC 29631

Dr. John Hayward, M.D.
Dept. of Biology
University of Victoria
Victoria, B.C. Canada V8W 2Y2

Mr. Richard C. Hiscock
P.O. Box 218
545 Old Harbor Road
Chatham, MA

Dr. William R. Keatinge, Ph.D.
Department of Physiology
London Hospital Medical College
Turner Street, London, E128D, England

Dr. Evan LLoyd
Dept. of Anesthetics
Royal Infirmary
Edinburgh, Scotland

Mr. John McAniff
URI Diving Safety Officer
Dept. Mech Eng. & Physical Education
227 Wales Hall
Kingston, RI 02881

Dr. Joseph MacInnis, M.D.
Undersea Research Ltd.
178 Balmoral Avenue
Toronto, Ontario M4V 1J6, Canada

Jon W. Miller, M.D.
Univ. of Louisville School of Medicine
Dept. of Emergency Medicine
323 East Chestnut
Louisville, KY 40202

Dr. William J. Mills, M.D.
742 K Street
Anchorage, AK 99501

Cpt. H.F. Nicodemus, M.C., USN
Naval Medical Research Lab
NNMC, Navy Department
Bethesda, MD 20014

Dr. Dennis Nixon
Dept. of Marine Affairs
Washburn Hall
University of Rhode Island
Kingston, RI 02881

Dr. E. O'Brien, M.D.
Systems Engineering Program
Clemson University
Clemson, SC 29631

Dr. Robert S. Pozos, M.D.
Director, Hypo & Water Safety Inst.
Univ of Minnesota, Schl of Medicine
2205 East Fifth Street
Duluth, MN 55812

SPEAKERS (continued)

Dr. Erling Oskerholt
2930 W.Devil Lake Road
Lincoln City, OR 97367

Ms. Nancy Richardson
Marine Education Specialist
Girl Scouts of the U.S.A.
830 Third Avenue
New York, NY 10022

Lieut.Cmdr. David Smith
Boating Safety Branch
Second Coast Guard District
1520 Market street
St. Louis, MO 63103

Dr. Alan Steinman, M.D.
U.S. Coast Guard
C-KOM
400 Seventh Street, SW
Washington, D.C. 20590

Stephen Suess
Foundation for Ocean Research
San Diege, CA

Dr. Lorentz Wittmers Jr., M.D.
Hypo & Water Safety Inst.
Univ of Minnesota, Schl of Medicine
2205 East Fifth Street
Duluth, MN 55812

E. R. Baker, IV, Ph.D.
Associate Professor of Systems Engineering
Clemson University

Dr. Baker earned his BS and MS in Physics in 1970 and 1972 and his Ph.D. in Systems Engineering in 1975 from Clemson University. In 1975 he was appointed to the Systems Engineering faculty at Clemson University, where he is presently an Associate Professor. His primary interest is in large-scale system simulation.

ABSTRACT

SIMULATION OF IMMERSION HYPOTHERMIA PROTECTIVE DEVICES

E. R. Baker, IV
R. M. Harnett
J. L. Ringuest
Clemson University
Clemson, S. C.

The use of human subjects for testing immersion hypothermia protective devices is not without risk. Additionally, such in vivo tests can be used only to mild states of hypothermia (rectal temperatures not less than 35°C). A mathematical model capable of simulating a protected man under immersion conditions would be a viable alternative to human experimentation. No models presented in the literature were directly applicable to this situation. Several models were chosen from those presented in the literature and modified to simulate the presence of a protective device. Validation runs were made against data obtained by human experimentation in a concurrent study. The initial results were discouraging. To improve the model performance, several changes were made to the metabolic control subsystem. The modified models performed acceptably for certain classes of protective devices. The modified models are useful. However, further human experimentation must be done to provide more comprehensive data for use in the formulation of controllers. Additionally, the results may be improved by the inclusion of a more detailed passive model.

A STUDY OF IMMERSION HYPOTHERMIA

PART III:

Simulation of Immersion Hypothermia Protective Devices*

by

E.R. Baker, IV, Ph.D., R.M. Harnett, Ph.D., J.L. Ringuest

College of Engineering
Clemson University
Clemson, S.C. 29631

1.0 INTRODUCTION

The use of human subjects for testing hypothermia protection devices is not without risk. Additionally, such in vivo tests can be usec only to mild state of hypothermia (rectal temperatures not less than 35°C). A mathematical model capable of accurately simulating the thermal responses of a protected man in a cold environment would be an attractive alternative to human experimentation. In addition, the time required to perform the human experiments makes this alternative method of device evaluation extremely attractive.

1.1 Background

A variety of models have been proposed for the human thermal system. Some of the models have been established from experimentation while others have been constructed from the theories of thermodynamics and fluid mechanics. Some models predict the behavior of the whole body while others are specialized

* Sponsored by U. S. Coast Guard Office of Research and Development
Contract Number DOT-CG-72074-A

to a particular body segment. The interest in this research lies in models of the entire human body. Excellent reviews of the work in this field are available by Hardy (1972), Mitchell, et al. (1972), Shitzer (1972), Fan, et al. (1971), and Hwang and Konz (1977).

Mathematical models of the whole human body may be generally classified as single cylinder or multi-segment models. Further classification is accomplished by determining whether thermoregulation is internal or external to the model. Models with internal thermoregulation functions may be viewed as a composite of two submodels, one for the passive system (physical system) and one for the controlling system.

The complexity of models of the passive systems depends upon the number of body segments modeled, their geometries, the number of nodes and shells (layers of segment composition) attributed to each segment and the sophistication of the model circulatory system. The complexity of controller models range from simple function-evaluation types to those which compute error signals based on variables such as average skin temperature, core temperature and skin heat flux. All controllers determine metabolic rate and in some models, the control system also determines the sudometer (sweating) and vasometer (variable blood flow) responses.

The models are most generally expressed as a set of differential equations. Early models were solved using analog computers. The advent of larger, faster digital machines has resulted in most models now being programmed for digital computers. The solution methodology most often employed is that of finite differences.

1.2 Objectives

The objective of this research was to determine the feasibility of using an existing human thermal model in the evaluation of immersion hypothermia protection devices. To accomplish this task a review of the literature was conducted leading to the selection of candidate models representing the general types available. Computer codes for these models were obtained and modified as necessary to implement them on the computer system at Clemson University. These modifications of the computer-based models were not intended to accomplish basic structural changes to the models or to improve their intrinsic capabilities.

The selected candidate models were to be validated against the data collected from the human immersions discussed in Part I of this paper, see Harnett, et al. (1979). Based on the results of these validations, recommendations were formulated regarding the potential usefulness of each selected model. Also, the most important areas for model improvement were determined and recommendations regarding their priorities were developed for consideration prior to undertaking any efforts aimed at improving the capabilities of a model.

1.3 Scope

The scope of this effort included only an evaluation of existing models. No new model development or modification of existing models was required. However, in the course of implementing the computer-based models and experimenting with them, it was also possible within project cost and schedule constraints to develop and implement a number of substantive model modifications. These modifications improved the performance of the affected models and in some cases were necessary in order to give the models any chance of performing as required for the evaluation of cold water protection equipment.

2.0 MODEL SELECTION

After a review of the literature it was decided that this investigation would be limited to non-steady state models containing controllers. This decision was predicated on two facts: (1) the human response to cold water immersion was unlikely to be steady state and (2) we would be unable to externally control the model since no experimental immersion data was available which correlated metabolic rate, vaso-constriction and surface blood flow to the physical parameters of the model such as core, skin and water temperatures.

References were found in the literature to but a few models fitting these criteria. Conversations and correspondence with the authors of these models revealed several other unpublished models. However, these models were all reported to be very similar to those found through the literature search. The following five models were obtained: Stolwijk, (1972); Montgomery, (1972); Gordon, (1972); Kuznet, (1974); and Winton and Linebarger, (1971). An additional model, without a controller, Wissler (1966) was requested from its author; but this request was not granted.

These models represented several different philosophies in the modeling of both the passive and control systems. Stolwijk's and Kuznet's models had been used primarily for investigation of hyperthermia. The applications were in support of the NASA manned space flight program. Both models were implemented on Clemson's IBM 370/165 and exercised with test data as specified by their authors. Neither model, however, was modified for further evaluation. Stolwijk's model was dropped from further investigation because Montgomery's model was determined to be an extension of it which had been used for diving studies. Kuznet's model was dropped because of its similarity to both the Gordon and Montgomery models. The three remaining models, Winton's, Montgomery's and Gordon's were chosen because of the contrasts among them in terms of their general approaches and complexity.

The Winton and Linebarger Model

The Winton and Linebarger (1971) model is the simplest of the models studied. This model was intended for study of both the steady-state and transient response of the human thermoregulation system to various degrees of internal and external thermal stress. Emphasis in this model was placed on the feedback structure and controller mechanisms involved in thermoregulation. This model has been exercised using both analog and digital simulation.

Winton and Linebarger represent the shape of the body as a cylinder having three concentric layers. The inner-most layer represents the core of the body, which is composed of the deep tissues and internal organs. Surrounding the inner core is a middle layer made up of muscle and fat. The skin comprises the outer layer of the cylinder. For purposes of analysis the thermal properties of the three-layer model are represented by an analogous electrical circuit. The thermal system and its electrical analog are governed by identical differential equations which form the basis of this model.

Three primary control mechanisms are included in this model: sudometer, vasometer and metabolic. These control mechanisms are incorporated into the model by varying the related parameters of the circuit analog in an appropriate manner. Physiological studies have shown the importance of both core and skin themperatures in thermoregulation. Based on these studies feedback signals from the core and skin have been included in this model.

The Montgomery Model

The Montgomery model is an extension of the Stolwijk (1970) model intended to allow investigation of heat loss/gain during underwater diving work. Its thermoregulatory system is divided into two distinct subsystems: the physical-controlled subsystem and the dynamic-controlling subsystem. The controlled subsystem consists of the physical portions of the body.

The controlling subsystem contains the central hypothalamic thermo-integrator, the central set point temperature and associated afferent and efferent signal pathways. The controlling subsystem receives afferent signals from all portions of the body, integrates the signals, compares the results to the central set point and distributes the appropriate effector command signals to all portions of the body.

The controlled subsystem, Figure III-I,consists of the head which is considered a sphere and cylinders representing the trunk, arms, hands, legs and feet. Both arms, hands,legs and feet are represented,because of symmetry,by one

FIGURE III-1
SCHEMATIC OF THE
MONTGOMERY CONTROLLED SYSTEM

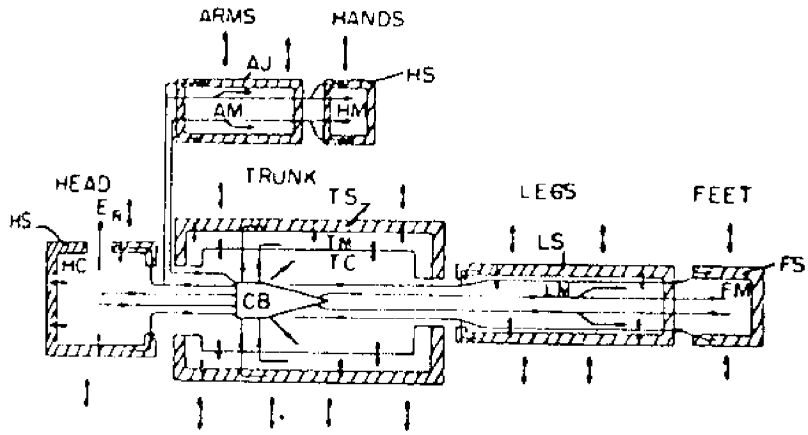
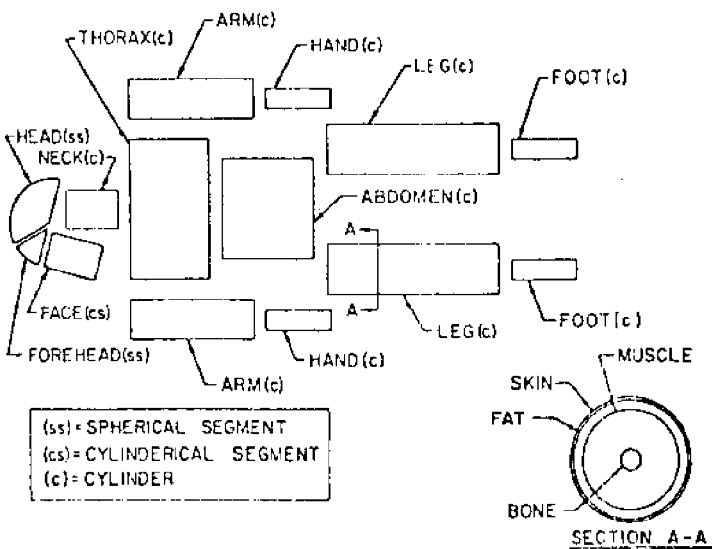


FIGURE III-2
SCHEMATIC OF THE
GORDON CONTROLLED SYSTEM



Body elements that comprise the passive system cylinder each. Each body segment is composed of eleven concentric layers: four representing the body core, four representing the muscle layer, and one each representing the body layers of fat and skin, and one representing the outer wet suit layer. A central blood compartment simulates the body's central blood pool which exchanges heat with all other body compartments, via convective heat transfer, through simulated blood flow to each compartment. Each of sixty-one body compartments is represented by a heat balance equation which accounts for internal heat generation, conductive heat transfer between adjacent compartments, and convective heat exchange with the central blood compartment. Where applicable, respiratory heat generation and heat loss are included in the body compartment heat equations. Additional heat balance equations represent a wet suit on the six body segments and include the effects of conductive heat transfer with the skin and conduction-convection with the ambient water. Each of the sixty-seven heat balance equations includes the thermal capacitance of the compartment enabling the transient response of the compartment to be simulated.

The Gordon Model

The Gordon model is the most complex of the three models examined. Gordon also divides the temperature regulatory system into two major subsystems: the passive subsystem and the control subsystem. The passive subsystem is divided into ten body segments. Cylinders are used to represent the neck, thorax, abdomen, arms, hands, legs and feet. A cylindrical segment represents the face and spherical segments represent the head and forehead. All segments consist of four concentric layers. Both the number of segments and the number of integration nodes per layer is variable. The model was implemented at Clemson with the segmentation described above and eleven nodes per segment. Both of these choices were used by Gordon in his initial validation of the model. They represent a logical balance between computational burden and numerical precision.

Since the body is modeled as concentric spherical or cylindrical shells, (Figure III-2) the governing equations were obtained by considering a shell of uniform properties. An energy balance equation is used for each shell. To complete the passive subsystem model, heat transfer involving the blood pool was modeled, including counter-current heat exchange between certain body elements and the blood pool. The partial differential equations (which from the energy balancing) are nonlinear and are solved by finite difference techniques.

The control subsystem in this model generates several "error signals" which are deviations of average skin heat flux, average skin temperature, and hypothalmus temperature from set-point values obtained passively during basal conditions (resting with no food in stomach). Combinations of these error signals are weighted to produce the control subsystem signal. The equations which describe this control signal make up the control system model. Although the original emphasis of this model was to simulate exposure to cold air, provisions were made for the future addition of a warm-environment controller. The computer code for the Gordon model was written in FORTRAN.

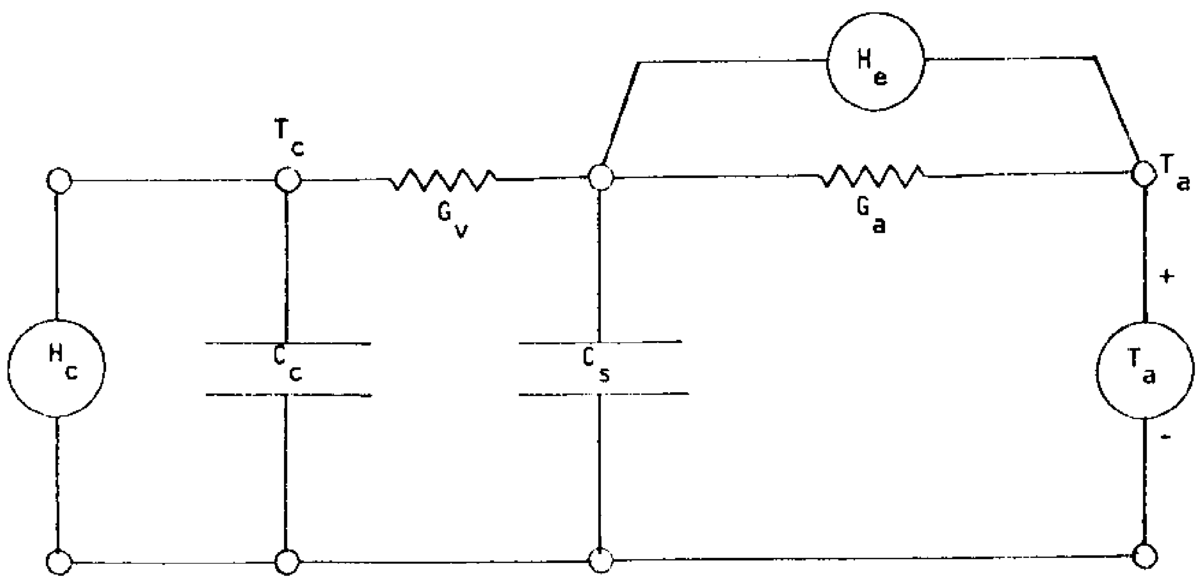
3.0 EVALUATION OF THE SELECTED MODELS

The models selected were modified to accept the inputs from the thermal testing described in the last chapter. This simplified the process of exercising the models for the variety of test articles considered in the study. It was also necessary to modify by adding a layer to represent the protection equipment. Further, it was necessary to modify the modeling of convective-conductive heat transfer at the interface with the environment to reflect the differences resulting from water as opposed to air immersion.

3.1 The Winton and Linebarger Model

The Winton and Linebarger model is the simplest of the three selected for evaluation. The three-layered cylinder used to model the body was represented by the electrical circuit analog shown in Figure III-3.

FIGURE III-3
WINTON-LINEBARGER 3-LAYER MODEL

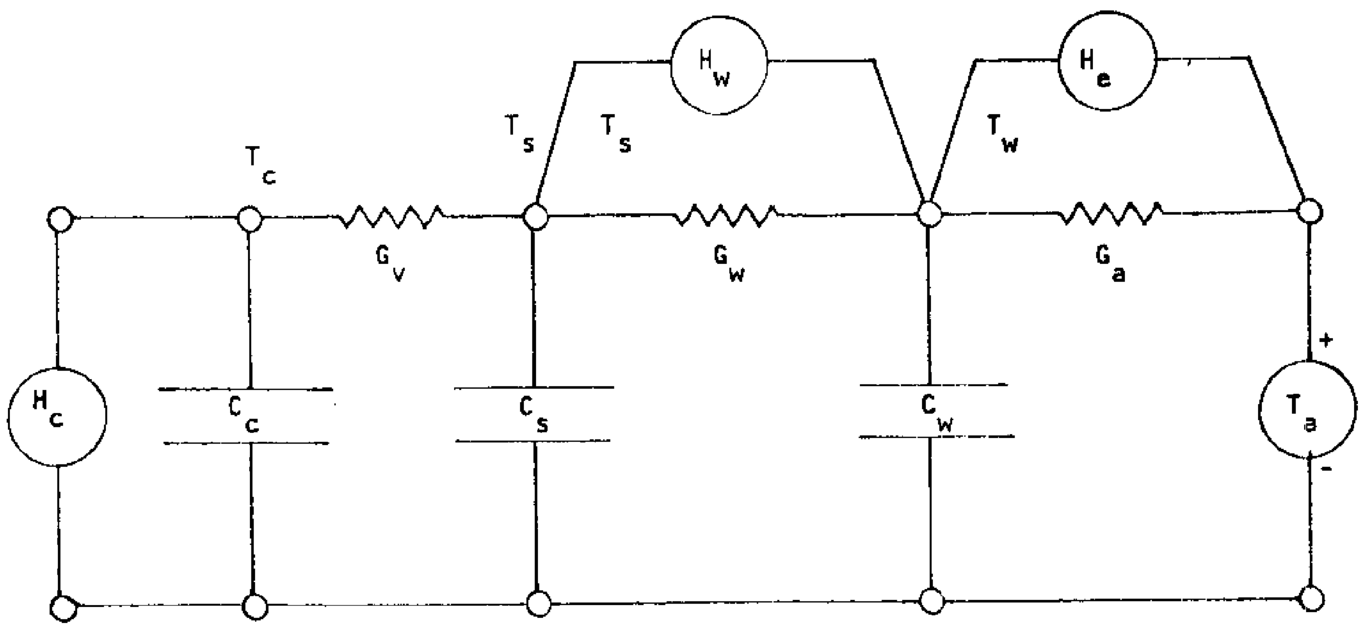


The model, originally implemented on an analog device was later written in CSMP. A CSMP version of the model was implemented and evaluated in this study.

In Figure III-3, H_c is a current source which represents basal metabolic thermogenesis, shivering thermogenesis and respiratory heat loss. G_v is a resistor representing the net heat conduction of the body tissues and G_a represents the net conduction from body to environment. C_c is a capacitor representing the heat capacitance of the body tissues except for the skin which is represented by C_s. H_e is a current source representing evaporative heat loss. T_a is a voltage source representing ambient environmental temperature and T_c and T_s represent core and skin temperatures, respectively.

To accommodate modeling of a thermal protective device it was necessary to modify the circuit in Figure III-3. Figure III-4 shows the modified model.

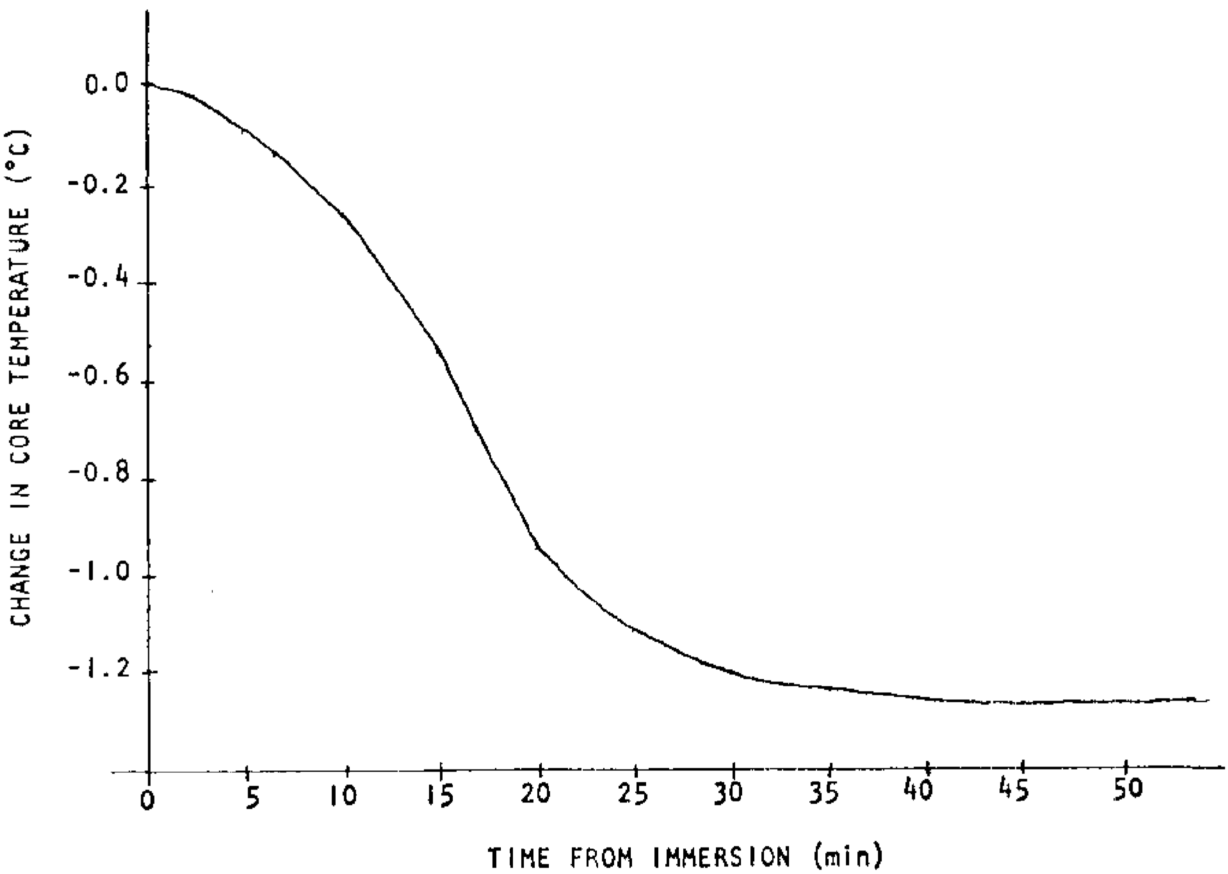
FIGURE III-4
MODIFIED WINTON-LINEBARGER MODEL



Here G_w represents the conductance of the protective device, and C_w its thermal capacitance. The current source, H_w, was included to allow the modeling of devices which, themselves, produce heat. T_w is the temperature of the protective device. For immersion simulation H_e is set for zero. All of the protective devices considered in this study are passive, so H_w was set to zero.

The model performed well considering its simplicity. Core temperature losses were of the same magnitude as those observed during a human immersion. The time trace itself however was not the same as is seen in Figure III-5. The model loses a significant amount of heat before the metabolic process can begin to compensate. The metabolic rate is driven as high as necessary to overcome the rate of heat loss and the model finally exhibits a plateauing.

FIGURE III-5
TIME-TEMPERATURE PROFILE
FROM WINTON'S MODEL



The initial large loss of heat, as reflected by a rapidly declining core temperature, is attributed in the main to the controllers inability to react to the high gradient experienced upon immersion. As with many models, Winton's was developed for use in estimating steady-state conditions. As a consequence, large continuing changes are required in core and skin temperatures before the metabolic rate becomes sufficiently elevated to overcome the rate of heat loss due to the immersion.

Making the model more useful for evaluating protective devices would require modification of the controlling subsystem. Because the model represents the surface of the subject as a single cylinder, it is applicable only to the study of full body protective devices. Some generalizations to this model are possible. With modification of the controller good estimates of cooling rate may be possible for full body suits. Since the model requires small amounts of both computer time and storage, there may be sufficient justification to warrant this modification effort.

3.2 The Gordon Model

As described in Section 2, Gordon represented the body by a set of spherical and cylindrical segments consisting of concentric layers. Each layer was subdivided to finally represent each segment as a set of partial differential equations across eleven nodes. Each node was centered in a shell of uniform material. The resulting equations are solved using finite difference techniques.

The addition of a protective device to this model required only two small changes to the model. An additional layer was modeled for each body segment covered by the device. Each segment originally had four layers. Because of the rapid transient temperatures to be experienced in this layer, it should be modeled with not less than two integration nodes, Wissler (1971). Thus, at a minimum, the model would consist of thirteen differential equations for each protected segment.

The second change required was in the control subsystem. In the original model, the controller is hooked to the last integration node, that of the skin. Since the model was built to accept a varying number of nodes per segment, the addition of the protective device would cause the controller to use as input temperatures and fluxes calculated for the furthest node from the segment core which would be protective device surface temperatures and fluxes. This is easily remedied in either of two manners. First, one may fix the number of nodes representing body in each segment thus affixing to the skin a constant node number. Alternatively the node number representing the skin may be calculated by including as input the number of nodes used to represent the protective device on each segment.

As mentioned above, the three models to be modified were first examined under conditions for which they had been designed. In this testing Gordon's model was found to be the best overall analog. Before modifications were made to model the protective device, the model was set up to simulate a nude cold immersion. As a result of these runs, a major problem was observed in the Gordon model. One would expect that, after an initial rise in core temperature, a decrease would occur which may or may not find an equilibrium level. The period of initial rise and the magnitude of the rise can vary. However, from experimental evidence one would expect the period to be relatively short with a magnitude of at most a few tenths of a degree celsius for a nude man in cold water. The Gordon model exhibited the initial increase upon immersion. However, the core temperature continued to climb as the simulated immersion continued. At the end of a 5-hour simulated immersion, the core temperature had reached approximately 42°C.

A re-examination of the model under the conditions for which it was validated by its author showed that the problem could have existed at that time. It was validated during relatively short (2 hour)simulations of exposure to cold air (5°C). Increasing core temperatures were expected during this period. Their appearance in the simulation results seemed to indicate that the model was working well. Unfortunately, the validations with cold air immersions did not extend into the time period when core cooling occurs. This problem was not observed in the initial testing at Clemson because the simulations were also of relatively short duration.

The Gordon model employs the most detailed modeling of the human physical structure of the three models examined. It was anticipated that it would prove to be the most accurate of the three selected models. For this reason, while it was not an objective of this effort to identify and correct modeling errors, an attempt to do so was made. The equations for the physical system were verified by rederivation. The coding was checked and several simplifications were made. However, the problem could not be identified. It was finally decided to terminate efforts to correct the Gordon computer code, in favor of concentrating on the Montgomery model.

3.3 The Montgomery Model

As suggested earlier, the Montgomery model is basically an adaptation of Stolwijk's model designed for use in evaluating the thermal aspects of diving activity. The model divides the body into ten compartments/segments. Each segment is subdivided into eleven concentric layers. Each compartment represents a lumped thermal capacitance with appropriate modes of heat production and heat transfer to other compartments. Each body layer generates metabolic heat at a basic rate and exchanges convective heat with the central blood pool. The eleven compartments of each segment exchange heat via conductive transfer with adjacent compartments as function of layer geometry and tissue thermal conductivity. Each wet suit segment exchanges heat with the environment as a function of wet suit properties and ambient water conditions.

The starting point in the development of the thermal network for a given subject is to estimate his percent body fat from his height and weight. His total surface area is also estimated from his height and weight. The surface area of each segment is then calculated from the total surface area.

The relative weights of the various segmental layers are calculated from the subject's total body weight and a percentage weight distribution. The various compartment weights, when multiplied by the corresponding specific heat value, yields the thermal capacitance value for each compartment. Since the core of each segment consists of both skeletal and visceral tissue which have different specific heat values, they must be treated separately and averaged.

The central blood compartment, representing the blood in the heart and the great vessels, is assumed to contain 2.5 liters of blood. The thermal capacitance of the central blood compartment is subtracted from the total thermal capacitance of the trunk core. The metabolic heat generation in each body compartment is calculated using the distribution given by Stolwijk and Hardy (1966).

The convective heat exchange that takes place between each body compartment and the central blood pool as a result of blood flow is calculated using the basal blood flow values for each compartment. The thermal conductances of each compartment are assumed to be uniform, concentrated at the compartment's center of mass and only dependent upon compartment temperature. Thermal conductance between layers is a function of the thermal conductivity of the material between compartments, the distance between compartments, the area of the heat transfer surface located at the mid-plane between compartments and the temperature of the two compartments.

The wet-suit-to-ambient-water heat transfer coefficients are dependent upon the geometric shape of the body segment, the ambient temperature and pressure; the viscosity, thermal conductivity, heat capacity and density of the surrounding water; and the water velocity relative to the body segment. Wet suit compartment thermal capacitance values are calculated as a function of wet suit specific heat and wet suit density for each segment.

The Stolwijk (1970) biothermal model was used to form a basis for the controlling subsystem. The first change that was made to the Stolwijk model was to provide more compartments to represent the core and muscle tissue of each body segment. Finite difference methods of solution using lumped nodes will produce errors when new gradients develop in the relatively thick muscle and core layers. This type of error may be decreased by introducing additional compartments in the core and muscle portions of the controlled subsystem. This method was used by Wissler (1964) to improve the simulated response to cold exposure.

The core and muscle portions of each segment were divided into four compartments, each having one-fourth of the core of muscle mass of the given segment. An additional compartment was also provided to represent the wet suit covering each body segment.

The effect of evaporative heat loss from the skin compartments is negligible under diving or totally immersed conditions. The evaporative heat loss from the trunk core is equal to that amount of heat that is carried away from the body during expiration of the respiratory gas. The quantity of heat loss from the respiratory tract for any gas mixture can be calculated from the physical properties of the gas mixture and the thermal and dynamic characteristics of the respiratory system. Respiratory heat loss is proportional to the respiratory minute volume, which is in turn related to the amount of oxygen required to provide energy for metabolic needs. The respiratory loss of heat is somewhat offset by the work of breathing. the net amount of evaporative heat loss from each of the trunk core compartments is taken to be one-fourth of the difference between the total respiratory heat loss and the total heat generation due to respiration.

Net heat flow into or from each compartment is then calculated. The skin compartment in each segment loses, through conduction to the wet suit, an amount of heat equal to the heat transfer coefficient multiplied by the temperature difference between the skin and wet suit compartments. Since a diver does not receive solar heat input and does not transfer radiant heat to his surroundings, the environmental heat transfer coefficients used by Stolwijk (1970) have been replaced by convective-conductive heat transfer coefficients between the wet suit and ambient water. The water-neoprene skin surface heat transfer coefficient is dependent upon the geometrical shape of the body segment; the ambient temperature and pressure; the viscosity, thermal conductivity, heat capacity and density of the surrounding water; and the water velocity relative to the body segment.

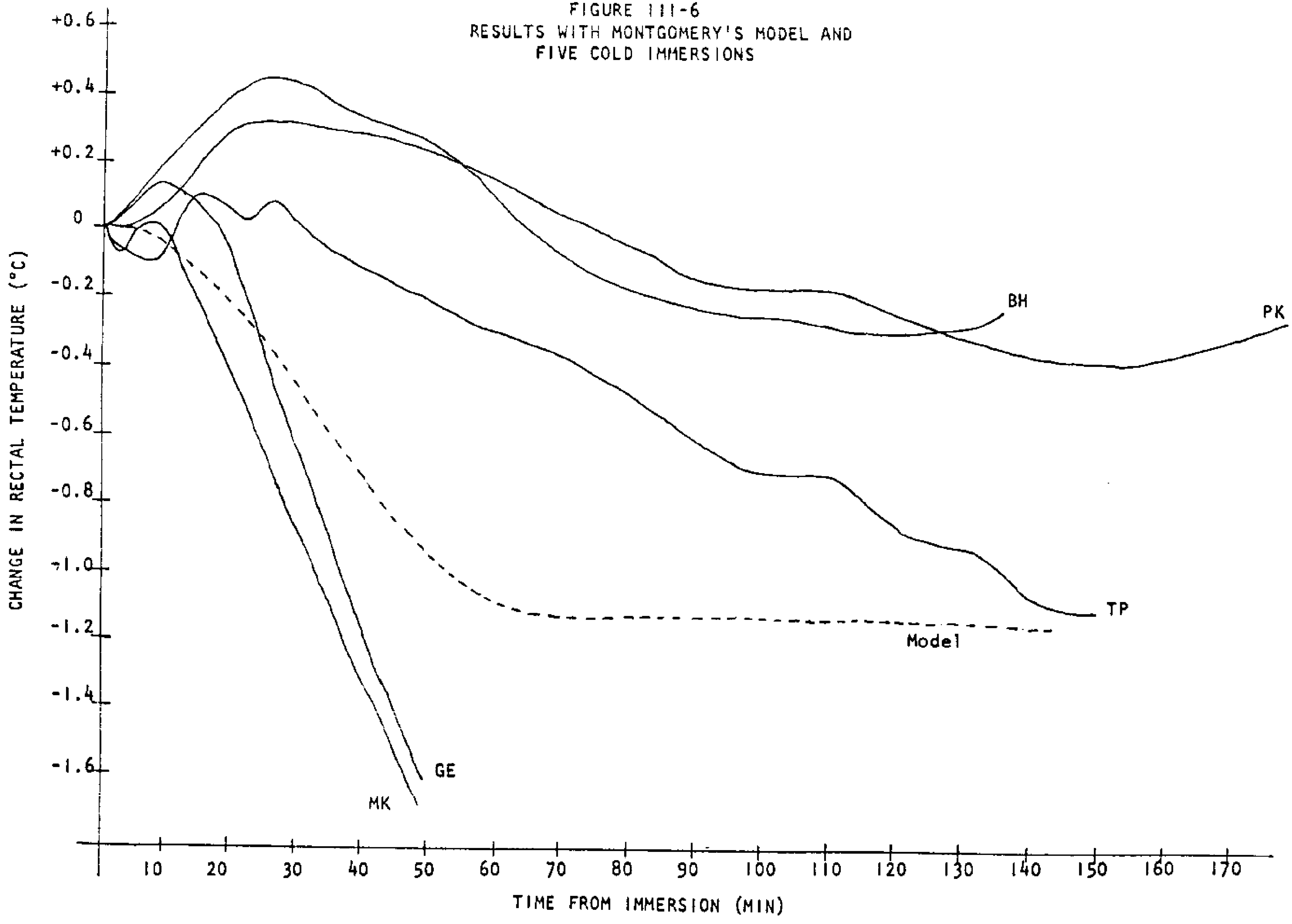
Little modification was necessary to the physical system of Montgomery's model since it already had provisions for an additional layer between the skin and environment. Initial modifications were directed toward increasing the flexibility of device modeling to allow simulation of other than full body suits. In addition, modifications suggested by Montgomery (personal communications) were implemented to simulate immersion of the body with the head and neck (modeled as a single segment) exposed to air. These changes were made in the WETMAN subroutine of the model computer code.

Typical Results with Montgomery's Model

Runs were made to simulate several of the devices included in the cold immersion test described in Part I of this paper. The results of one series of these simulations is shown in Figure III-6. The article modeled (WP) was a jacket-type device providing protection basically to the trunk and arms. The figure presents the simulation results, for a man 172 cm tall weighing 74.4 kg, and the experimental observations for five volunteers testing this device.

Considerable variation in response is exhibited by the five experimental observations, largely due to somatotype differences among the subjects. None of the individual responses is represented well by the model results. The model's metabolic control subsystem initially fails to recognize the heat drain caused by the cold immersion. This results in a too slow increase in the rate of thermogenesis and a rapid cooling shortly after immersion.

FIGURE III-6
RESULTS WITH MONTGOMERY'S MODEL AND
FIVE COLD IMMERSIONS



When the metabolic controller does recognize the loss it elevates the metabolic rate by large steps to compensate for the decline in average skin* and head core temperature. The result is a complete stabilization of core temperature.

Montgomery's Metabolic Rate Controller

The controller for metabolic rate formulated by Stolwijk and used by Montgomery calculates changes in metabolic rate based upon the following formulation.

$$\Delta MR = C_c \cdot (\Delta T_c + R_c \cdot T_c') + C_s \cdot (\Delta T_s + R_s \cdot T_s') + C \cdot (\Delta T_c + R_c \cdot T_c') \cdot (\Delta T_s + R_s \cdot T_s')$$

where ΔMR = change in metabolic rate

C_c, C_s, C, R_c and R_s are weighting factors

ΔT_c = deviation of head core temperature from a set point value

T_c' = rate of change of head core temperature

ΔT_s = deviation of average skin temperature from a set point value

T_s' = rate of change of average skin temperature

The weighting factors (constants) are defined as follows.

$R_c = 0$

$R_s = 0.03$

$C_c = 0$

$C_s = 0$

$C = 21.0$

The definitions of C_c, C_s and C were used by Stolwijk based upon the experimental evidence of Benzinger, et al. (1963). With these definitions the metabolic rate controller simplifies to the following.

$$\Delta MR = 21 \cdot \Delta T_c \cdot (\Delta T_s + 0.03\, T_s')$$

*Average skin temperature is defined as the average of the outer surface temperatures of each compartment, weighted by their proportional amounts of surface.

This simplified model is completely insensitive to the rate of head core cooling and is not particularly sensitive to the rate of skin cooling. The model is largely based on the amounts of cooling in these two temperatures and places essentially equal emphasis on the two. Initially, there will be a rapid decrease in average skin temperature but very little change in core temperature. This implies that the product in the above equation will be small, resulting in small increases in the metabolic rate, until there has been a significant decrease in head core temperature.

This helps explain the behavior of the model as depicted in Figure III-6. It is obvious then that there is considerable room for improvement in modeling metabolic control. While not included in the scope of this project, the development of a new controller was seen to be essential to a positive finding that a model can serve the purpose addressed in this study.

The validity of Montgomery's (Stolwijk's) metabolic controller for certain conditions (e.g., a nude man in cold air) has been shown by many people including Stolwijk. It was, as stated above, based on experimental data. It was decided, therefore, to formulate a new controller for the immersion environment based on the data collected in the human immersion portion of this study summarized in Part I of this paper.

Improved Metabolic Controllers

Relevant data available included rectal temperature at 15 cm, skin temperatures at the toe, thigh, forearm, bicep, groin and subscapular sites and periodic measurements of metabolic rate. The procedure used to develop the controller was to establish,through regression analysis, linear models relating changes in metabolic rate to changes in the rectal and skin temperatures. The basis of comparison for determining these changes were measurements made following a 30-minute rest period prior to commencing cold immersion.

The initial attempt was based upon regression analysis applied to the pooled sample of observations obtained in the laboratory. When the resulting metabolic controller was implemented in Montgomery's model, fair predictions of cooling rates resulted for most of the wet-mode suits but the predictions for the abandon-ship type dry suits were much worse.

The experimental data was then segregated in two subsets -- one obtained during immersion in 11.8°C water with wet-mode suits and one obtained during immersion in 1.7°C water with dry-mode suits. These data sets were analyzed separately to produce a metabolic controller for each condition. For the wet-mode suits the following model was obtained.

$$\Delta MR = 7.004 - 5.822 \cdot \Delta T_{th} - 2.407 \cdot \Delta T_f - 37.382 \cdot \Delta T_r$$

where ΔT_{th} = change in thigh temperature

ΔT_f = change in forearm temperature

ΔT_r = change in rectal temperature

This model had a correlation coefficient (R- value) of 0.77. The accuracy with which regression relations conform to the data is often expressed by "F test statistics". The significance of these statistics may be interpreted by the "level of significance" at which the hypothesis (that the observations follow the model) may be rejected. Small levels of significance indicate that the regression conforms well to the observations. The "level of significance" for this regression was 0.001.

The control model obtained from regression analysis of the data obtained with the dry-mode suits is the following.

$$\Delta MR = 1.987 - 2.654 \cdot \Delta T_t - 4.595 \cdot \Delta T_{th} - 5.361 \cdot \Delta T_b - 8.920 \cdot \Delta T_r$$

where ΔT_t = change in toe temperature

ΔT_b = change in bicep temperature

other symbols as previously defined

This model had a correlation coefficient of .85 and a "level of significance" of .0001.

These two relationships were implemented in the Montgomery model. It was necessary to accept some approximations in marrying the list of variables required by the controllers with those available in Montgomery's model. The variables were matched as follows.

Controller Variable	Model Variable
Toe temperature	Average foot temperature
Thigh temperature	Average leg temperature
Bicep temperature	Average arm temperature
Rectal temperature	Trunk core temperature

These approximations are unavoidable because of the simplifications involved in modeling the physical structure of the body in Montgomery's model.

Model Validation

The question of model validity is dependent upon the use to which the model is to be put. The objective in this case is to use the model rather than human experimentation as the basis to estimate the survival time associated with new developments in protection equipment. If one accepts the survival time model and prediction procedure presented in Part I, then all that is required of the model is a prediction of core cooling rate which may than be used to estimate survival time. This would relieve the need to be particularly concerned with absolute temperatures predicted by the model for various body sites or transient aspects of their profiles.

Based on this method for estimating survival time, model validity may be determined by establishing the accuracy of its predictions of the rate of core cooling. This may be done by performing statistical tests comparing the rates observed with the volunteer test subjects (Part I of this report) to corresponding rates predicted for them by the model. This data is naturally "paired" and so lends itself to paired analysis as a means of variance reduction. The "paired t test" described by Steel and Torrie (1960) was used for this purpose. The procedure is illustrated below. The test was run at the 0.05 level of significance with a two-tailed rejection region.

Null Hypothesis (H_o): There is no difference between mean simulated and mean experimentally observed cooling rates

Subject	Predicted Cooling Rate(°C/hr) Simulation	Experimental	Deviation (d) Simulation - Experimental
MK	1.037	2.510	-1.473
GE	1.472	1.800	-0.328
TP	1.100	0.556	0.544
BH	.697	0.391	0.30
PK	.621	0.244	0.376

$\Sigma d^2 = 2.808$ $\Sigma d = 0.575$ $n = 5$ (No. of pairs)

$$\bar{d} = d/n = 0.115$$

$$s^2_{\bar{d}} = \frac{\Sigma d^2 - \frac{1}{n}(\Sigma d)^2}{n(n-1)} = 0.137$$

$$s_{\bar{d}} = 0.367$$

$$\text{t-test statistic} = \bar{d}/s_{\bar{d}} = 0.310$$

Critical value of t at 0.05 level of significance with 4 degrees of freedom = 2.776

Since the calculated statistic is less than the critical value we cannot reject H_o.

A summary of these tests for each of the devices included in the cold immersion testing, except for the PFD is presented in Table III-2. From the table we observe that the model performed well for all of the wet-mode suits.

Those suits for which we must reject the hypothesis of sameness between model and observed average cooling rates are largely the abandon-ship suits. Reference to Figure I-I in Harnett et al.(1979) will help explain the models failure. The model "sees" all simulated immersions with the subject completely underwater from the neck down. As can be easily observed from the pictures of the flotation attitudes of these suits in Figure I-I, much of the upper surface areas covering the legs, arms and trunk of each of these suits is exposed to air. The heat transfer coefficient for air is much less than that of water. One would therefore expect the cooling rates predicted by the model for these devices to be greater than that observed in the

TABLE III-2
RESULTS OF PAIRED t TEST
WITH REGRESSION-BASED CONTROLLERS

TEST ARTICLES	Calculated Statistic	Critical Value @ 0.05 Level	Degrees of Freedom	Accept or Reject
Bayley Exposure Suit (PVC foam)	5.367	2.776	4	Reject
Bayley WeatherMate Plus	1.599	2.776	4	Accept
Helly-Hansen Survival Suit (D-600-0)	4.789	2.571	5	Reject
Henderson Zip-On Exposure Suit (2080-4)	5.237	2.776	4	Reject
Henderson Prototype Jacket	1.180	2.776	4	Reject
ILC Industries Prototype Survival Suit	0.387	2.776	4	Accept
Medalist Ski Shorty (7010)	8.172	2.776	4	Reject
Mustang U-VIC Thermofloat (1661)	0.009	2.776	4	Accept
NADC Goretex Experimental Coverall	9.102	2.571	5	Reject
Dr. S. B. Rentsch's Prototype Survival Suit (without respiratory heat reclamation)	1.289	2.776	4	Accept
S.I.D.E.P. Seastep Survival Suit	15.931	2.776	4	Reject
Stearns Windjammer Jacket (FJ-55)	0.416	2.776	4	Accept
Stearns Offshore Survival Jacket (FS-500)	1.823	2.571	5	Accept
Stearns Heavy-Duty Offshore Survival Suit (FS-71)	6.068	2.776	4	Reject
U.S. Air Force Modified Anti-Exposure Assembly (CWU-21/AP)	2.187	2.776	4	Accept

experimentation, as is the case.

The Stearns Heavy-Duty Offshore Survival Suit and the Henderson Zip-On Exposure Suit failed to pass the test. Reference to Figure I-1 shows the same type of flotation attitude for these suits as for the abandon-ship suits. In addition to the above-stated reason, the inadequacy of the controller may be contributory to their failure.

Model results for two additional suits failed the paired t test. In both cases the model-predicted cooling rate was faster than that observed from our testing. Again reference to Figure I-1 shows that both of these devices were tested with the subjects wearing a "water wings" type flotation device which exposed a significant amount of the trunk to the air. Additionally, the flotation device allowed the subjects to keep their arms and hands out of the water. Thus a faster predicted cooling rate from the model seems very reasonable.

Three suits passed the test which, by the above arguments, should have failed, the ILC prototype, Dr. Rentsch's prototype and the U. S. Air Force's CWU-21/AP. All three of these had simulation predicted cooling rates slower than we expected. For the ILC and Dr. Rentsch's prototypes this is most probably due to error in the estimation of their thermal conductivities. The estimated conductivities are, therefore, probably smaller than the reality. Thus while the model saw a completely submerged suit, it also saw a thermal resistance probably larger than reality. The combination of these two "errors" acted to cancel each other.

The average of the observed cooling rates was higher than the average of the model predictions for the CWU-21/AP. This suit, while ostensibly a dry suit, was observed to leak during testing, as noted in Part I. Since the only thermal protection was the thin dry shell and arimid underwear, it is reasonable to assume that the major portion of the thermal protection offered by the underwear was lost when it became wet. Thus the model may have expected more thermal resistance than probably existed in the experimentation.

If one is concerned only with the prediction of cooling rates, the model, when used on suits that do not expose a great deal of body/device surface to air, appears acceptable. Overall, cooling rates predicted by the model are faster than observed. Thus, in general the cooling rate obtained by simulation will lead to conservative estimates of survival time when used with the survival-time prediction model presented in Part I of this paper.

The failure of the model lies in its inability to accurately predict time traces of body temperatures. Figure III-7 shows a plot of rectal temperature as a function of time for two subjects wearing the U-VIC Thermofloat. The solid lines are plots from experimental data. Broken lines show the results obtained when the physical parameters of the two subjects were put into the model. Two important observations may be made. First, there is a complete absence in the simulation results of any initial rise in rectal temperature. Second, the average slopes of the observed and simulated rectal temperature traces (from maximal temperature to last observation) are very nearly equal. In fact, if the model traces are displaced to the right to coincide with the return of the experimental trace to entering temperature, the simulated and observed traces correspond very well. Since the slopes are approximately the same, the predicted cooling rates will be very similar. Thus the model was able to pass the paired t test even though the predicted and observed rectal temperature behaviors varied notably.

Tuning the Metabolic Controllers

For two of the human immersion tests we had the use of a Waters continuous reading oxygen consumption meter computer (MRM-1). The time profiles of metabolic rate observed using this device revealed several very interesting points. It was observed that immediately upon immersion the metabolic rate jumps by about 40 kcal/hr above a resting rate of approximately 70 kcal/hr. Since even the revised metabolic control models did not show this immediate increase, an experimental controller was constructed which included it as a constant. The resulting experimental controller for the wet-mode devices is the following.

$$\Delta MR = 40 + 1.237 - 5.339 \cdot \Delta T_{th} - 4.547 \cdot \Delta T_f$$

The last three terms of this experssion were obtained by regression and had an R-value of .69 and a level of significance of .04. For dry-mode suits tested in 1.7°C water, the 40 kcal/hr constant was added to the regression

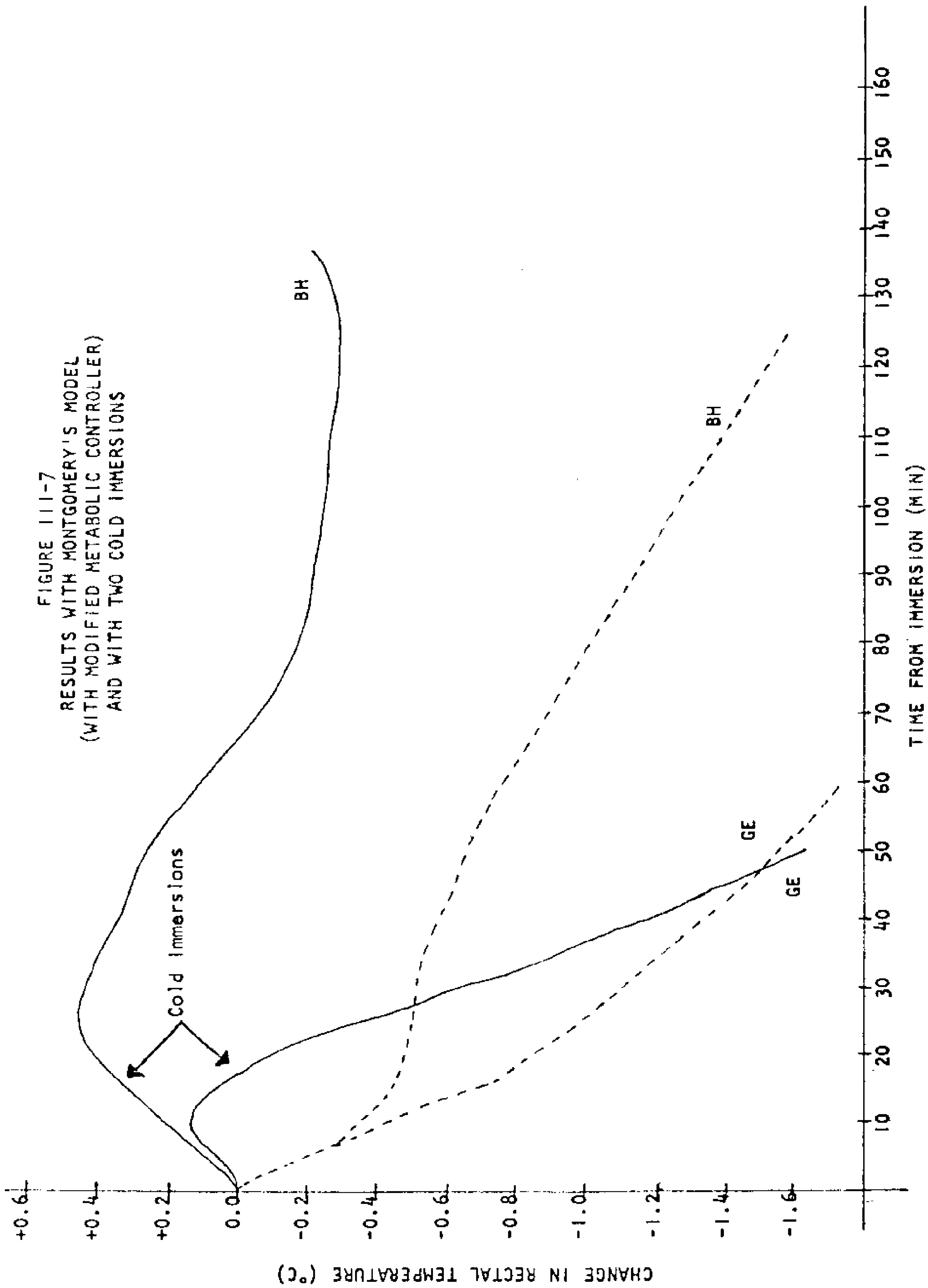


FIGURE III-7
RESULTS WITH MONTGOMERY'S MODEL
(WITH MODIFIED METABOLIC CONTROLLER)
AND WITH TWO COLD IMMERSIONS

equations determined above for these suits.

Figure III-8, shows the profile of change in rectal temperature for two subjects wearing the U-VIC Thermofloat. The observations are shown as solid lines while the simulation results are represented by the broken lines. The agreement between observation and simulation is much improved over that depicted in Figure III-7 for the modified controller based solely on regression.

Table III-3 presents the results of paired t test carried out between the simulation predicted cooling rates using these experimental controllers and those observed experimentally. The results are much the same as those presented for the modified controllers in Table III-2. The notable changes are the ILC prototype and Rentsch's prototype which fail now, exhibiting slower predicted than observed cooling rates as would be expected with a higher average metabolic rate. The increase in metabolic rate also helped the S.I.D.E.P. Seastep and Stearns Heavy-Duty Offshore Survival suits to pass the test. Overall, while these controllers are not as firmly supported by experimentation, the results are subjectively more satisfying.

Figure III-8 presents the profiles of three skin temperatures predicted by the model for an "average" man, as described in Part I of this report, versus the average results obtained experimentally. The experimental points are bracketed by one standard deviation. The profiles show only the first fifty minutes of the immersions. This is necessitated by the removal of one of the subjects at that time.

The profile of leg temperature predicted by the model, as shown in Figure III-8(a), lies outside of the bounds of the experimental data. However, the temperature plotted for the model is an average leg temperature while that plotted from experimental data is a thigh temperature. One would certainly expect an average leg temperature to be lower than a thigh temperature.

The profile of arm temperature is shown in Figure III-8(b). The initial deviation is due most probably to the rapid decrease in skin temperatures when the protective device initially floods with water. The model does not see this flooding and the simulated temperatures drop more slowly. In the model heat must be lost through the simulated device to the water. The frequent movement of the subjects (e.g., shivering) during the immersion helps to maintain some continual flushing. Thus the average arm temperature from the model would be expected to be somewhat warmer than that observed.

FIGURE III-8
RESULTS WITH MONTGOMERY'S MODEL
(WITH EXPERIMENTAL METABOLIC CONTROLLER)
AND WITH TWO COLD IMMERSIONS

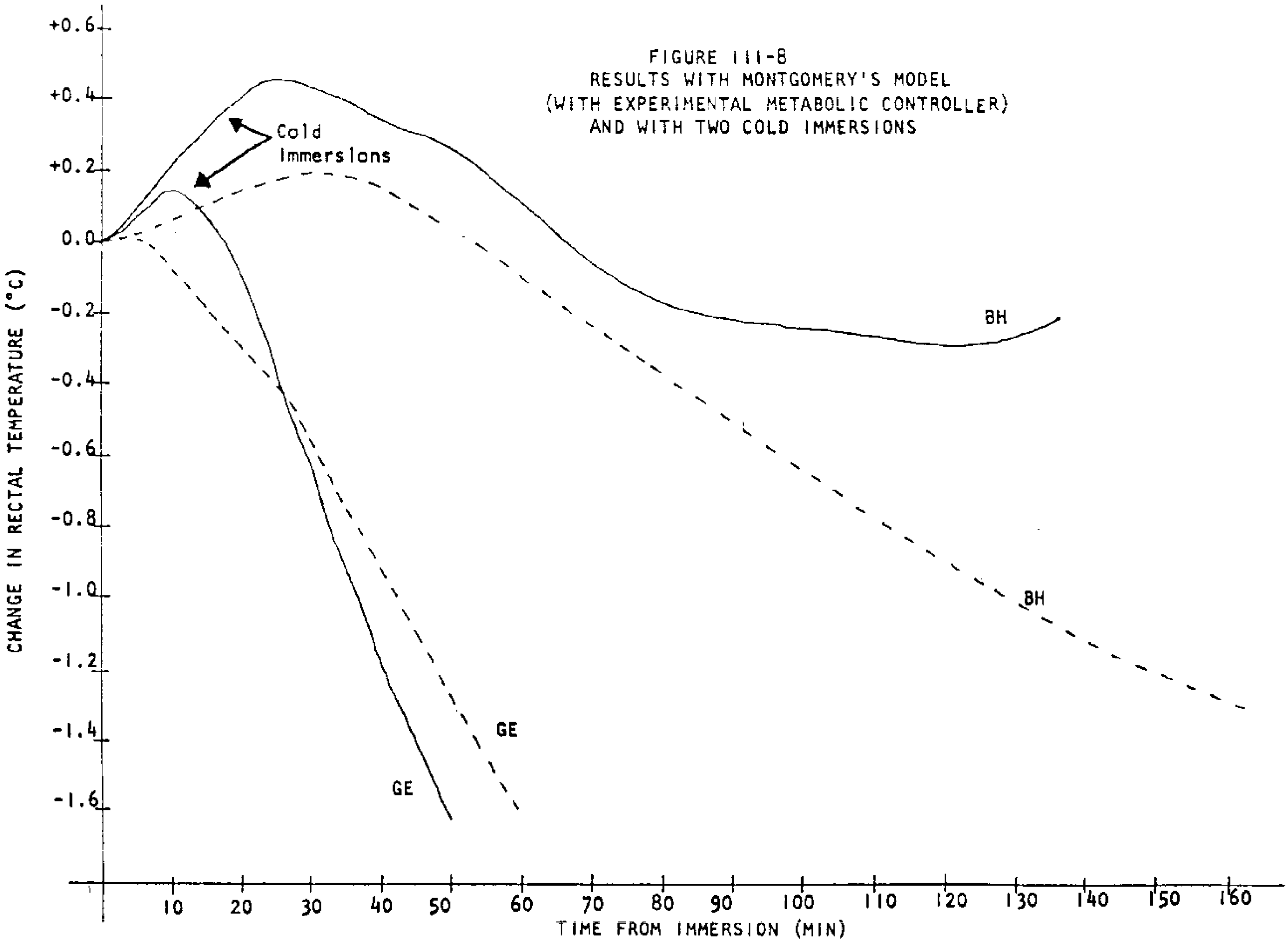


TABLE III-3
RESULTS OF PAIRED t TEST
WITH EXPERIMENTAL REGRESSION-BASED CONTROLLERS

TEST ARTICLES	Calculated Statistic	Critical Value @ 0.05 Level	Degrees of Freedom	Accept or Reject
Bayley Exposure Suit (PVC foam)	4.088	2.776	4	Reject
Bayley WeatherMate Plus	2.03	2.776	4	Accept
Helly-Hansen Survival Suit (D-600-0)	2.926	2.571	5	Reject
Henderson Zip-On Exposure Suit (2080-4)	4.552	2.776	4	Reject
Henderson Prototype Jacket	0.945	2.776	4	Accept
ILC Industries Prototype Survival Suit	4.750	2.776	4	Reject
Medalist Ski Shorty (7010) with Flight Suit	3.143	2.776	4	Reject
Mustang U-VIC Thermofloat (1661)	0.310	2.776	4	Accept
NADC Goretex Experimental Coverall	4.369	2.571	5	Reject
Dr. S. B. Rentsch's Prototype Survival Suit (without respiratory heat reclamation)	14.609	2.776	4	Reject
S.I.D.E.P. Seastep Survival Suit	2.597	2.776	4	Accept
Stearns Windjammer Jacket (FJ-55)	1.170	2.776	4	Accept
Stearns Offshore Survival Jacket (FS-500)	1.178	2.571	5	Accept
Stearns Heavy-Duty Offshore Survival Suit (FS-71)	1.706	2.776	4	Accept
U.S. Air Force Modified Anti-Exposure Assembly (CWU-21/AP)	1.323	2.776	4	Accept

FIGURE III-8(a)
LEG TEMPERATURE PROFILES

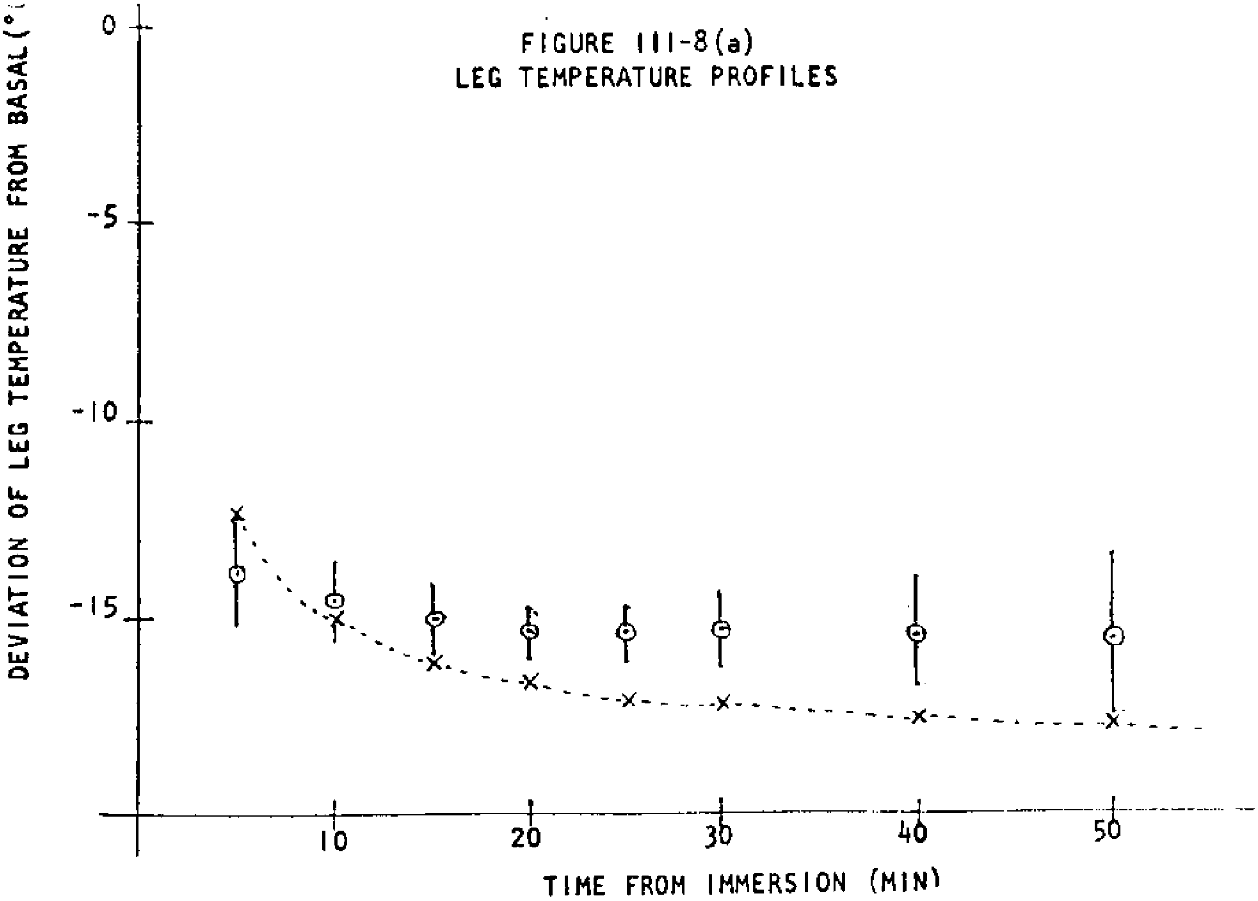


FIGURE III-8(b)
ARM TEMPERATURE PROFILES

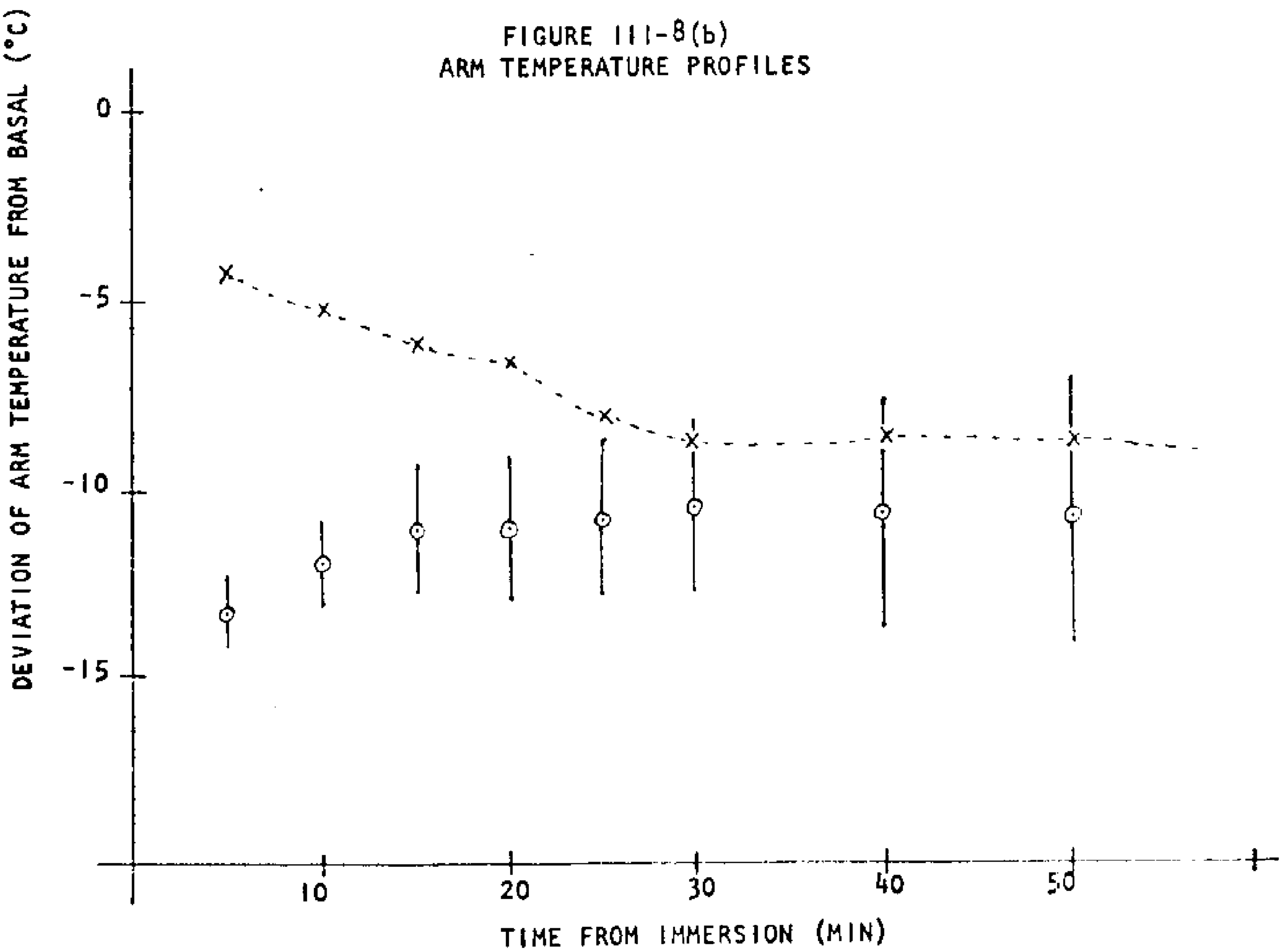


FIGURE III-8(c)
TRUNK TEMPERATURE PROFILES

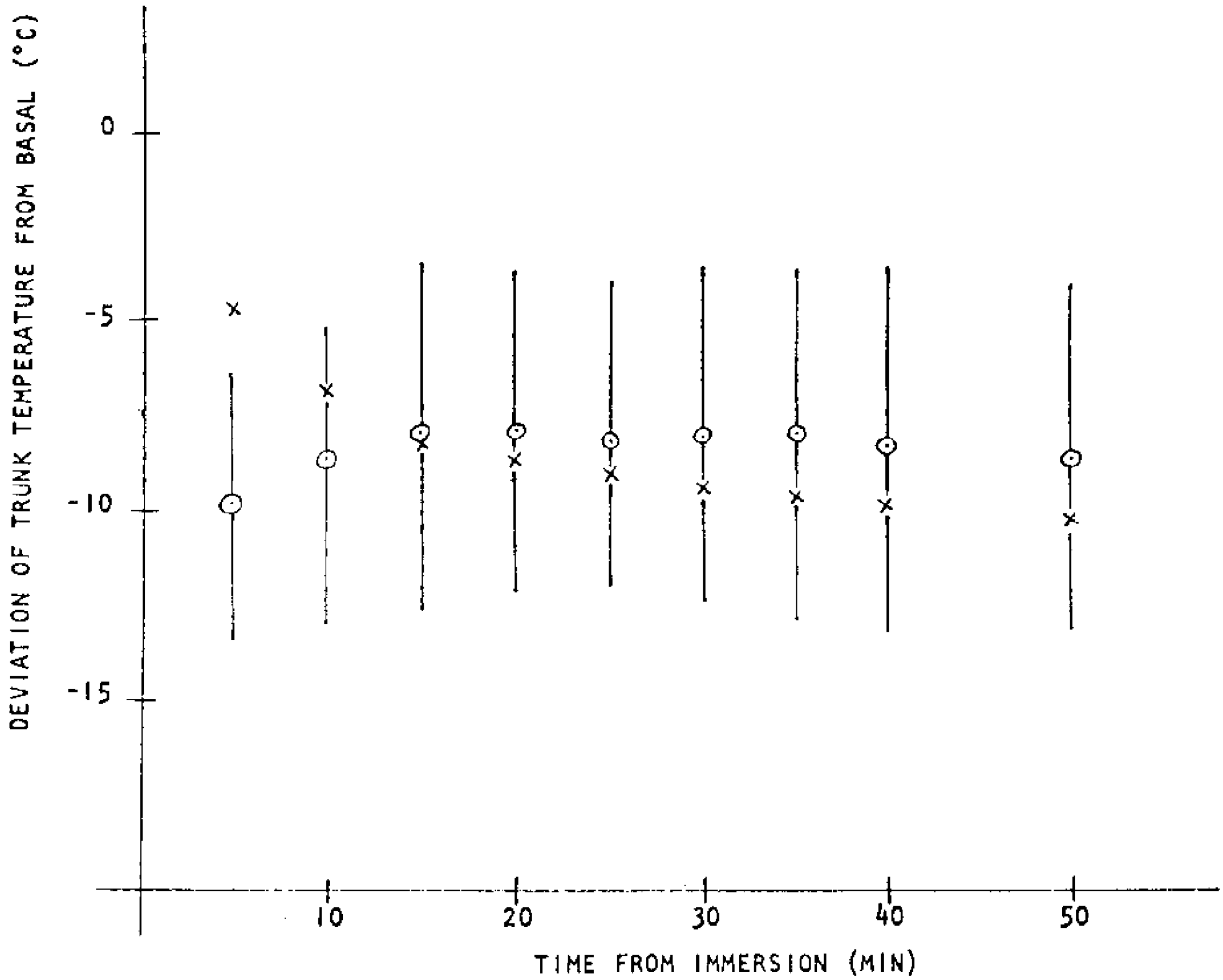


Figure III-8(c) shows the relationship between model predicted and observed temperatures for the trunk. Experimentally the trunk temperature was taken to be that monitored at the subscapular site. Again an initial deviation may be seen which is easily attributed to initial flooding of the suit. In the long run the experimental profile is at a slightly higher temperature level than the simulated one. The simulated data is for the average trunk temperature which might reasonably be expected to be cooler than the subscapular site.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The potential usefulness of a simulation model for evaluation of an immersion protective device is without question. In addition to eliminating the risk associated with human experimentation, there are economic advantages in conducting evaluations by simulation rather than by human experimentation. Furthermore, simulation of an immersion may be accomplished in a short time. The computer resources required by the model are small, most will run in under one minute of CPU time on an IBM 3033 and use less than 256k of core. The cost of a typical run made with Montgomery's model in this study was approximately $7.80. Obviously this is a much more economical approach than direct human experimentation.

An additional advantage lies in evaluation of new postulated designs. Currently, these designs must be fabricated and tested by human experimentation. Using a simulation model one need not physically construct the prototype. Rather, one need only describe it to the simulation model. Obviously, this approach would greatly increase the number of prototype devices which might be examined and the cost would be much reduced.

The modified Montgomery model, discussed in Chapter 3, represents a good start toward a useful model. One may be reasonably confident of survival times calculated from predicted cooling rates generated by this model. There is, however, some room for improvement. The major areas include: improvement of the controller, more detail in the physical model and improved methodology for the determination of protective device thermal properties.

The most immediate need is for an improved controller. Review of the literature has shown that all controllers presently in use were designed from data collected in low rate of heat loss experiments, generally nude cold air immersions. The validation of models with these controllers has been accomplished under the same conditions. There is no reason to expect that a controller thus developed will function correctly under the conditions one encounters during cold water immersions (e.g., high rates of heat loss).

As has been demonstrated, improved model performance may be obtained by using a controller developed from data collected during cold water immersions. The controllers investigated in this study were all based on simple deviations of temperatures at various body sites from predescribed resting temperatures for those sites. The behavior of the model, using a controller based solely on a linear regression of deviations in surface temperatures leaves much to be tried.

It was seen in Figure III-7 that a basic problem appears to be a too slow start of the metabolic furnace. That is, the simulated metabolic rate did not increase sufficiently, compared to the rate of heat loss, until a large rectal temperature drop occurs. This leads one to believe that controllers based on rate of heat loss, rate of change of various body site temperatures or whole or partial body heat flux may be required in order to obtain improved accuracy in temperature prediction from the model. One of the reasons Gordon's model was chosen for inclusion in this study was because its controller, unlike others, used whole body heat flux in determining deviation of metabolic rate from its basal level. Unfortunately, most of the experimental work has been carried out under low rate of heat loss conditions. That work which has been performed under conditions of high rates of heat loss has not been done with controller formulation in mind. One finds that metabolic rates were not always taken or if taken were taken at long intervals. During the human immersion portion of this study we observed a great deal of fluxation in metabolic rate as a function of time.

Improved controllers can certainly be developed with existing data. More human immersion work may need to be done continuously recording metabolic and temperature data in order to formulate an accurate controller. An attempt could then be made to correlate data collected in this fashion with data from low rate of heat loss work in order to develop a controller good for all modeling dealing with conditions of heat loss.

As was discussed in Section 3, most of the suits which failed the paired t test were believed to fail, at least in part, because of the model's inability to simulate the flotation attitude observed in the experimentation. The Montgomery model assumes immersion to the neck. Experimentally, it was often seen that much of the trunk, legs and arms was exposed to air. Obviously, the model should and did predict higher than observed cooling rates. Therefore, to be applicable to the evaluation of suits of this type (basically abandon-ship suits) the model should be modified.

An additional problem encountered with Mongtomery's model was the inability to properly describe some of the suits. The model represents the human body as composed of a complete head and trunk, complete arms, hands, legs and feet. There is no way to distinguish between thorax and abdomen, upper and lower arm or upper and lower legs. As a consequence, protective devices which only partially covered the extremities were modeled as not covering them at all (devices such as the Medalist Ski Shorty and U-VIC Thermofloat).

It is certainly possible to model this structure in more detail. As, for example, Gordon's model does. This affords one the capability to more accurately describe the physical structure of the device to be evaluated. One would expect this to lead to much more reliable predictions from the model.

No model thus far reviewed has the detail in the physical system to allow adequate description of flotation attitude. The inability is inherent in the modeling philosophy adapted by all authors. Specifically, each body element has been modeled as either a cylinder or a sphere. In order to derive the differential equations describing heat conduction within cylindrical body elements, a simplifying assumption has been made: all heat transfer is radial and uniform. To model an element partially exposed to air would necessitate consideration of longitudinal heat trarsfer. The derivation of model equations including this consideration would not be easy.

The changes necessary to give proper consideration to flotation attitude in the model may not be necessary. We have observed that parts of the legs, arms and trunk are exposed to air for some suits. In rough sea or other open water conditions the continual washirg of water over surfaces exposed to the air should result in a rate of heat loss very similar to that which would occur if the surface was continually covered by water. Under this assumption, the model's prediction of cooling rate may be very much in line with reality for these types of protection devices.

No method has been included in the modified Montgomery model for simulating flushing in wet-mode suits. Flushing is believe to do two things. First, it periodically places a large amount of cold water between suit and skin thus causing a rapid heat loss. Second, the water acts as additional insulation, once warmed, between the subject and his environment. Little is known of the dynamics of flushing and no attempt was made to include its effects in these simulations. In extremely rough water, flushing may play a significant role in increasing the rate of heat loss.

While many refinements may and should be made to Montgomery's model, its ability to pass a significant number of the paired t tests indicates its potential usefulness for predicting cooling rates and thus survival times. The model could, with the present modified controller, perhaps be used in screening devices prior to in vivo tests. In the long term, a modified model with improved physical definition of the body, provisions for simulating flushing and a more accurate controller would be very useful in the suit design and evaluation process. The physical system modification can be accomplished easily. The modification of the controller may require additional human experimentation.

6.0 REFERENCES

Benzinger, T. H., C. Kitzinger and A. W. Pratt (1963), "The Human Thermostat", Temperature - Its Measurement and Control in Science and Industry, J. D. Hardy (Editor), Vol. 3, pp 637-665, Reinhold, New York.

Fan, L. T., F. T. Hsu and C. L. Hwang (1971), "A Review on Mathematical Models of the Human Thermal System", IEEE Transactions on Bio-Medical Engineering, Vol. BME-18, pp 218-34.

Gordon, R. G. (1972), The Response of a Human Temperature Regulatory System Model in the Cold, Ph.D. Dissertation, University of California, Santa Barbara.

Hardy, J. D. (1972), "Models of Temperature Regulation - A Review" in Essays on Temperature Regulation, Bligh, J. and R. E. Moore (Editors) North-Holland-Amsterdam, American Elseview-New York, pp 163-186.

Hwang, C. L. and S. A. Kong (1977), "Engineering Models of the Human Thermoregulatory System - A Review", IEEE Transactions on Bio-Medical Engineering, Vol. BME-24, pp 309-325.

Kuznetz, L. M. (1970), 41-Node Transient Metabolic Man Program, MSC Program Number J196, NASA Manned Spacecraft Center, Houston, Texas.

Mitchell, D., A. R. Atkins and G. H. Wyndham (1972), "Mathematical and Physical Models of Thermoregulation", in Essays on Temperature Regulation, Bligh, J. and R. E. Moore (Editors), North-Holland-Amsterdam, American Elsevier-New York, pp 37-54.

Montgomery, L. D. (1972), A Simulation of Heat Transfer in Man Under Immersed Conditions, Ph.D. Dissertation, University of California, Los Angeles.

Shitzer, A. (1972), "Mathematical Models of Thermoregulation and Heat Transfer in Mammals", NASA Technical Memorandum, NASA TMX-62, 172.

Steel, R. G. D. and J. H. Torrie (1960), Principles and Procedures of Statistics, pp 78-80, McGraw-Hill Co. Inc., New York.

Stolwijk, J. A. J. (1971), "A Mathematical Model of Physiological Temperature Regulation in Man", Contract Number NAS 9-9531, Report Number NASA CR-1855, NASA, Washington, D. C.

Wissler, E. H. (1966), "A Mathematical Model of the Human Thermal System", Mathematical Biophysics, pp 147-166.

Wissler, E. H. (1971), "Comparison of Computed Results Obtained from Two Mathematical Models - A Simple 14-Node Model and a Complex 250-Node Model", J. de Physiologie, pp 455-458.

Warren D. Bowman, Jr., M.D.
The Billings Clinic
Ninth Avenue, North
P. O. Box 2555
Billings, Montana 59103

Dr. Bowman is the National Medical Advisor to the National Ski Patrol System, Inc. since 1970. He is Board Certified in Internal Medicine and Hematology, a Fellow of the American College of Physicians and of the International Society of Hematology, and a member of the American Society of Hematology. He is also a clinical assistant Professor of Medicine, University of Washington School of Medicine. Besides practical experience in treating frostbite and hypothermia, both in the field and in the hospital, he was a consultant to the section on cold exposure of the American Academy of Orthopedic Surgeons' publication "Emergency Care and Transportation of the Sick and Injured" and authored the "Winter First Aid Manual" and "Ski Mountaineering and Off-Area Rescue Supplement to the Winter First Aid Manual", both published by the National Ski Patrol System, Inc.

PREVENTION AND FIRST AID OF ACCIDENTAL HYPOTHERMIA

Warren D. Bowman, Jr., M.D.
National Medical Advisor
National Ski Patrol System, Inc.

Current projections call for a shortfall of some 25 million barrels of oil per day in all of the free world by the year 2000, so that during the conversion to alternate forms of energy some areas of the U.S.---particularly the densely populated Northeast----are likely to lack fuel oil to the extent that diseases due to cold, particularly hypothermia, may be much more common than they are at present. The purpose of this paper is to examine the experience which members of the National Ski Patrol and other groups which operate in cold weather and mountainous terrain have had in cold weather survival and the prevention and first aid of hypothermia, and to apply any lessons which can be learned, particularly to urban hypothermia. The recent rapid increase in popularity of outdoor sports in cold weather has provided an increasing number of victims suffering from immersion and other types of acute and subacute hypothermia. Much of our knowledge of hypothermia has come from Great Britain where large numbers of elderly people have developed hypothermia due to inadequate heating in housing units.

Prevention of hypothermia requires at least a working knowledge of the principles of production, conservationn and loss of heat by the body and of heat exchange between objects in the environment. Human beings as well as all other warm-blooded creatures are homeothermic, which means that they must maintain their temperatures within relatively narrow limits for survival and within even narrower limits for optimum function. This is largely because the enzyme systems on which body metabolism depends are temperature dependent and function best at normal body temperature or slightly above it. The body will not survive for long at temperatures of above 108°F or below 80°F. The observed body temperatures are the net result of the action of opposing mechanisms tending to increase or decrease heat production on the one hand and to increase or decrease heat loss on the other. These mechanisms include not only those mediated by the autonomic and endocrine systems but also somatic effects and behavioral changes.

Basal heat production in man proceeds at a rate of about 40 Kcal/hour and can be increased by muscular activity---both involuntary or shivering and voluntary; and by eating, exposure to cold, and fever. Cold exposure appears to increase hunger and the secretion of adrenal medullary hormones such as epinephrine and norepinephrine, and perhaps also TSH with a resultant inecrease in thyroxine secretion, all leading to a slight increase in the BMR. Semiconscious activity such as foot stamping and dancing up and down is stimulated, and the individual instinctively tends to curl up in a ball so as to present the smallest possible surface area to the cold.

Heat can be actively added to the body by external means such as the sun, a fire or other heat source, and internally by hot food and drink.

Heat is lost from the body in 5 ways---by conduction, convection, radiation, evaporation and respiration. To give some idea of the part each of these plays, in resting man body heat loss is about 55% through radiation, 15% through convection and conduction, 23-27% through insensible evaporation from the lungs and skin, and 2-9% from the warming of inspired air. As external temperature decreases, proportionally less heat loss is from radiation and proportionally more from conduction, convection and evaporation (Hedblom).

When exposed to cold, the body attempts to decrease heat loss by gradually reducing circulation to the body shell---the skin, muscles and extremities---and by decreasing sweating.

With these basic principles in mind, what can be done to prevent the development of hypothermia?

1. The body can be kept in the best possible "condition"---rested, well fed and exercised, so that heat production will be maximal and can be maintained.

2. Loss of heat can be kept to a minimum. This requires:

a. Insulation through proper clothing. Clothing must be of the proper material, thickness, looseness, size and shape, and the layer principal must be utilized. Wool, down, foam and older synthetics are still the standbys, such as Dacron and Orlon. Garments must be generously sized and designed so as to protect the neck and wrists and long enough to protect the waist and hips. Hats must protect the ears and face masks must be designed so that wearers of spectacles can wear them without fogging. Mittens are preferred to gloves, boots must be spacious enough to admit several pairs of heavy, wool socks, and tight clothing must be avoided.

Although proper clothing is available in mountaineering shops and other outlets catering to outdoorsmen, and to some extent in Army Surplus stores, the design of generally available winter clothing is woefully inadequate and the general public will have to be educated in what to look for.

b. Awareness of the windchill effect. Windproof outer garments such as a parka with hood, overmitts, wind pants and face mask must be available. Persons must be adivsed to seek shelter when windchill factors of 1400 or higher exist---easily reached by a moving skier or snowmobiler at -10°F.

c. Awareness of the effects of moisture, especially when combined with wind. The layer principal is used to avoid overheating with excessive perspiration and loss of heat by evaporation, remembering that wet clothing conducts heat many times faster than dry. Persons who become wet, as by falling into a mountain stream, should change immediately to dry clothing if possible.

d. Adequate coverings available for body parts with a large surface area to volume ratio, such as the head, ears, nose, hands and feet. Remember that at 5°F you can lose up to 70% of your total body heat production by radiation from an uncovered head.

e. Avoidance of heat loss by conduction by sitting down on a log, pack or piece of ensolite rather than in the snow or on a cold rock. Don't handle metal objects with your bare hands and don't spill gasoline or other liquids with a freezing point lower than water on your skin.

f. Prevention of heat loss from respiration by avoiding overexertion and overheating with excessively heavy breathing in cold weather. When it is extremely cold, prepare shelter and get into it.

3. Principles of cold weather survival should be learned. Remember that snow is your friend and has great insulating value. Persons outdoors in cold weather in isolated areas or driving long distances should carry:

a. Adequate clothing for the most severe temperatures and chill factors likely to be experienced.
b. Shelter constructing equipment---tent, snow shovel, snow saw, tarp, ax, saw, cord.
c. Emergency food and water.
d. Fire-building equipment: stove, fuel, matches, cooking utensils.
e. First aid kit.

FIRST AID OF HYPOTHERMIA

The following principles are currently being taught to members of the National Ski Patrol through its Winter First Aid Course. The insidious nature, high mortality and early and late signs and symptoms of hypothermia are emphasized. Due to the difficulty of obtaining a low-reading thermometer, the NSPS is currently stocking a suitable one which can be obtained from your local Patrol for $3.95.

For pedagogic purposes, we classify hypothermia into acute, subacute and chronic. The acute type is the typical immersion hypothermia, in which early on at least serious metabolic and electrolytic abnormalities have not had time to develop. The chronic type is the type found in seniles, alcoholics and other persons with serious medical problems. The subacute type, which is the type seen by ski patrols and mountain rescue organizations, is the type which occurs in basically healthy, young persons who become hypothermic because of inadequate insulation or environmental stresses.

The 4 principles of first aid are:

Prevent further heat loss
Rewarm as safely and rapidly as possible
Rewarm the core in advance of the shell if possible
Avoid the serious complications of ventricular fibrillation and rewarming shock

The first aid is divided into two catagories:

Category I. Rectal temperature 85°F or above, victim conscious. When a member of a party begins to show signs of hypothermia, or when a search party finds such a victim, the party should stop immediately and make shelter. The victim must be gotten out of the wind and insulated against the cold, replacing wet clothing with dry if necessary, and getting him into a sleeping bag. Heat must be added to the victim in any way possible; this includes the use of canteens filled with hot water, hot, sweet drinks, hot rocks, and naked human bodies. A useful first aid device is the "hydraulic sarong", a nylon blanket large enough to encircle the trunk with plastic tubes sewn in it through which hot water can be pumped using a pot, a backpacking stove and a bilge pump. If a tub is available, the victim can be placed in it in water at 105-110°F, with his arms and legs left out.

Category II. Rectal temperature below 85°F, victim usually unconscious. The mortality is quite high in these people, even in the hospital. Therefore, since they are literally in cold storage, we feel that the best results will be obtained by preventing further heat loss and spending your time evacuating them, rather than trying to rewarm them in the field. There has recently been considerable interest in the use of core rewarming as a first aid device, particularly using gadgets for warming the inspired air, and I am sure that Dr. John Hayward and others will bring us up to date on these---there is a great need for a light-weight, portable, effective model.

The victim should be transported very gently, avoiding sudden jolts, with his head downhill. An intravenous of 5% glucose in saline should be started and 2-3 ampuls of sodium bicarbonate given. Ventricular fibrillation should be treated with closed chest massage and mouth-to-mouth or mechanical ventilation.

N. Bradley
Department of Physiology
School of Medicine
University of Minnesota-Duluth

ABSTRACT

MULTIPLE FACTORS THAT INFLUENCE THE SAFETY OF PHYSICALLY HANDICAPPED PEOPLE IN COLD WATER

N. Bradley
Department of Physiology
School of Medicine
University of Minnesota-Duluth

Approximately 10-20 million people in the United States are classified as physically handicapped. A significant number of these people use the waters for recreation. Many factors contribute to the potential hazards which the cold water presents to the physically handicapped. Cold water increases the sensitivity of the stretch receptors in the muscles and increases spasticity and possibly bradykinesia in physically handicapped people. The net result is that physically handicapped people would not be able to move as well in cold water. In addition, various kinds of physical handicaps would contribute to possible altered centers of buoyancy. Thus the design of personal flotation devices might have to be altered due to this fact.

Personal Flotation Devices for the Handicapped

N. Bradley, R. S. Pozos, and L. E. Wittmers, Jr.
Department of Physiology, School of Medicine
University of Minnesota-Duluth, Duluth, Minnesota 55812

> . . . He might not be able to manage a tricycle, but he had the freedom of a large safe beach where he could run for a mile if he felt inclined. Beach balls eluded him--he could neither throw nor catch--but there was the warm sand to mess with, and the water itself. The big movement of Mike's young life came at three-and-a-half, when he learned to swim . . . The beach baby turned into a water rat. By five he could swim safely out of his depth, and by six he not only had a crawl stroke, but was so at home in the water that he literally did not seem to know if he was on it or under it![1]

A number of recent developments and new laws have provided more opportunities and facilities for the physically handicapped to use water for their therapeutic and recreational needs.

The focus of attention on special education and recreation by such a large segment of our population (approximately 22 million people with varying degrees of disability) has provided the stimulus to increase the number of programs on/in/around the water, which is the most desirable medium for the handicapped. Water presents a challenge whether it's an individual with cerebral palsy swimming competitively or a paraplegic out for a day of fishing. Water is physically and mentally beneficial since it provides opportunities for socialization. Personal flotation devices are the mainstay of any aquatic program dealing with physically handicapped individuals. PFD's are widely used but their effectiveness is questionable and has never been tested. Therefore it is important to quantitate the ability of personal flotation devices to maintain buoyancy and also to take into account the various

---

[1] Louise Clark, Can't Read, Can't Write, Can't Talk Too Good Either (New York: Walker & Company, 1973), p. 9.

physiological factors, i.e. weak neck muscles which would impair motor function of the physically handicapped individual using such a device.

The ability of an individual to maintain themselves in water is dependent on several factors: buoyancy, wave action, and water movement. A person may not be an efficient floater but compensates for that by using his muscles to maintain himself in the water. Conversely, a good floater can minimize motor control since buoyancy compensates for this.

At present the institute is identifying physically handicapped individuals with regard to their aquatic and recreational uses of the water. In our initial study, it has been found that the present day design of PFD's is geared to the non-handicapped person.

There are also concerns with the present PFD's promoting discomfort, instability, and confined movement and possibly jeopardizing a person's life. All of the above problem areas are magnified by the person's degree of disability.

Since a large segment of the handicapped population uses water either for recreational and/or for some form of therapy, the need exists to quantitate how effective personal flotation devices are in these groups. It should be noted that physically handicapped individuals at present have housing, boats, and automobiles that are individually customized to their handicaps. It is therefore reasonable to assume that the same kind of attention be given to their PFD and water safety.

In our preliminary studies information has been collected in the following areas with regard to the physically handicapped:

Buoyancy

It has been demonstrated that not all physically handicapped persons can assume a horizontal float or even float with the head above water. This information has significant importance as to the quantity and correct distribution of flotation material necessary to maintain adequate freeboard and mobility of the individual wearing the PFD. Refer to pictures 3 and 4.

Equilibrium

Photographs were taken of subjects while in the water thus demonstrating differences with regard to individual orientation. Refer to pictures 4 and 6.

Freeboard

Difficulty with a consistent breathing pattern magnifies the problems involved in maintaining a good surface position while in the water. Therefore a motor impaired person depends upon the additional support provided by their PFD for a safe measure of freeboard. Refer to pictures 3, 5, and 6.

Movement

A person must apply force to move or to keep in motion. Therefore PFD's fitting improperly cause more resistance, consequently increasing even more the high energy cost of swimming. Refer to pictures 3, 5, and 6.

Donning a PFD

Many factors govern the methods and techniques used by the disabled while donning a PFD. Listed below are some of the problem areas of which we are already aware. Refer to pictures 1, 2, and 3.

-- Respiratory problems--improper breath control decreases buoyancy and increases the possibility of water entering the mouth and/or nose.

-- Improper or partial use of upper limbs--difficulty with closures and movement of limbs--quickly fatiguing the person.

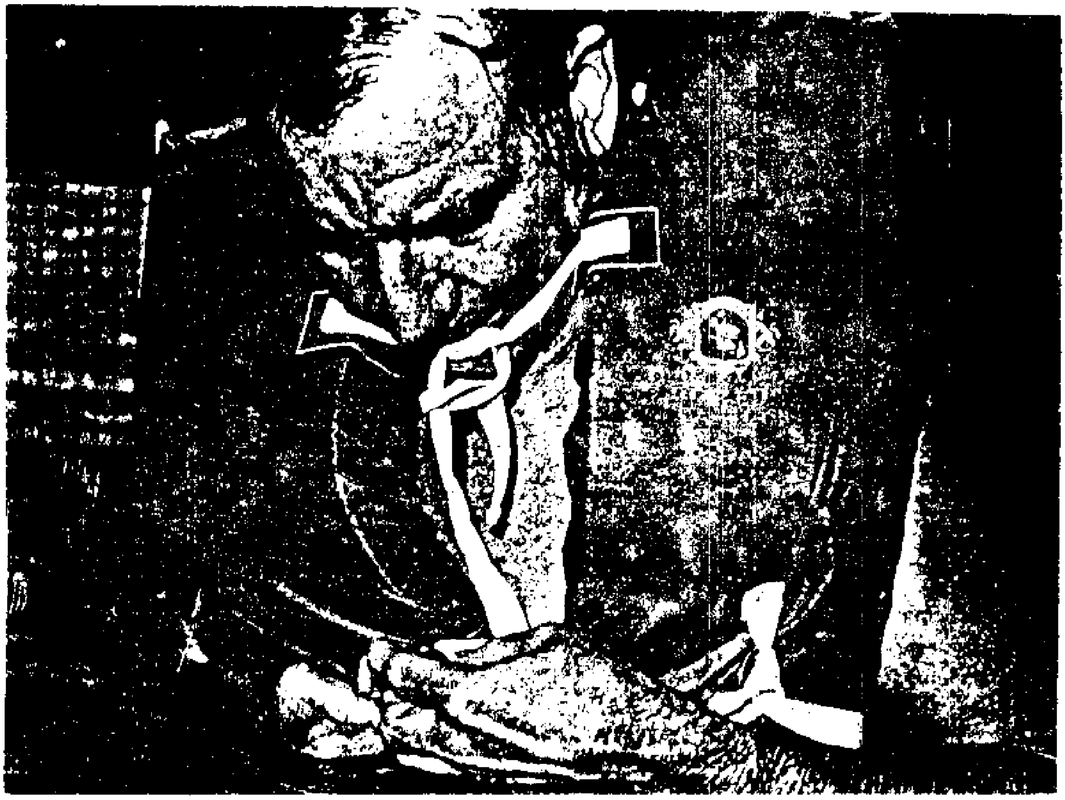
-- Lower limb disability--increases downward pull or negative buoyancy thus creating anxiousness and fatigue.

EMG Studies

The electromyographic studies will determine which muscles are working correctly or being fatigued. EMG's will provide the information necessary to individually assess subjects' motor movement and to compare the differences in handicapped populations.

There is little doubt that the need of personal flotation devices for the handicapped population has been largely ignored. With the increases in aquatic programs geared for the disabled, it is imperative they have some measure of safety equal to the non-disabled.

Picture 1. Motor impairment inhibits closure of PFD.

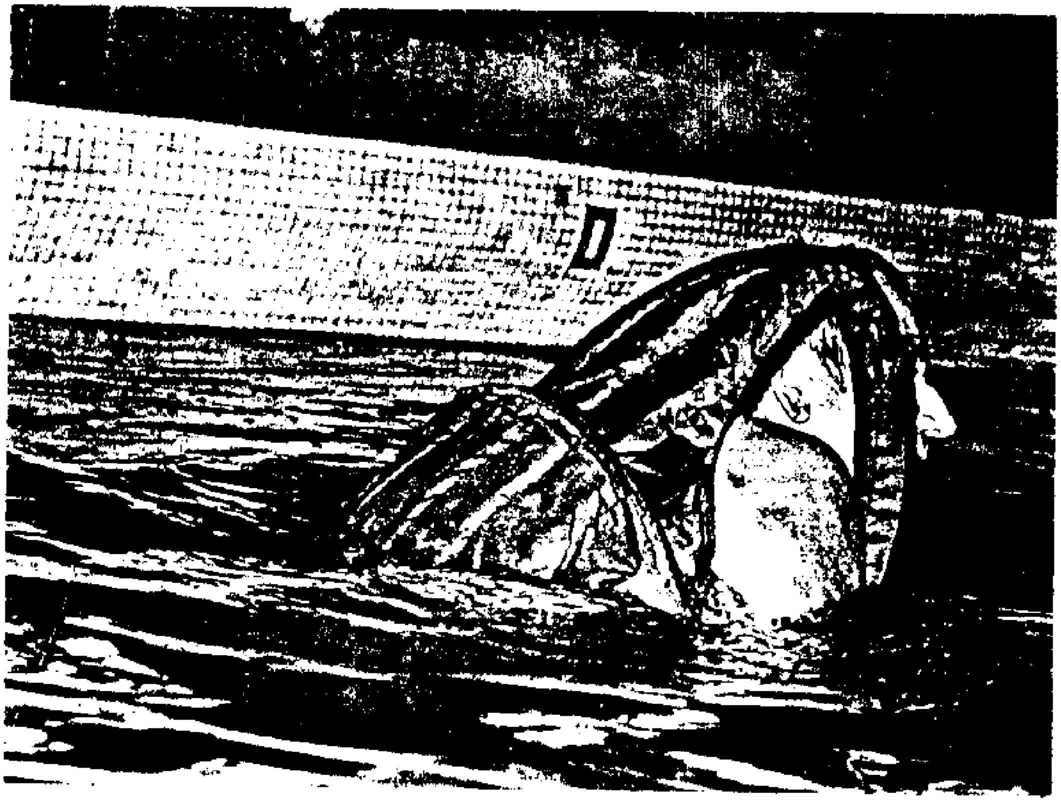


Picture 2. Inability to tie closure prevents safe wearability.

Picture 3. Untied closures create imbalance and instability.

Picture 4. Existing PFD's do not take into consideration individual disabilities, therefore magnifying problems with balance, equilibrium, mobility, and floating position.

Picture 5. Movement and freeboard are jeopardized by loose fitting PFD.



Picture 6. Riding up of PFD forces face into waves creating breathing problems, anxiousness, and fatigue.

R. C. Eggleton
Indiana University School of Medicine

ABSTRACT

NON-INVASIVE TEMPERATURE DETERMINATION FOR THE HYPOTHERMIA VICTIM UNDER FIELD CONDITIONS

R. C. Eggleton
Indiana University School of Medicine

Temperature data on hypothermia victims is very limited and field measurements are completely lacking in the literature. Two reasons account for this: first, there is no suitable field instrument for making such measurements and second, the paramedical personnel are not trained to make temperature measurements of the hypothermia victims. Such data are needed, however, for proper management of the patient as well as being required for a better understanding of the basic mechanisms of thermal regulation in the human.

The physiology of homotherm temperature regulation has been studied in animals and the regulating centers have been identified in the hypothalmus that make reflex responses to deviations from a temperature norm. Impulses from temperature receptors are transmitted via the lateral spinal thalamic tract and the thalmus to the hypothalmus from which various anatomic reflexes responses are activated. The hypothalmus also contains temperature sensors which respond directly to blood temperature. Despite our knowledge of the temperature regulating mechanisms of animals, we have insufficient understanding of the human clinical picture for proper management of the hypothermia victim. To correct this deficit, it is proposed that emergency vehicles carry simple but accurate temperature measuring equipment to determine non-invasively the temperature of the core and extremities.

We propose a thermistor type probe for core temperature using a short time constant digital readout. The probe consists of thermistor imbedded in the flexible rectal catheter. The temperature of the extremities can be determined non-invasively by measuring the speed of sound in the tissues of the limb. Then speed of sound can be equated with temperatures using the nomogram designed for this purpose. Other data required will include: air temperature, water temperature, time of exposure, conditions of exposure, patient weight, height, sex, etc.

When such data is compiled for both acute and chronic hypothermia, it will be possible to prescribe more precise emergency care and minimizing complications such as after drop, electrolite imbalance and other trauma which are all too frequently the cause of morbidity or mortality in the hypothermia victim.

NON-INVASIVE TEMPERATURE DETERMINATION FOR THE HYPOTHERMIA VICTIM UNDER FIELD CONDITIONS

by

R. C. Eggleton
Indiana University School of Medicine

Introduction

Temperature data on hypothermia victims is very limited and field measurements are completely lacking in the literature. Two reasons account for this: first, there is no suitable field instrument for making such measurements and second, the paramedical personnel are not trained to make temperature measurements of the hypothermia victims. Such data are needed, however, for proper management of the patient as well as being required for a better understanding of the basic mechanisms of thermal regulation in the human.

The physiology of homotherm temperature regulation has been studied in animals and the regulating centers have been identified in the hypothalmus that make reflex responses to deviations from a temperature norm. Impulses from temperature receptors are transmitted via the lateral spinal thalamic tract and the thalmus to the hypothalmus from which various anatomic reflexes responses are activated. The hypothalmus also contains temperature sensors which respond directly to blood temperature. Despite our knowledge of the temperature regulating mechanisms of animals, we have insufficient understanding of the human clinical picture for proper management of the hypothermia victim. To correct this deficit, it is proposed that emergency vehicles carry simple but accurate temperature measuring and recording equipment to determine non-invasively the temperature of the core and extremities.

Two instruments are envisioned, one of which will read the rectal temperature, and the second will read the temperature in the extremities. These two instruments will be designed for field use and will not only measure temperatures, but also record them. The temperature history is, perhaps, more important in assessing the state of the patient than the actual temperature. When such data are compiled for the acute and chronic hypothermia victim, it may be possible to prescribe more precise emergency care and to minimize complications such as afterdrop, electrolyte imbalance, cardiac arrest, etc. which are all to frequently the cause of morbidity or mortality in the hypothermia victim.

Instrumentation

Instrumentation for measuring and recording core temperature should meet the following minimum specifications:

1. The equipment must be capable of operating under field conditions including cold, snow or wet environments.

2. The unit should be suitable for attaching to the victim's thigh with Velcro tapes or other quick connecting straps.

3. A rectal probe should be constructed of a flexibile biocompatible plastic with smooth edges which can be cleaned and sterilized.

4. An indicator display should read the temperature in °C to the nearest 0.1° and displaying a 3-digit number.

5. A digital record of the victim's temperature (in three digits) should be stored every 5 minutes for a period of at least two hours.

6. A means of interrogating the memory sequentially by operating a sequencing button, thereby enabling the physician to transcribe the recorded temperatures. A 2-digit number will show the entry number.

7. The accuracy of the temperature reading should be within ±0.5°C absolute and ±0.1 relative.

8. The temperature calibration should be insensitive to environmental changes and if the instrument indicates either a rise or fall in temperature, this must correspond to a rise or fall in temperature at the probe, and not a response to an environmental change in temperature for the circuit. Temperature trends are very important in the treatment mode; therefore, a change of 0.2 C indicated must correspond to an actual temperature change within the victim.

9. The circuits shall be sealed and potted to protect them against damage.

10. The power supply shall consist of long-life batteries. The device will receive infrequent useage, but then be operated continuously for several hours.

11. The circuits shall be designed to minimize power drain, which shall be as low as practical. The stored temperature data shall be protected against loss due to low supply voltage.

The system specified is shown in Fig. 1, and consists of a digital type probe for recording core temperature using a short time constant digital readout and digital memory to record the temperature history of the victim. The probe contains a sensor embedded in the flexible rectal catheter and a waterproof circuit module which straps to the victim. Although no such recording thermometer has been constructed, the technology is straightforward, and such an instrument can be constructed for relatively low cost.

The technique for the measurement of limb temperature, however, is not so far advanced. To find the temperature of the extremities on a non-invasive basis requires a new approach. The speed of sound, for example, offers possible means of determining the temperature because the speed of sound in tissue is temperature dependent. By recording the speed of sound across the

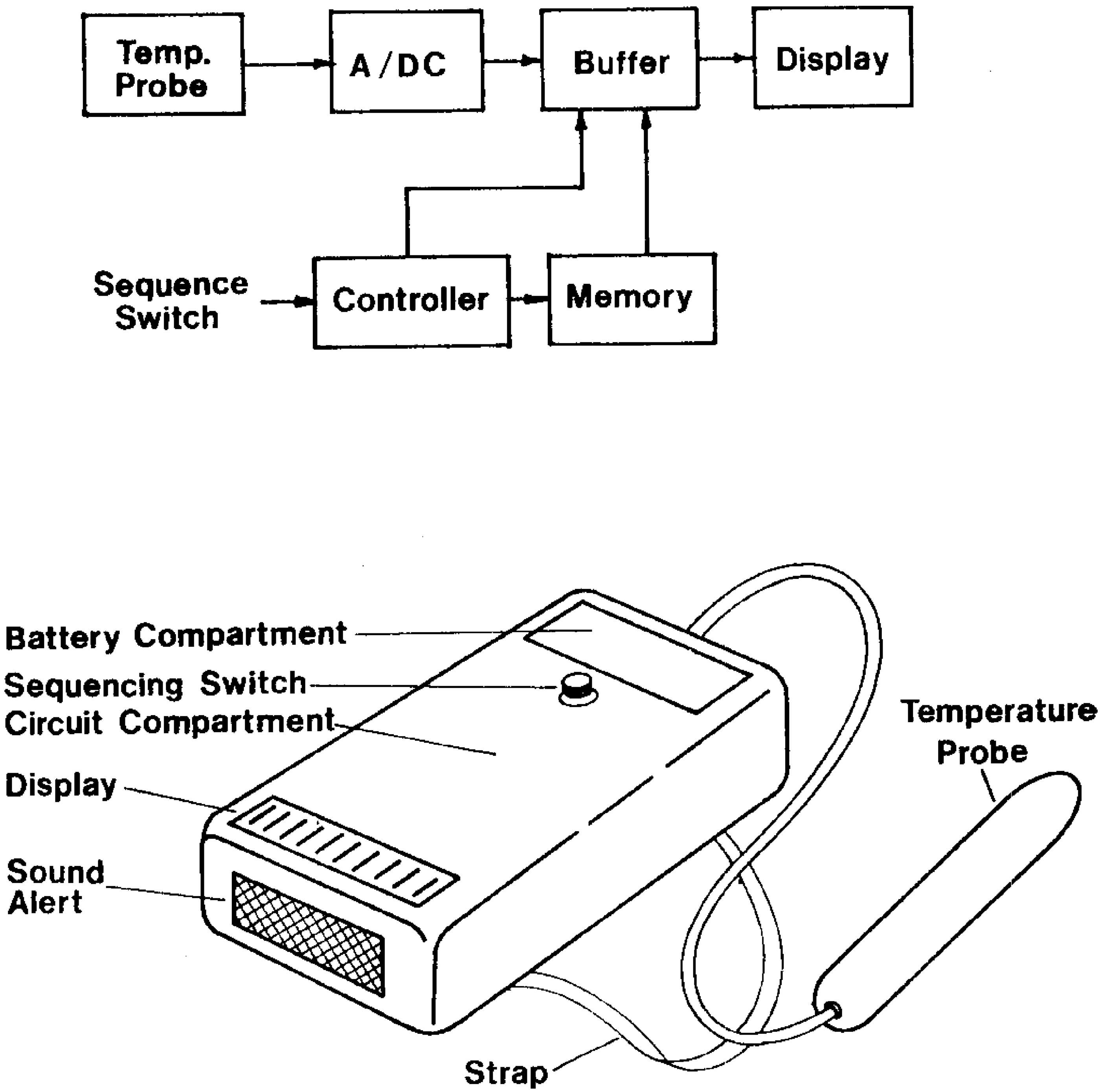


Fig. 1 A rectal probe senses the temperature of the hypothermia victim, and a digital circuit records and displays this data.

extremities of the hypothermia victim, it would be possible to estimate the temperature. A precise temperature determination, however, will require calibration. This calibration can be achieved in any one of several ways. 1) A speed of sound calibration can be made after the patient recovers and returns to normal temperature; 2) the calibration can be determined invasively in the hospital setting using a needle probe; 3) a nomogram can be used for calibration which takes into account the path length in muscle, fat and skin based on the physical condition of the victim. The need for calibration is based on the fact that fat and skin have different temperature dependencies. Fat has a slower speed than the speed of sound; and the more collagen in the pathway, the higher the speed of sound. The nomogram would be used to estimate the contribution of these two tissue components can be estimated.

A very precise method for measuring the speed of sound has been devised. This method makes use of a phase lock loop in which the frequency of the sound is adjusted to maintain a constant number of wavelengths at a constant phase across the propagation pathway. The system is shown in block diagram in Fig. 2, where the transmitted and received waves are compared in the Phase Detector (PD). The output of the phase detector is a signal whose amplitude depends on the degree of phase shift between the transmitted and received signals. The output of the phase detector is an error voltage is applied to the Voltage Controlled Oscillator (VCO) which, in turn, adjusts the frequency to maintain a constant phase relationship between the transmitted and received signals. The operation of this circuit can be appreciated by examining the simple but fundamental relation, $c = f\lambda$, where c is the speed of sound, f is the frequency, and λ is the wavelength. If λ remains constant, then c is equal to f times the constant and evaluation of the constant λ. The evaluation of the

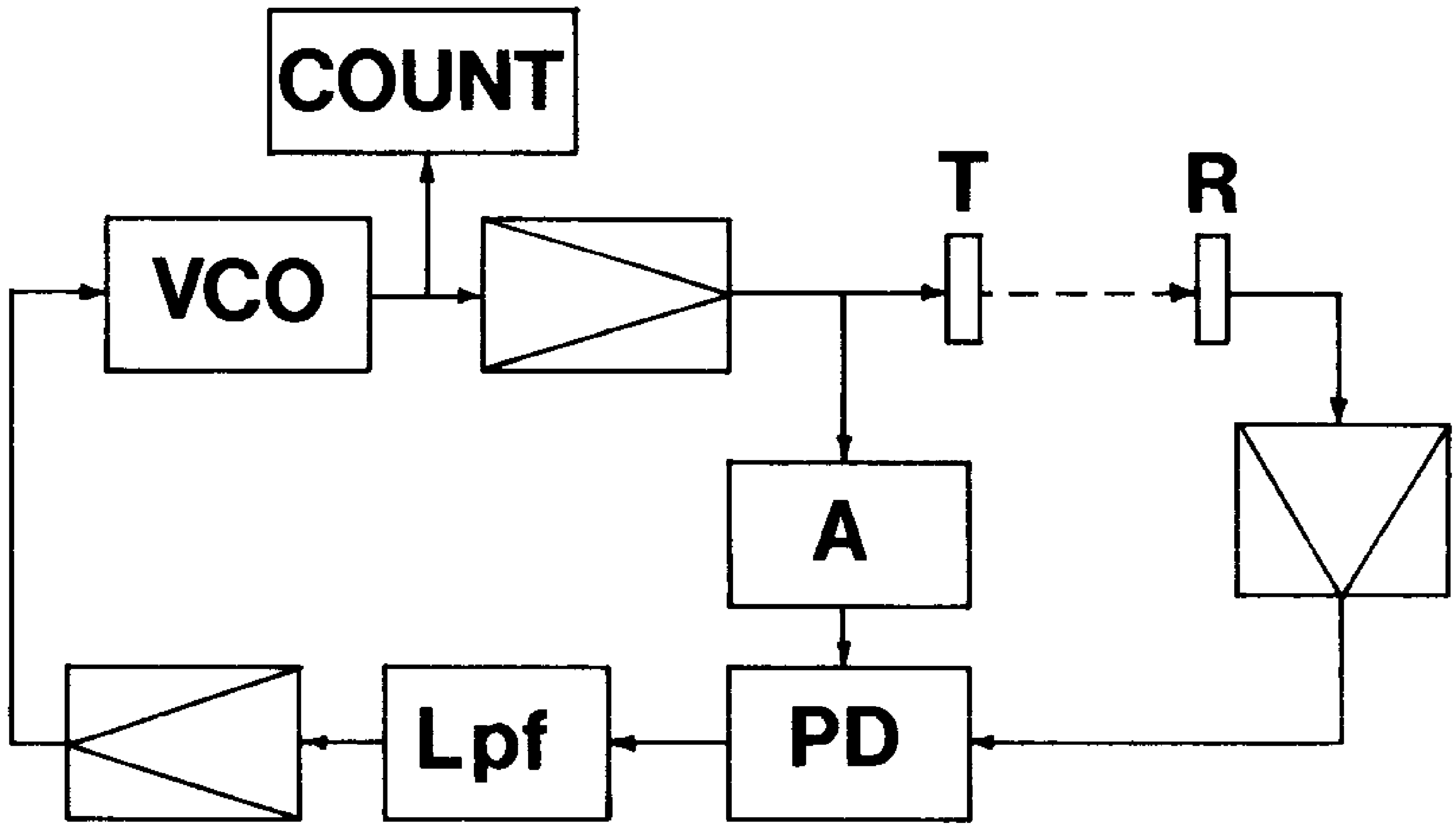


Figure 2 A method of measuring the temperature of the extremities involves determining the speed of sound in the tissue using a phase lock loop. The phase of the transmitted (T) and received (R) signals is compared in the phase detector (PD). The output is used to control the frequency of the voltage controlled oscillator)VCO) to fix λ in the equation $c = f\lambda$; thus the counter (count) records the speed of sound.

constant λ is the calibration required by this method and is the subject of a paper now in preparation for IEEE Transactions on Sonics-Ultrasonics. The speed of sound has been measured across the arm of several individuals with normal body temperatures. The speed of sound has also been measured in excised muscle at various temperatures ranging from 40°C to 20°C for the purpose of illustrating the sensitivity of the method. These data are shown in Fig. 3. The absolute level and the slope of the curve will differ for skin and fat and, therefore, to use this method for precise temperature determination, it is necessary to have an individual calibration or some means of estimating the amount of propagation pathway devoted to the three primary constituents, namely, skin, fat and muscle. To implement the measurements, the device is designed to hold the transducers in contact with the skin on either side of the arm, as shown in Fig. 4.

The Afterdrop Hypothesis

Everyone has personally experienced the operation of temperature control mechanisms within their bodies in which circulation is shut down in the extremities to prevent further heat loss from the core. In this heat conservation mechanism, blood is shunted away from the skin of the affected limbs. The limb continues to cool because of the interruption of flow through the periphery. With the temperature of the limb well below core temperature, there would be a drop in core temperature if circulation through the extremity were allowed to return to normal. Such flow can be initiated with warming of the skin receptors; thus a potentially dangerous situation could occur if the core temperature of the victim is close to the critical temperature, and warming of the limbs caused flow to commence through the cold tissues of the extremities before sufficient re-warming of the arms and legs had occurred

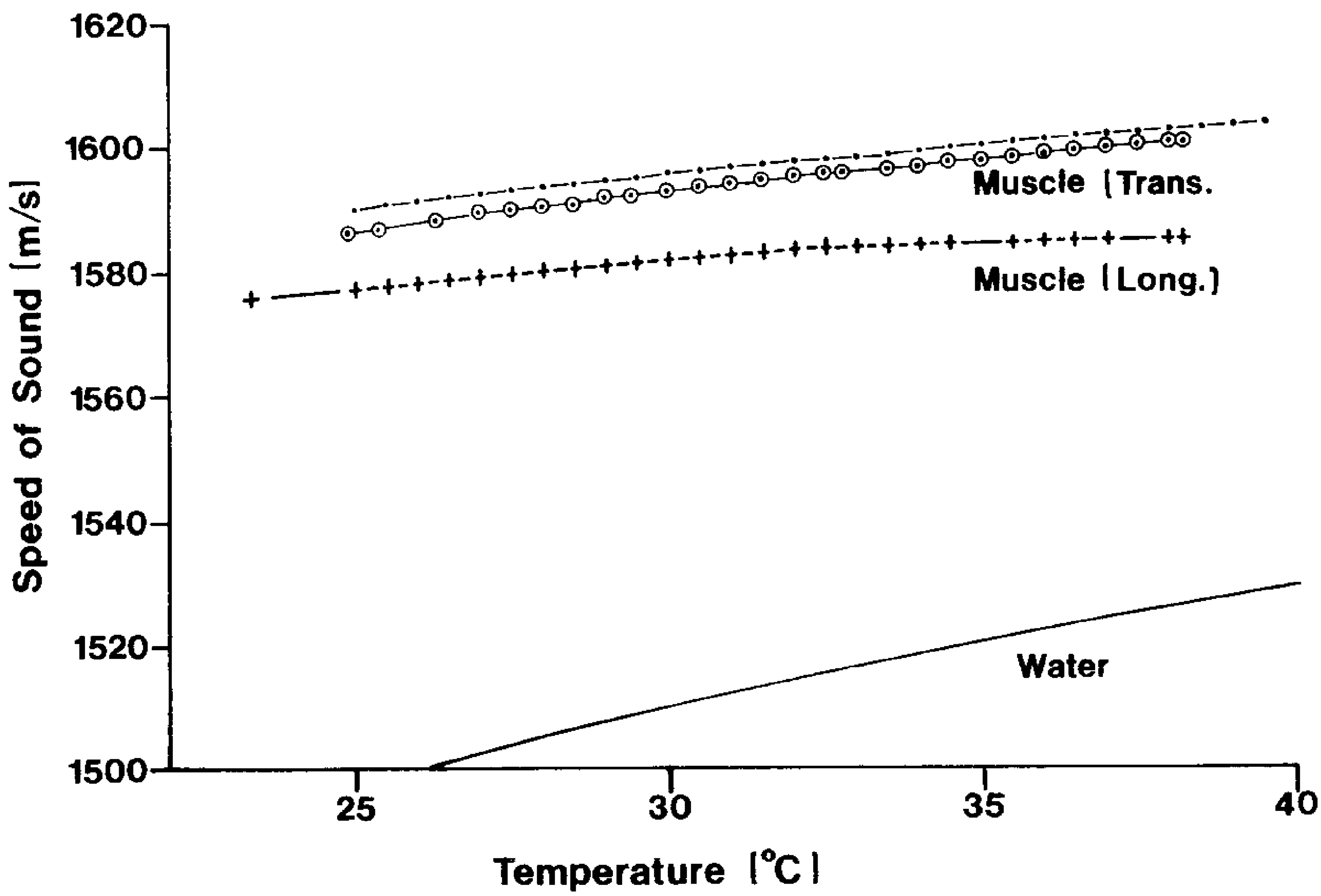


Figure 3 The speed of sound in muscle as a function of temperature is plotted over the range from 25°C to 40°C, and is found to range from about 1590 to 1610 m/s.

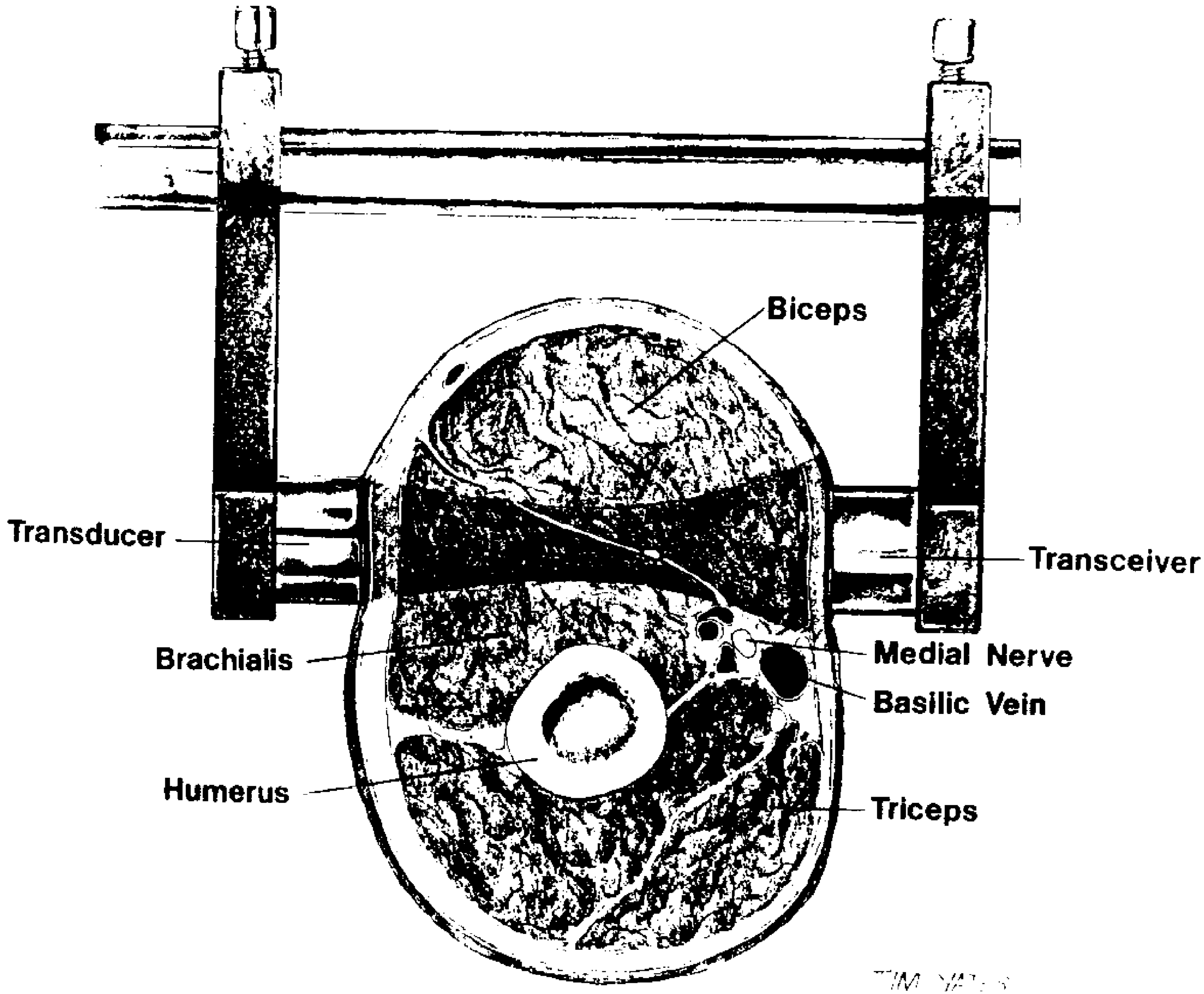


Figure 4 The ultrasound transmitter and receiver are supported on a frame and applied to the skin of the arm. The speed of sound measured with this system can be used to determine the temperature of the tissue.

with the result that blood cooled below the critical temperature would be returned to the heart at a temperature below the critical point. The victim would go into cardiac arrest as a result of the improper re-warming technique.

Future Possibilities Using Miniaturized Digital Systems

In addition to recording the temperature of the hypothermia victim in digital memory, digital processing systems could be used to warn the emergency medical personnel of potentially dangerous situations for the hypothermia victim; during transport and intensive care stages. A checklist of tests and suggested treatment modes for the re-warming process as well as warning critical conditions could be programmed into the microcomputer. Algorithms may be generated in the future which will optimize the status of the patient at any particular temperature and a set of physiological conditions. Such a device could materially aid in the treatment of the patient subjected to low temperature trauma. But, before any systems are designed or computers programmed to assist the hypothermia victim, it is necessary to have the basic data which the study presented here is designed to acquire.

NOTES ON PROFOUND HYPOTHERMIA AND ITS MANAGEMENT

R. C. Eggleton

Introduction

The acute hypothermia victim, who has lost heat through immersion in water of, say, 12°, may be on the threshold of consciousness when rescued, with only sluggish, uncoordinated movements of the limbs, unable to assist his rescuers. The rectal temperature may be 24° as attempts to rewarm the victim are commenced in the emergency vehicle. Despite the application of warm blankets, the core temperature continues to fall, and by the time the victim reaches the emergency room he has become unconscious and the core temperature has dropped to 22°. The patient is now in a state of profound hypothermia. Past experience shows that the chances of recovery are less than 50 percent. What is profound hypothermia and how should it be treated to maximize recovery of the patient?

Physiological Basis for Profound Hypothermia

Profound hypothermia for homeotherms is that temperature where catastrophic events are occurring when the temperatures of the organism reaching the lower limits of the biokinetic zone. Cardiac arrest is the most dramatic of the endpoints, and perhaps the easiest to detect. Profound hypothermia has no discrete temperature boundaries, but for man ranges from about 25°C to 20°C, or 76°F to 70°F. At this point, most of the regulatory mechanisms of the body have failed. Most cells become relatively inactive as the temperature falls to the lower limits.

Hypothermia, both naturally occurring in hibernators and induced in other organisms, results in decreased metabolism. Although some organisms, such as artic fishes and invertebrates, carry out life activities at temperatures as low as 0°C, their metabolism is sluggish. The reaction rates of biological processes are temperature dependent. They increase up to a maximum, and with further increase in temperature, the rate again declines. The effect of temperature on the rates of various biological processes and reaction rates must be compared for the same temperature interval. Usually one determines the ratio of the rate of activity at a given temperature with the rate at a temperature 10° lower. This ratio is called the temperature coefficient and is designated Q10. (Q10 then refers to the slope of the curve; i.e., the Q10 may vary over the 10° interval.

Four relatively different kinds of temperature coefficients have been found for cell processes, each corresponding to a different mechanism of action; a) those in which the Q10 is about 2, b) those which are considerably above 2, c) those which are considerably less than 2, and d) those which have a Q10 of about 1. Thermobiological reactions, in general, have a Q10 of about 2, and these reactions follow the van't Hoff's rule. The underlying mechanism is related to the kinetic energy of the system. A rise in temperature of 10° increases the average kinetic energy of a molecule by 10/T, where T is the absolute temperature. For instance, at room temperature the absolute temperature is about 300°, therefore, 10/T would be 10/300, or 3.3 percent.

This seemingly trifling increase in the average kinetic energy of the molecule, by itself, may seem inadequate to explain the two-fold rise in the rate of reactions which follows a 10° rise in temperature of the environment. However, consider the molecules which are likely to react on collision, the rate of reaction may well depend on the population of molecules with the critical amount of energy required for the reaction at the time of collision. This is called the energy of activation, and such a process would show a sensitivity to either too much or too little kinetic energy. As with railroad cars, if the car produces too little energy, it will not link up to form the train, and if it possesses too much energy, it may also fail to couple.

The Maxwell-Boltzman distribution law determines the number of molecules possessing the proper energy of activation. Calculations show that several times as many activated molecules are present at higher temperatures as at a temperature of 10° lower. It seems most likely that the rate of thermochemical reactions with a rise in temperature is attributable to the disproportionate increase in the fraction of molecules which have acquired the requisite energy of activation for a particular reaction. In the profound hypothermic state, the Q10 or slope of the reaction rate curves are at the lower limits.

When a molecule moves from one energy level to another in a reaction, it must pass over an energy barrier, even though the overall effect is to decrease the free energy of the system. In biological reactions, control is exercised over the reaction rates through the mediating effect of enzymes whose function is to reduce this energy barrier. At low temperatures, the enzymatic function is decreased and, therefore, reaction rates are decreased. The barrier is the energy of activation which a molecule must possess in order to pass over the barrier and enter into the reaction. Passage of molecules or ions through a cell membrane at times appears to be a simple diffusion process, thus the Q10 for such diffusion through the tissue can be shown to be dependent on the change in viscosity of the cell membrane through which the ions or molecules must pass. There may, of course, be other explanations, since the passage of molecules and ions through cell membranes is not always governed by the same mechanism.

Most biological reactions occur in a series of steps, and each step being controlled by specific enzymatic process depending on the conditions, one or another of these stepwise reactions may become the bottleneck or rate limiting reaction. The temperature coefficient for the biological process will, therefore, depend on the condition of the experiment. The temperature coefficient (Q10) of photosynthesis, for example, at low light levels is about unity, but at higher light levels, the Q10 increases to about 2 or higher. At low light levels, the rate quanta absorption by the photochemical reaction is the rate setting reaction. At the higher light intensities, however, the chlorophyll molecule of the plant is saturated with light, and the rate is then determined by the synthesis of carbohydrate. The nature of the photochemical and thermochemical reactions is the factor which causes the change in the Q10 with the change in light level.

The point to be made from the foregoing discussion is that biological processes in the human are dependent upon the maintenance of temperature within a narrow band. When temperatures fall below critical values, the regulation ceases, and any number of mechanisms become out of balance. Some of these are vital mechanisms, and simply reinstating the temperature of the victim will not establish the controls required for survival.

If the heart stops, there are many preconditions which must be satisfied before the heart could or should be restarted, some of which are known, and many of which still remain to be discovered. First, the tissue temperature has to be brought to the critical value; the blood in the lungs must be fully oxygenated. The electrolyte balance must be within acceptable limits, and fluid level must be within acceptable limits. Levels of toxins in the blood and tissues may also require treatment before circulation is reestablished. The titer of urea in the blood may be unacceptable. Further, toxins from the gut may diffuse across the barrier into the portal system and interfere with the ability of the circulatory system to maintain plasma. In some instances, it may be possible to detoxify the patient with the use of peritoneal dialysis.

As the temperature and circulation is reestablished, the regulating mechanisms throughout the body will again begin to exercise control and a homeostatic condition will be reestablished. In the broader sense, we can consider profound hypothermia as a failure of homeostasis through the catastrophic loss of regulating mechanisms and enzymatic control of body functions.

Peritoneal Dialysis for the Hypothermia Victim

Peritoneal dialysis is not without intendent risks, and should, therefore, only be used in cases of profound hypothermia. A patient with cardiac arrest and evidence of edema would be a likely candidate. The dialysate should be administered initially at a temperature well below normal. If the patient's core temperature is in the vicinity of 22°C or less, a dialysate temperature should not exceed 30°C. The dialysate should be the standard electrolyte solution containing sodium lactate, 1.5 percent, or 4.25 percent glucose, no antibiotics should be necessary if reasonable technique is utilized. A small amount of heparin, e.g., 250 units per liter, has been suggested. As the core temperature of the victim begins to respond, a temperature differential between the dialysate and the core temperature should not exceed 10°, and at no time should the dialysate temperature exceed 37°C.

Some of the complications that have been reported include moderate pain, hemmorhage, leakage, and inadequate drainage. In some cases, neurological complications resulting from the dialysis have occurred including confusion, transient focal neurologic findings, headaches, neuromuscular irritability and, in a few instances, seizures. Some of these responses could be associated with other disease mechanisms and simply triggered by the dialysis.

Conservative medical management can successfully control potassium and acid base balance, and were this the only problem, dialysis would not be required. The two principal problems which require dialysis are 1) detoxification and 2) the rather rapid heat exchange which occurs during the dialysis process bringing the regulatory mechanisms within a temperature range where they can again protect the hypothermia victim. Careful technique can be applied which will alleviate the problem of hemmorhage and drainage. Inadequate dialysate drainage has been a major problem resulting from improper location of the drain tubes. The spectrum of peritoneal infections associated with peritoneal dialysis seem to involve rather benign strains which, in many cases, result in no overt signs of peritonitis. Although streptococcus and staphylococcus organisms have been found, as well as hemophyllius influenza, gram negative rods and candida are all shown to occur, control of infection has not been a major problem.

Metabolic complications are the most frequent complaints, and blood sugar should be checked frequently. It is probably desirable to discontinue the dialysis before the patient has reached normal temperature. Dialysis need only be administered for the time required for detoxification and temperature rise well above the critical point, say, to about 30°C to 35°C.

It is probably true that the hypothermia victim, in general, will be suffering less underlying disease than the average patient requiring clinical dialysis for kidney failure. The mortality associated with dialysis was not related to the length of the dialysis, the number of treatments for positive peritoneal cultures, but rather the dialysis related death seemed to have more strongly correlated with underlying clinical complications due to the presence of other medical illnesses.

If the hypothermia victim is in good physical condition before the incident, and if dialysis is terminated before reaching normal body temperature, it is reasonable to expect that the dialysis treatment will be administered without complications.

David J. Franz
Department of Physiology
Baylor College of Medicine
Houston, Texas

ABSTRACT

David J. Franz
Department of Physiology
Baylor College of Medicine

Cold-induced vasodilatation was assessed from records of foot pad temperatures of six domestic cats during immersion of the hind feet in a 0°C ice water bath. Animals were anesthetized with phentobarbital Na. Four days after the control recording, the animals were given indomethacin, 5 mg/kg, I.V., and the cold-induced vasodilatation response was tested once again; a third test was performed four days after the treatment with indomethacin. Periodic rises in foot pad temperature (cold-induced vasodilatation) were less in magnitude ($P < 0.05$) and delayed in onset ($P < 0.05$) on the day of treatment with indomethacin. It is proposed that cold-induced vasodilatation involves a balance between central sympathetic tone (vasoconstrictor) and periodic local prostaglandin release (vasodilator).

Ralph F. Goldman
U.S. Army Research Institute of Environmental Medicine
Natick, MA 01760

Presently the principal consultant to the Department of the Army on Environmental Physiology and Director of the Military Ergonomics Division. Dr. Goldman has his BA in chemistry from the University of Denver (1949), MA in biology from Boston University (1951), PhD in physiology from Boston University (1954, and MS in mathematics-physics from Northeastern University (1962). He currently teaches at Boston University and the Massachusetts Institute of Technology. He has published some 100 publications, 103 abstracts, 27 technical reports and 4 classified reports. In 1976 the Secretary of the Army presented Dr. Goldman with the "Exceptional Civilian Service Award."

ABSTRACT

INSULATING AGAINST HEAT LOSS IN AIR AND WATER ENVIRONMENTS

Ralph F. Goldman
U.S. Army Research Institute of Environmental Medicine
Natick, MA 01760

Hypothermia, whether from exposure to cold air or cold water, simply reflects an imbalance between the heat produced by the body and the heat loss from it. The accumulated heat debt can be considered to be apportioned between at least two body compartments: (1) a "shell", the skin, represented by only the outer 1.6mm thickness of the $1.8m^2$ body surface of an average man but comprising about 10% of his 70 kg mass, depending on the amount of blood contained; (2) a "core", representing the rest of the body. The skin compartment loses heat most readily and, because of its large surface area in proportion to mass, skin temperature approaches water temperature rapidly following immersion. In contrast, core temperature will usually increase during the first 20 to 30 minutes of cold exposure since heat production, which occurs in the core, is maintained at the 105 watt resting level or slightly increased by apprehension on immersion, while the heat transferred from the core to the skin is dramatically reduced as a result of vasoconstriction; heat flow from core to skin can be limited, depending on the thickness of the subcutaneous fat layer, to between 5 to $9W/m^2$ per $^{\circ}C$ of difference between core and skin temperature. Each $1^{\circ}C$ drop in mean body temperature (i.e., $T_b = \chi$(shell temperature) + $(1-\chi)$(core temperature) is equivalent to a loss of body heat. Accordingly, a loss of about 6 kcal from the shell results in a $1^{\circ}C$ lower skin temperature, compared to a loss of 52 kcal from the core to reduce core by $1^{\circ}C$. While skin temperatures maintained well above $+15^{\circ}C$ can result in cold injuries, if prolonged, an individual with a core temperature below $35^{\circ}C$ is at risk from hypothermia, with ventricular fibrillation as a result of cardiac irritability peaking at about $28^{\circ}C$ core temperature a frequent cause of hypothermic death even though some individuals have been resuscitated despite core temperatures near $15^{\circ}C$.

PUBLICATIONS - Hypothermia

Iampietro, P.F., J.A. Vaughan, R.F. Goldman, M.B. Krieder, F. Masucci and D.E. Bass. Heat production from shivering. J. Appl. Physiol. 15: 632-634, 1960.

Beckman, E.L., E. Reeves and R.F. Goldman. Current concepts and practices applicable to the control of body heat loss in air crew subjected to water immersion. J. Aerospace Med. 37: 348-357, 1966.

Goldman, R.F., J.R. Breckenridge, E. Reeves and E.L. Beckman. "Wet" versus "Dry" suit approaches to water immersion protective clothing. J. Aerospace Med. 37:485-487, 1966.

Witherspoon, J.M., Goldman, R.F. and J.R. Breckenridge. Heat transfer coefficients of humans in cold water. J. de Physiologie 63: 459-462, 1971.

ABSTRACTS - Hypothermia

Witherspoon, J.M. Thermoregulation during immersion in water from 20 to 40°C. In Proc: Intern. Symposium on Environmental Physiology, Bioenergetics and Thermoregulation, Dublin, Ireland, February 1971.

Gee, Gin K. and R.F. Goldman. Prediction of whole body cooling. Biophysical J. 13:214a, 1973.

Gee, Gin K. and R.F. Goldman. Heat loss of man in total water immersion. The Physiologist 16:318, 1973.

Soule, R.G., G.K. Gee (R.F. Goldman). Reducing heat storage or debt by water immersion. Fed. Proc. 33:442, 1974.

Bynum, G.D. and R.F. Goldman. Whole body cooling with protective clothing during cold water immersion. The Physiologist 17:191, 1974.

Goldman, R.F. Effects of environment on metabolic heat production. In Proc: First Ross Conference on Metabolism, Jackson Point, Maine, June 1978.

Goldman, R.F., H. Friedman, G. Gee, G. Bynum, J. Bogart, C. Levell and L. Strong. Metabolic versus vasoconstrictive responses to cold water immersion. The Physiologist 22(4):46, August 1979.

Dr. Murray P. Hamlet, D.V.M.
Director, Experimental Pathology & Cold Division
US Army Medical Research Institute of Environmental Medicine
Natick, MA.

Dr. Hamlet has been the director of the Experimental Pathology & Cold Division for eight years. Previous to this he worked at the Arctic Medical Research Laboratory in Alaska. In his position as Director, Experimental Pathology & Cold Division he directs the cold research program at USARIEM for the US Army.

ABSTRACT

RESUSCITATION OF ACCIDENTAL HYPOTHERMIA VICTIMS

Dr. Murray P. Hamlet
US Army Research Institute of Environmental Medicine

Accidental hypothermia or whole body cooling is a serious medical emergency. The physician is often faced with a critically ill patient and is often uncertain of how to approach the clinical management and resuscitation of these patients. This paper outlines the physiology of hypothermia and describes the major decision making points in the resuscitation procedure and attempts to define the approach to returning these patients to a normal physiologic state and temperature.

Special reference is given to utilization of internal methods of rewarming, in particular, warm peritoneal dialysis and its effect on hypothermic patients.

R. W. Hamilton, Jr., Ph.D.
Hamilton Research, Ltd.
President
Tarrytown, New York 10591

ABSTRACT

R. W. Hamilton, Jr., Ph.D.
Hamilton Research, Ltd.

If things go as planned I should have some significant hypothermia research to make a brief report on, and in any case will have a problem to throw before the group.

The problem relates to surviving in a lost diving bell, pressurised with helium and at a temperature about 4 C. To have a good chance for rescue, the divers should be able to survive for 24 hours. It ought to be possible to do this with passive protection, the right type of suit, and a means of conserving breathing gas heat. Rather than wait for "development", the Norwegian Underwater Institute (at the request of Norwegian and British sponsors) plans to test 3 existing thermal protection systems under conditions of a saturation dive in early January. I would like to present the results of this test (assuming it does take place) and ask the assembled experts on hypothermia for suggestions on how to proceed with solving the problem. I also hope to have a handout.

My role in the test is as a consulting investigator to the Norwegian Underwater Institute.

RESUSCITATION OF ACCIDENTAL HYPOTHERMIA VICTIMS

Murray P. Hamlet, D.V.M.
Director, Experimental Pathology & Cold Division
US Army Medical Research Institute of Environmental Medicine
Natick, MA

The recognition of hypothermia as a serious medical emergency is the first step to successful resuscitation. Patients often present cold, cyanotic and pale, stiff as if in rigor with no palpable pulse, no audible heart sounds, no visible respiratory excursions and fixed pupils. They may be in various states of undress and if cooled in a crouched or huddled position impossible to straighten out on an examination table. Their EKG may be extremely bizzarre ranging from flat to ventricular fibrillation. Because patients have been successfully resuscitated at core temperatures of 64°F with flat EKGs, the axiom here is "no one is dead until he is warm and dead; attempt rewarming and resuscitation of all cold patients."

There are essentially three types of hypothermia: acute, subacute and chronic, and each has specific requirements for resuscitation and clinical management. Acute hypothermia results from rapid cooling, such as seen in cold water immersion. This acute drop in core temperature is accompanied by few metabolic, electrolyte, and pH abnormalities other than those caused by the direct effect of temperature. The slow cooling rate of chronic hypothermia is usually produced by alcoholic stupor, barbiturate overdose, endocrinopathies, stroke, etc., that subject a person to long-term cold exposure. Slow cooling produces severe alterations in pH, electrolyte balance, and serious alterations in fluid volume. This occurs as the normal physiologic defense mechanisms against cold attempt to counteract the cooling process. The subacute hypothermic patient falls somewhere in-between, that is, as alcohol imbibition, rain, heavy winds, poor clothing, etc., subject him to varying cooling rates.

Careful analysis of the immediate prior history can lead to determination of both how and at what rate the patient became hypothermic. Both will impact on how they are handled in the emergency room and in the hospital. Keep in mind that freezing temperatures are not necessary for the production of hypothermic patients.

<u>Resuscitation Tips</u>:

1. Low reading clinical thermometers should be readily available in the emergency room.

2. Core temperature should be taken rectally and is a reliable indication of the progress of rewarming.

3. Careful handling of the patient is essential. Any changes in body position or rough handling can initiate ventricular fibrillation.

4. The blood glucose levels of hypothermic individuals may give a clue to the type of cooling that occurred. Acute hypothermia produces hyperglycemia, while chronic and subacute cooling produces hypoglycemia. The long term shivering of the chronic hypothermic utilizes vast amounts of blood glucose, and, conversion of glycogen to glucose decreases as temperature decreases.

5. Atrial fibrillation is more common in acute than in subacute or chronic hypothermia.

6. Renal failure after rewarming is more common in chronic hypothermia.

7. Current British literature suggests that in acute hypothermia, rapid external rewarming is usually indicated. In chronic hypothermia they prefer slow rewarming to allow for reversion of metabolic aberrations. This author feels, however, that rapid internal rewarming of chronic hypothermia is a more physiologic procedure.

PHYSIOLOGY OF HYPOTHERMIA

Hypothermia, the lowering of core body temperature to 94°F or below is a potentially lethal disorder requiring aggressive therapy. As body temperature decreases below 94°F, central nervous system functions are depressed. Initially, patients exhibit behavioral changes, then depression of consciousness, culminating in coma. The respiratory center is progressively inhibited until apnea supervenes. Cardiac output falls to such extent that despite maximum peripheral resistance the blood pressure falls. The pulse rate decreases. Conduction and heart rhythm abnormalities occur. The "J" wave, various degrees of heart block, atrial premature contractions (APC's), atrial flutter and fibrillation, ventricular premature contractions (VPC's), ventricular tachycardia and fibrillation (VF), and if the patient is cold enough, ventricular standstill can take place. The shift of water out of cells and the intravascular space into the extracellular space as well as decreased renal tubular fluid resorption can render the patient hypovolemic. Some profoundly hypothermic patients exhibit a syndrome similar to disseminated intravascular coagulation (D.I.C.). Since insulin release and glucose utilization decline with temperature, blood glucose tends to be normal or elevated. Acid-base and electrolyte parameters are little affected by temperature alone but are often deranged by the disorder underlying the hypothermic episode.

The physician must bear in mind that patients who present with hypothermia often have underlying disorders which prevent appropriate physiological responses to the cold environment. Such illnesses include stroke, central nervous system trauma, shock, sedation, use of tranquilizer, or ethanol overdose, endocrinopathies like myxedema and hypoadrenocorticism, hypoglycemia, and old age.

Over medication while cold is a common problem. Subsequent rewarming brings patient into toxic areas for the drugs used. Most drugs are contraindicated in early hypothermia resuscitation.

Much controversy exists over which method of resuscitation, that is, active or passive, external or internal, yields the lowest mortality. The most frequent mechanism of death from hypothermia itself is ventricular fibrillation or standstill. These events can occur at temperatures in the mid 80°'sF (27°C) and below. Apnea can occur somewhat higher but usually occurs at lower levels. External warming techniques, active or passive, can actually increase the likelihood of fibrillation during the early phase of resuscitation. The application of heat to the body surface causes peripheral vasodilation, leading to the draining of heat away from core organs, the return of large volumes of cold blood to the core and thus the lowering of core temperature to increasingly dangerous levels, and a drop in the already low blood pressure. Although this reasoning militates for methods of rewarming the core before the periphery, as through peritoneal dialysis and extracorporeal blood rewarming, the literature suggests that with close monitoring and rapid correction of life-threatening aberrations, external rewarming, both active (with a heated bath or hypothermia blanket), or passive (by wrapping the patient in blankets to prohibit the escape of body heat) yield high survival rates. The author feels that it is physiologically more reasonable to use active than passive methods.

Because of the potential for cardiopulmonary death, the hypothermic patient must be admitted to the intensive care unit. Skull and chest x-ray, blood gasses electrocardiogram, blood count, BUN, creatinine, electrolytes, amylase, calcium, blood sugar, fibrinogen, prothrombin time, and platelet count will help in immediate management. If possible the attending physician should be cognizant of the mechanism of the patient's loss of proper thermoregulation. Continuous electrocardiographic monitoring should be instituted. Bizarre EKG tracings are to be expected. Respiratory support including intubation and mechanical ventilation is almost mandatory to keep the supply of oxygen ahead of the rewarming organ demand. Care should be taken during intubation as any rough manipulation can lead to ventricular fibrillation. Ventricular premature contractions are abolished by lidocaine infusion and correction of hypoxia and acidosis. APC's, atrial flutter, and fibrillation will spontaneously revert to normal without medication as cardiac temperature approaches normal. Atropine and electrical pacing have little beneficial affect on conduction in the hypothermic heart. On the contrary the irritation of the myocardium by the pacemaker electrode itself or by its discharge can lead to VF. If ventricular tachycardia fails to respond to lidocaine or if VF takes place, rapid extracorporeal blood rewarming must be instituted immediately. Because the hypothermic heart is unresponsive to countershock, cardiac temperature must be raised before cardioversion can be successfully accomplished. In such emergencies, the cardiopulmonary bypass machine, equipped with heat exchanger, connected to the femoral artery and vein has been successfully employed. Like any cardiac arrest this situation calls for continuous closed cardiac compression and forced ventilation until the appropriate machines can be placed in operation.

Hypoxia and acidosis are major factors predisposing to ventricular arrhythmias. pH, P_{CO_2} and P_{O_2} may appear to be low but may in fact be correct for the organ and brain demand at the depressed temperatures seen in hypothermia. Blood gasses and pH, corrected for temperature, should be determined, and abnormalities corrected by adjustment of respiratory parameters or bicarbonate infusion, whichever is necessary but do not overmedicate. Intubation and suction may be necessary to manage bronchorrhea, the physiological response of the airway to exposure to cold air. The rate of spontaneous respiration will increase as the temperature rises.

Maintenance of the central venous pressure at 5-10cm water, with suitable volume expanders, will insure that intravascular fluid volume keeps pace with the capacity of the intravascular space, enlarging in response to peripheral vasodilation which in turn is caused by external rewarming. Thus, when cardiac temperatures and correspondingly cardiac output and heart rate begin to rise, blood pressure will follow suit. Avoid the use of pressor agents which have no effect on the maximally constricted vessels but which increase the likelihood of ventricular arrhythmias. Similarly, in order to avoid myocardial irritation leading to VF the CVP catheter tip should not be advanced into the heart until some degree of rewarming has occurred and the myocardium is not exceptionally sensitive to physical irritation by the catheter tip. As with respiration, the heart rate will rise spontaneously with temperature. Begin intravenous heparin therapy if clotting tests indicate the occurrence of a DIC-like syndrome.

Other fluid, electrolyte and metabolic abnormalities should be treated as the clinical situation dictates. Therapeutic doses of steroids may be given if hypoadrenocorticism is suspected. Because of the high failure rate of resuscitation of hypothermic myxodematous patients, the latter state must be recognized and treated immediately. After the patient's condition has stabilized, perform whatever additional studies are called for to determine the disease process underlying the hypothermic episode.

HYPOTHERMIA CHECKLIST

1. Recognize that the patient is hypothermic - use low temperature thermometer.

2. For patients with compromised mental status or cardiovascular irregularities intensive care is necessary.

3. History of predisposing disease - (Myxedema, hypoadrenocorticism, etc.)

4. Begin, continuous or frequent temperature recording with low temperature recording thermistor or thermometer.

5. Install I.V., (possibly an arterial line), C.V.P., foley catheter (may be extremely difficult).

6. Begin continuous cardiac monitoring.

7. Frequently monitor vital signs and urinary output (at least every hour or more frequently as necessary during rewarming).

8. Wrap patient in rewarming blanket and set to as high a temperature as can be tolerated without burning the patient (104-110^{o}F).

9. Give respiratory support - oxygen by mask or by endotracheal tube (may produce VF) with mechanical ventilation - Aim for high PO_2 normal pH and PCO_2, and clearance of secretions. Monitor arterial gasses and pH as frequently as necessary.

10. Tests: CBC, BUN, creatinine, electrolytes, glucose, amylase, calcium, fibrinogen, prothrombin time, platelet count, chest and skull x-rays, 12 lead E.K.G., arterial blood gasses and pH (corrected to core temperature).

11. Maintain C.V.P. between 5 and 10cm with appropriate expanders or fluids calculated to correct electrolyte imbalance gradually.

12. Give bicarbonate to correct acidosis.

13. Treat VPC's with standard boluses 1.5mg/kg of lidocaine and the correction of hypoxia and acidosis. If ventricular tachycardia, fibrillation, or standstill occur begin closed-chest cardiac compression and assisted ventilation until extracorporeal blood rewarming can be instituted with cardiopulmonary bypass with heat exchanger. Electrical cardioversion will succeed when the heart warms sufficiently. Atrial premature contractions, flutter and fibrillation will revert to normal with rewarming.

14. Give therapeutic doses of corticosteroids or thyroid hormone if called for.

15. Give heparin for a D.I.C. like syndrome.

R. Michael Harnett, Ph.D.
Associate Professor Systems Engineering
Clemson University

Dr. Harnett received his BS in Mathematics in 1968 from Louisiana Polytechnic University and his MS in Operations Research in 1972 and Ph.D. in Industrial and Systems Engineering in 1974 from the University of Alabama in Huntsville. He was employed for 3 years with Northrop Space Labs and for 4 years with the SAFEGUARD Systems Command in Huntsville, Alabama. In 1974, he was appointed to the Systems Engineering faculty at Clemson University, where he is currently an Associate Professor. His interests are wide ranging and include the biological aspects of systems problems.

ABSTRACT

AN EXPERIMENTAL EVALUATION OF METHODS FOR TREATMENT OF PROFOUND ACCIDENTAL HYPOTHERMIA

R. M. Harnett
E. M. O'Brien
F. R. Sias
J. R. Pruitt
College of Engineering
Clemson University

Accidental hypothermia may be dichotomized into, a) those cases which are so serious that the method of treatment applied when the victims are first recovered materially effects their prospect for survival, and b) those cases which are sufficiently mild that normal careful handling virtually assures survival. These cases may be roughly distinguished on the basis of core temperature if there are no mitigating circumstances. At core temperatures below 32°C (profound hypothermia) the choice of treatment is a matter of concern.

Six methods of treatment are postulated for use at the rescue site and during transport to a site of definitive care. They are experimentally compared to: a) spontaneous shivering thermogenesis and b) trunk immersion in hot water. The experimental therapies are: c) inhalation therapy, d) heating pads therapy, e) plumbed garment therapy, f) inhalation and heating pads therapy, g) inhalation and plumbed garment therapy, and h) body-to-body heat exchange. The performance of the therapies is expressed in terms of three parameters: afterdrop, recovery period and rate of rewarming.

Surface applications of moderate amounts of heat are shown to produce relatively large afterdrops. Spontaneous rewarming under a blanket is shown to rewarm shivering subjects with relatively small afterdrops. Inhalation therapy is shown not to promote afterdrop as does surface heating. Compensations in interpreting the implications of the experiments to the choice of a method of treatment for profound hypothermia are necessitated by fundamental differences between the experimental subject's conditions and those anticipated in the patients. These compensations are discussed.

A STUDY OF IMMERSION HYPOTHERMIA

PART II:

An Experimental Comparison of Methods for Rewarming from Deep Hypothermia in the Field*

by

R.M. Harnett, Ph.D., E.M. O'Brien, Ph.D.,
F.R. Sias, Ph.D. and J.R. Pruitt, M.D.

College of Engineering
Clemson University
Clemson, S.C. 29631

1.0 INTRODUCTION

The objective in rewarming victims of immersion hypothermia is the restoration of normothermia without precipitating additional fatal side effects. Since it is known that victims of mild hypothermia will normally recover if they are simply removed from the cold, the primary concern is in the treatment of profoundly cold people.

Profound hypothermia is defined to be the level of hypothermia in which the method of treatment received by the patient can materially effect his prospects for survival. Based on the literature survey by Harnett, et al. (1979) profound hypothermia is taken to involve core temperatures at or

---

* Sponsored by U. S. Coast Guard Office of Research and Development
Contract Number DOT-CG-72074-A

below 31°C (about 88°F). Above this level the patients are generally conscious and shivering, their respiratory function is not significantly depressed and myocardial irritability is not sufficiently pronounced to necessitate delicate handling. Below this level the patients are generally unconscious and not shivering, their respiratory function becomes progressively more depressed and myocardial irritability increases.

Intense debate has persisted over the best approach to treating such patients and was summarized by Harnett, et al. (1979). While the present purpose is not to reiterate the details of this debate, it will be useful to state the major points. The debate has produced two schools of thought - one supporting "rapid" rewarming by the application of "active" rewarming measures and the other supporting "slow" rewarming through a more "passive" approach. The debate has been fueled at least partially by the ambiguity of the terms rapid and slow, but there are two basically different underlying philosophies. Individuals advocating active rewarming cite the desirability of minimizing the amount of time the patient is in the hypothermic state and claim that active rewarming can, when properly applied, minimize the tendency toward afterdrop (additional core cooling after removal from the cold). The advocates of passive rewarming cite the tendency of active rewarming to produce hypotension and to restore heat to parts of the body before the distributions of electrolytes, the acid-base balance, the respiratory minute volume, and the distribution of fluids within the body return to near-normal. However, the preponderence of evidence for and against specific therapies is expressed in terms of their thermal performance.

A phenomenon termed "post-rescue collapse", in which individuals rescued from cold-water immersion die within the next half hour or so, has been well documented (Keatinge, 1969). Unfortunately, the cause of these deaths remains a matter for conjecture. For some time the leading explanation has been afterdrop in the temperature of the heart resulting from the return of relatively cold blood, associated with increased circulation through the limbs. However, relatively recent British research (Golden and Hervey, 1977) has cast doubt on this mechanism.

Golden and Hervey (1977) demonstrated that profoundly-cold, anesthetized pigs (rectal, esophageal and central venous blood mean temperatures all of

30.7°C) when put in a hot bath (41°C) exhibited some rectal afterdrop (mean about 0.4°C), less esophageal afterdrop (mean about 0.2°C) and essentially no afterdrop in central venous blood temperature. Furthermore, Golden and Hervey indicate that when rewarmed with circulation stopped (by cessation of cardiac function), the pigs' core temperatures: "again showed afterdrops with rectal and gastric temperatures lower than central venous."

This report has provided the basis for a new trend in thought which may be characterized as follows:

1. Probably too much has been made of the phenomenon of afterdrop which is so regularly observed at the rectal site but which does not occur at core sites of greater concern, e.g., the heart.

2. Since afterdrop does not require circulatory redistribution of heat to occur, it is not significantly influenced by peripheral vasodilatation during initial rewarming. Thus, attempts to heat the core without promoting peripheral vasodilatation are wasted effort.

No new trend in thought has yet come forth to replace afterdrop as an explanation for post-rescue collapse.

These views are, of course, not universally supported. Criticisms of this new trend in thought include the following.

1. The pig is a poor analog for man in regards to peripheral vasculature. It has only about 15 percent of its body mass in the limbs compared to 40 percent for man; and there are obvious differences between hoofs and highly vascularized feet and hands. The pig therefore makes a weak case against the involvement of peripheral vasodilatation in promoting afterdrop in man.

2. The amount of the afterdrops occurring without circulation were not mentioned by Golden and Hervey, therefore, they can not be meaningfully compared to those occurring with circulation.

3. The hot bath rewarming used by Golden and Hervey is widely recognized to minimize afterdrop as compared to other techniques of rewarming. Hot bath rewarming therefore makes a weak case against the occurrence of afterdrop at any particular core site.

4. It ignores the observations of Cooper and Kenyon (1957). They demonstrated the involvement of circulation in the rewarming of profoundly cooled surgical patients who,

when circulation was instantaneously restored (by removal of aortic clamps), began a slight recession in rectal temperature and a larger recession in esophageal temperature.

There is no clear understanding of the nature of the response of profoundly cold humans to removal from the cold and the application of different rewarming treatments. As a result there is no well established criterion for evaluating the merits of alternative rewarming treatments. Candidate criteria include, but are not limited to, the following.

1. The propensity to preclude afterdrop (intended to avert post-rescue collapse)

2. The rate of rewarming (with some individuals supporting slow and others supporting rapid approaches)

3. The stabilization of blood pressure (intended to preclude hypovolemic shock)

4. The prevention of significant electrolyte disturbances.

Of course, some combination of these and other criteria could be used as a basis for selecting a rewarming treatment.

Regardless of what evaluation criterion is used, the therapy evaluation must be based on the following three imperfect sources of information.

1. experiments with mildly cooled human volunteers
2. experiments with profoundly cooled laboratory animals
3. clinical observations

Experiments with human volunteers present difficulties in getting core temperature measured at the heart site because of adverse effects of the instrumentation. And even if this problem is circumvented, only mild depressions in core temperature may be induced with reasonable safety. Thus the determination of selection criteria may have to compensate for indirectness of measurement as well as the mildness of the hypothermia being treated. Experiments with animals allow the treatment of profound hypothermia and direct measurement of temperatures at core sites of greatest interest. However, the applicability to man of conclusions regarding therapeutic effectiveness based on animal studies is difficult to establish beyond reasonable doubt. (This contrasts with the use of animals to identify "potential hazards".) Clinical observations may be obtained from cases of profound hypothermia but the temperature measurements are often superficial and are obtained in a millieu designed to save lives not to gather controlled scientific data. While clinical observations may suggest fruitful directions for systematic study, they are slow to provide a basis for evaluating therapeutic effectiveness.

The objectives of this investigation were to postulate candidate methods for rewarming victims of hypothermia in the emergency environment and to design and execute and experiment to determine their effectivenesses as rescue techniques. The rewarming methods were limited to those which could be performed by an individual trained at the level of an emergency medical technician. They were formulated to make maximum use of equipment that was commercially available. The present effort included no development of new prototype equipment. The therapies were evaluated for their prospective effectiveness in treating profound hypothermia. The experimental evaluation of the therapies was performed in conjunction with testing of cold-immersion protection equipment. The evaluation was based upon data which could be obtained by applying the therapies to volunteer subjects following their cooling during the cold-immersion experiments.

2.0 THERAPIES SELECTED FOR EVALUATION

The therapies selected for inclusion in the experimental evaluation are the following:

1. Spontaneous rewarming
2. Trunk immersion
3. Inhalation therapy
4. Heating pads
5. Plumbed garment
6. Combination of inhalation and heating pads
7. Combination of inhalation and plumbed garment
8. Body-to-body heat exchange

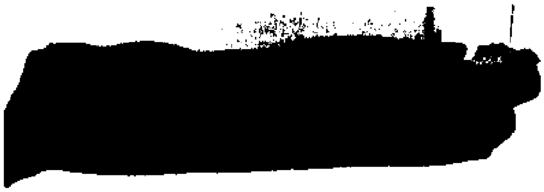
Therapies 3 through 8 were included because of their potential for effective use in the rescue environment. Therapies 1 and 2 were included for their usefulness as standards of comparison for the others. In the following sections of this chapter the conceptual basis for each therapy is discussed, the manner in which it was applied during the experimentation is described and all equipment used in administering the therapies is identified.

2.1 Spontaneous Rewarming

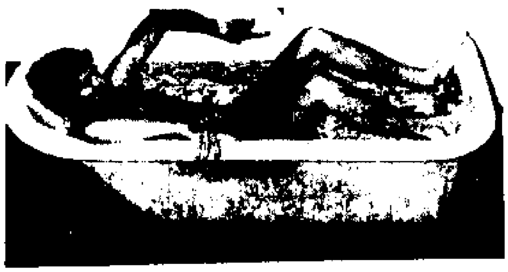
Spontaneous rewarming by shivering thermogenesis was used as a control experiment in the evaluation. No active heating of any kind was given the subjects. They were simply undressed to their undershorts, towel dried (if they were wet), placed in a reclined position on a 4 inch thick foam rubber mattress (covered by a cotton mattress pad) and immediately covered with a standard acrylic blanket. This is illustrated in Figure II-1 (a). This position and these materials were used in all "dry" rewarmings with only the exceptions cited in the later sections of this chapter.

Two approaches were considered for determining when to cover the subject with the blanket. The simplest was to cover him at the beginning of the rewarming period. The other was to cover him when his average skin temperature had spontaneously risen to the ambient temperature of the experiment area. Because reliable monitoring of skin and ambient temperature in the rescue environment would present an operational complexity and since afterdrop could potentially be minimized by insulating the surface of the cold body from an environment perhaps warm enough to promote peripheral circulation but not warm enough to produce significant warming, the simple approach of covering the subject at the beginning of rewarming was used.

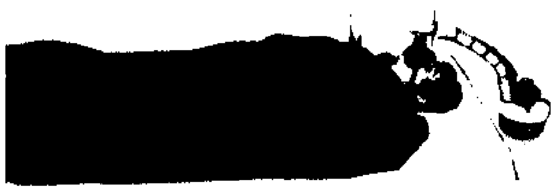
FIGURE II-I
REWARMING THERAPIES



(a) Spontaneous Rewarming

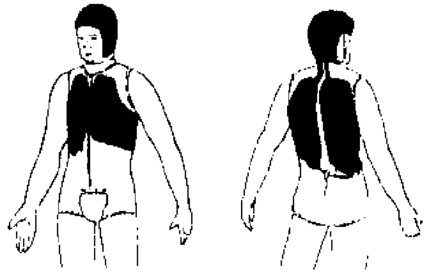


(b) Trunk Immersion

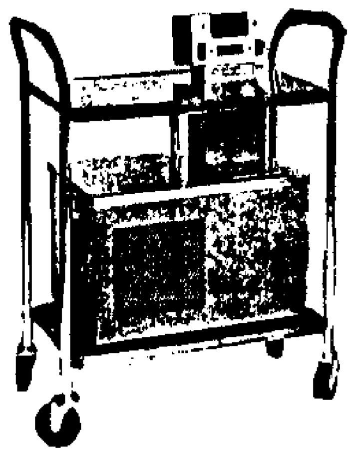


(c) Inhalation Therapy

(d) Heating Pad Placement



(e) Basic Plumbed Garment



(f) Thermal Conditioning Cart

(g) Position for Body-to-Body Heat Exchange

2.2 Trunk Immersion Therapy

The immersion of the body in hot water is generally recognized to be an effective way to restore heat to the core. The technique has been examined in previous research with various parts of the body immersed in the hot water with the trunk. The results have varied and are difficult to compare directly. Based on the simple notion that heat can be effectively gotten into the body core while minimizing afterdrop by applying the heat to the area immediately surrounding the core, it was decided to apply the hot bath therapy only to the trunk of the body. The subjects were not dried following the immersion phase of the experiment. They were lifted by members of the research team and placed on their backs in a "claw foot" bath tub half filled with 32.2°C (90°F) water. This position is illustrated in Figure II-1 (b). Their arms and legs were kept from coming in contact with the water at any time during the experimental rewarming. The water temperature was raised to 43.3°C (110°F) over a period of approximately 5 minutes and was maintained at this temperature for the duration of the experiment. The water level was adjusted to cover the chest and the water was continually agitated to eliminate thermal stratification.

With the subject in this quasi-reclined position his breathing passages were generally below the top of the tub and were a short distance above the surface of the water. One would expect that this would serendipitously provide, during trunk immersion therapy, some of the heat balance benefits of inhalation therapy.

2.3 Inhalation Therapy

The therapeutic objective of inhalation therapy is to terminate respiratory heat loss and to promote heat uptake by the tissues of the lung and the blood circulating through them. This is accomplished by providing the patient a warmed, humidified gas to breathe. Some heat is carried by the molecules of gas and some is released in the lungs by the condensation of water vapor. Inhalation therapy was conceived to permit the treatment of hypothermia in remote locations and in unfavorable conditions.

There is considerable latitude in the choice of a gas mixture to be used in the therapy (see Harnett, et al., 1979). Because the thrust of these experiments was toward the thermal performance of each therapy and mildly cooled test subjects were used, the therapeutic advantage of most mixtures (e.g., varying oxygen content) would be imperceptible.

For experimental purposes the therapy was formulated to use ambient air heated and humidified by a Bennett Cascade Humidifier. An open loop circuit was used to avoid the problems of sterilization of a carbon dioxide absorber. The thermostat was adjusted to maintain the temperature of the gas at 42 to 44°C in the mask. This required continual monitoring of the gas temperature and periodic manual adjustment of the thermostat. The therapy was applied with the subjects in the standard position as shown in Figure II-1 (c).

2.4 Heating Pads Therapy

If one accepts the notion that afterdrop is promoted by peripheral vasodilatation, the question then arises: "Is it possible to rewarm the core by applying heat only to selected surface areas and thereby avoid promoting afterdrop?". The heating pads therapy was formulated to answer this question. The surface areas to which the heat was applied (neck, lateral thorax and groin) were selected on the basis of thermographs by Hayward, et al.,(1973). They revealed that these areas radiate heat from cold subjects (15 minutes in 7.5°C water) at relatively high rates. It was postulated that since these areas mediate high rates of heat loss, they might, with sufficient heat applied, mediate high rates of heat uptake by the core. The positioning of the heating pads is illustrated in Figure II-1 (d). The therapy was applied under the standard acrylic blanket.

The heating pads utilized were 55 watt electric pads with a three-position control. They were operated on the "high" setting. Heating pad/skin interface temperatures around 44°C were achieved. The pads were preheated to thermal equilibrium prior to initiating rewarming. Terry cloth swatches moistened in warm water were placed between the pads and the subject to facilitate heat transfer.

2.5 Plumbed Garment Therapy

The plumbed garment therapy was conceived to perform in the same general manner as the heating pads therapy -- by surface heating of selected body areas. It was desired that the device tested be essentially one that is commercially available. The cap and vest garment shown in Figure II-1 (e) was selected. The device is marketed as shown by the Aerotherm Group of Acurex Corporation located in Mountain View, California. For purposes of the research the garment was modified to include two additional bladders which could be positioned to warm the groin area. Pressurized hot water was supplied to the garment by the termal conditioning cart shown in Figure II-1(f). The cart (part number 245-30013A) was operated at the temperature setting (114°F) indicated by the manufacturer to be the maximum safe level.

The plumbed garment therapy was applied with the subjects generally in the standard position. However, the subjects were rolled slightly toward their right side. This was determined to be necessary to avoid kinking of soft rubber connectors on the lines carrying the heated water to the garment and back to the cart. The garment was preheated to thermal equilibrium and its surfaces which contact the subjects were moistened, to facilitate heat transfers, prior to initiating rewarming.

2.6 Combination Therapies

Two therapies were considered which were formulated as simple combinations of therapies previously described in this chapter. A combination of inhalation and heating pads therapies was studied as was a combination of inhalation and plumbed garment therapies. Because of the simple way in which these therapies combined, no additional descriptions are needed.

2.7 Body-to-Body Heat Exchange

It has often been recommended in popular publications that emergency treatment of hypothermia should be performed by placing a normothermic individual in a sleeping bag with the victim if better methods of treatment cannot be applied. The potential exists for the moderate surface heating contributed by the normothermic companion to promote significant afterdrop while contributing little to the restoration of core heat. No objective data has existed to support or refute the treatment of hypothermia by the exchange of heat from one body to another.

In formulating the body-to-body heat exchange therapy it was decided that the therapeutic effect to be investigated would be restricted to simple heat transfer without introducing effects of arousal resulting from close contact between members of opposite sexes. Since the immersion volunteers were all males, only males were used as heat donors in the heat exchange therapy. To achieve procedural simplifications three of the authors served as heat donors. Their general physical characteristics are shown in Table II-1.

TABLE II-1
HEAT DONOR PHYSICAL CHARACTERISTICS

Donor	Age	Height (cm)	Weight (kg)
O'Brien	29	170.0	65.8
Sias	47	177.8	79.4
Harnett	34	182.9	86.3

The selection of a heat donor to participate in each rewarming experiment was generally made so as to match the heights and weights of the heat donor and the heat recipient as closely as possible.

It was decided that volunteers would be positioned to maximize upper body contact and that peripheral body contact would be avoided in an attempt to minimize the promulgation of afterdrop. Because localized vasodilatation in response to contact with the heat donor would facilitate subsequent heating of the subject's blood (and presumably his body core as well) it was decided that the entirety of rewarming would be accomplished with heat being applied to the same area of the subject's body. It was anticipated that there would be some surface cooling of the part of the heat donor's body contacting the rewarming subject. This would reduce the temperature gradient between heat donor and heat recipient and the rate of heat transfer as well. To determine the significance of this effect, a preliminary experiment was conducted with the donor's chest in contact with the recipient's back (both wearing only shorts). The donor's chest (pectoral) temperature was monitored. The donor's initial chest temperature was 33.2°C. It dropped to 30.8°C 4 minutes into rewarming. It recovered to 32.9°C 10 minutes into rewarming re-establishing much of the initial capacity of the donor's chest to yield heat. This experiment revealed that there is no compelling reason for the heat donor to continually change the area of his body which is in contact with the heat recipient.

The body-to-body heat exchange therapy was formulated with the donor and recipient lying on their left sides and clad in shorts. The donor's chest and stomach were in contact with the recipient's back. Their extremities were kept apart. They were reclined on the standard mattress and covered by the standard acrylic blanket as shown in Figure II-1 (g).

3.0 EXPERIMENT PROTOCOL

3.1 Methodology

It was recognized at the outset that physical exertion by the subjects during the transition from floating in the cold water to rewarming could affect their responses to the therapies. To minimize this effect a "chair lift" apparatus was installed (see Figure II-2) to permit effortless entering and exiting of the immersion tank. To further stabilize the subjects' condition during this transition, their cold-protection equipment and clothing were removed by members of the research team after the subjects had been instructed to stand still and relax as much as possible.

The rewarming experiments were conducted using the subjects whose morphology is described in Table II-2. The experiments were conducted between July 7, 1978 and April 27, 1979. A number of steps were taken to assure comparability of results obtained in different experiments.

1. To eliminate effects of diurnal variation the immersion experiments were generally started around 1:00 p.m. each day. There was some variation in the start times of the rewarmings but they generally began between 3:00 and 4:00 p.m.

2. Participation in immersion experiments, and hence rewarmings, required that the subjects have taken no medication or alcohol for 24 hours or food or tobacco for 2 hours.

3. The temperature in the research area was subject to some control. An attempt was made to conduct each rewarming in 21.1°C room air.Table II-3 shows the mean ambient dry bulb temperatures and relative humidities existing during the conduct of each rewarming therapy.

4. As mentioned earlier the "dry" therapies were performed while the subjects were in the standardized position on the foam rubber mattress covered by the acrylic blanket.

5. Because of the volunteer's freedom to withdraw from the experiments at any point, it could not be assumed that each would perform each therapy once. As the experiment program proceeded, subjects were assigned to therapies to maximize the useful comparisons among their experiments if they continued no further. The resulting assignment of subjects to therapies is indicated in Table II-4. The letters in the "Body-to-body" column indicate the initial of the heat donor from Table II-1 who participated in each experiment. No subject was allowed to experience any therapy more than once.

FIGURE II-2
HYDRAULIC CHAIR LIFT

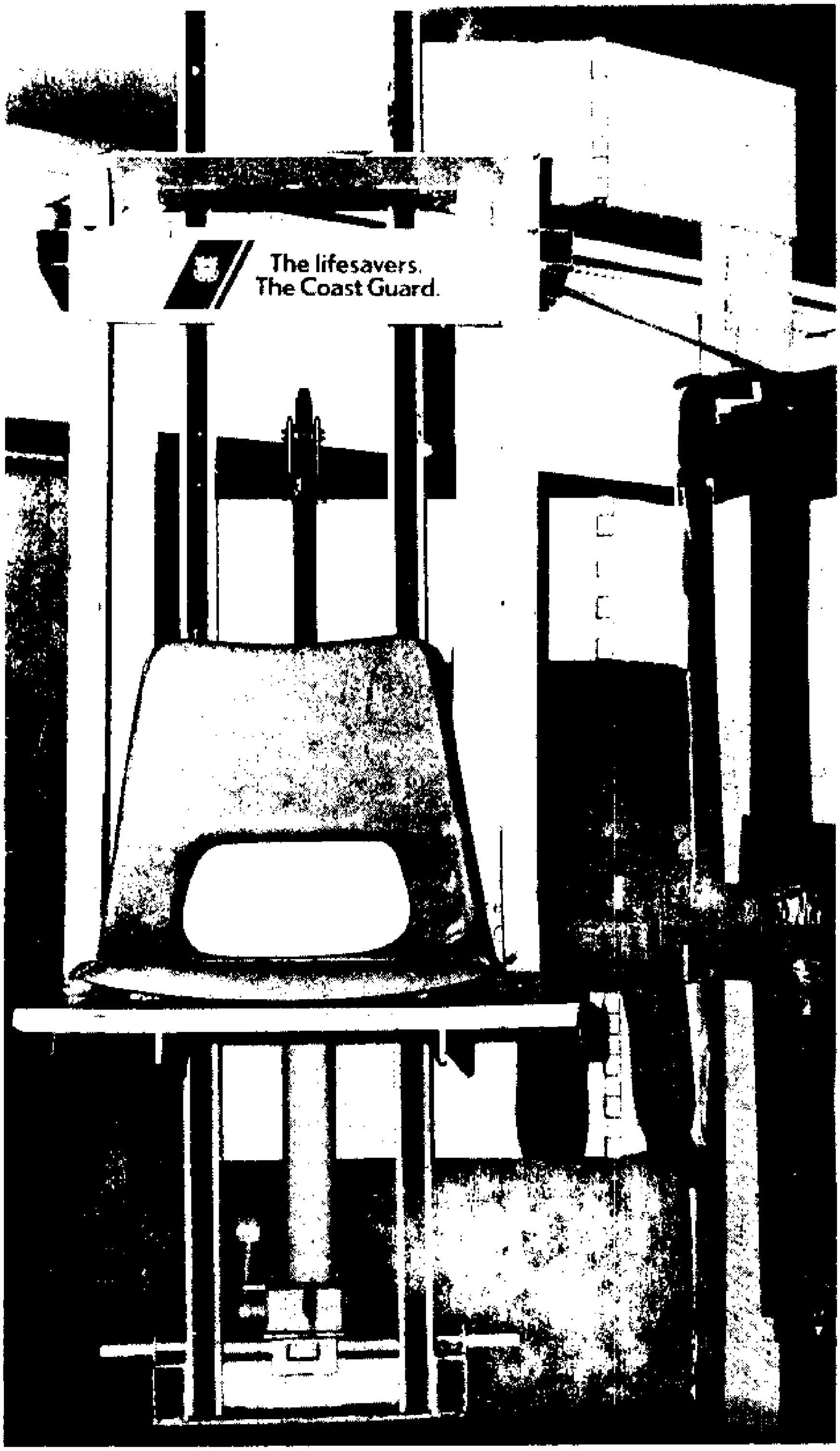


TABLE II-2
REWARMING SUBJECTS PHYSICAL CHARACTERISTICS

Subject	Age	Height (cm)	Weight (kg)	Heath-Carter Somatotype Components I	II	III	Surface Area (m^2)
KC	21	185.0	85.4	3 1/2	4	2	2.13
GE	23	182.9	65.5	2	4	4 1/2	1.86
GF	23	178.2	67.3	2 1/2	4	3 1/2	1.85
BH	23	178.9	82.7	4 1/2	4	1 1/2	2.03
MH	25	182.7	64.1	1 1/2	2 1/2	5	1.83
MK	22	183.0	75.9	2 1/2	5	3	1.98
PK	21	183.9	91.4	4 1/2	6	1 1/2	2.16
CM	21	186.6	70.2	2 1/2	3	4 1/2	1.95
RM	24	168.3	63.6	4	5	2 1/2	1.73
MO	21	180.0	76.4	3 1/2	6 1/2	2 1/2	1.96
TP	25	185.2	76.4	3	3 1/2	3 1/2	2.02
CR	19	180.4	69.3	2	4	3 1/2	1.90
JR	21	178.5	60.9	3	3	4 1/2	1.78
BS	21	187.1	71.4	2 1/2	4	4 1/2	1.96
SW	22	177.5	66.3	3	4	3 1/2	1.82
TW	22	177.0	74.5	4	4	2	1.92

TABLE II-3
COMPARISON OF MEAN AMBIENT TEMPERATURES AND
RELATIVE HUMIDITIES DURING REWARMING THERAPIES

Therapy	Temperature (°C) Mean	S.D.	Relative Humidity (%) Mean	S.D.
Spontaneous Rewarming	22.2	1.1	56.4	3.8
Trunk Immersion	22.7	2.3	59.0	4.0
Inhalation Therapy	21.1	0.6	57.7	3.4
Heating Pads	21.3	1.4	58.7	5.1
Plumbed Garment	21.2	0.2	61.3	2.6
Inhalation + Heating Pads	22.3	2.4	62.2	5.1
Inhalation + Plumbed Garment	21.3	0.8	60.6	6.2
Body-to-Body	21.8	1.4	58.1	6.6

TABLE II-4
ASSIGNMENT OF SUBJECTS TO REWARMING THERAPIES

Subject \ Rewarming Therapy	Spontaneous Rewarming	Trunk Immersion	Inhalation Therapy	Heating Pads	Plumbed Garment	Inhalation + Heating Pads	Inhalation + Plumbed Garment	Body-to-body*	Total
KC		X			X		X		3
GE	X	X	X	X	X	X	X	O	8
GF	X		X	X		X	X	O	6
BH					X		X		2
MH		X		X		X			3
MK	X	X	X	X	X	X	X	S	8
PK	X			X	X			H	4
CM				X		X			2
RM		X	X		X		X		4
MO	X	X	X						3
TP				X				S	2
CR	X	X	X	X		X		O	6
JR	X		X			X		O	4
BS	X	X			X	X	X		5
SW	X	X	X	X	X	X	X	S	8
TW	X		X			X		H	4
TOTAL	10	9	9	9	8	10	8	9	72

* Letters in this column indicate the heat donor (from Table II-1) participating in each experiment

The original experiment protocol involved monitoring on each subject six skin temperatures (great toe, thigh, groin, subscapular, bicep and forearm), rectal temperature (15 cm depth), tympanic membrane temperature, ECG and blood pressure. However, tympanic membrane temperature measurement was discontinued after only a few experiments. This was due to the discomfort and risk of injury to the tympanic membrane resulting from the impingement upon the temperature probes by various cold-protection devices worn during the immersion phase of the experiment. As a result, the estimation of body "core" temperature was based solely upon measurements made in the rectum.

3.2 Design of Experiment

It was anticipated in planning the experiment program that conducting an investigation of rewarming therapies integrated into an investigation of cold-protection devices as diverse as those considered in this study could complicate the interpretation of the rewarming results. This anticipation was based on the notion that variation in the amounts of cooling and rates of cooling experienced by the subjects due to variations in the protective equipment might affect the apparent performance of the therapies. Of these two rewarming initial conditions (amount of cooling and rate of cooling) it was thought that the amount of cooling might be the more significant. Therefore, a method of controlling the design of the experiment was adopted which sought to distribute this factor as uniformly as possible across the therapies. The specific control parameter utilized was the mean amount of cooling that occurred prior to the initiation of rewarming (including the period of transition from cooling to rewarming). This parameter was controlled by adjusting assignments of cooled subjects to rewarming therapies. Thus the scheduling of rewarming therapies was done in a two-stage manner. A preliminary assignment was made on the basis of the anticipated course of the cooling phases of experiments to be performed in a given afternoon. Then when changes in this course occurred (e.g., due to early termination of cooling at the request of the subject) adjustments to the therapy assignment were made to balance the anticipated final values of the control parameter. These final values are shown, along with the mean rates of cooling preceding each therapy, in Table II-5.

TABLE II-5
MEAN INITIAL CONDITIONS FOR REWARMING THERAPIES

Therapy	Number of Replications	Prior Cooling (°C) Mean	Prior Cooling (°C) S.D.	Rate of Cooling* (°C/hr) Mean	Rate of Cooling* (°C/hr) S.D.
Spontaneous Rewarming	10	1.44	.68	.82	0.73
Trunk Immersion	9	1.42	.42	.62	0.58
Inhalation Therapy	9	1.41	.70	.79	1.25
Heating Pads	9	1.34	.52	.81	0.96
Plumbed Garment	8	1.39	.64	.85	1.01
Inhalation + Heating Pads	10	1.43	.55	.85	1.26
Inhalation + Plumbed Garment	8	1.28	.62	.44	0.37
Body-to-Body	9	1.26	.63	.68	0.59

*Based on last 30 minutes prior to initiation of rewarming.

The mean cooling prior to each therapy exhibits a range of only 0.18°C (from 1.26 to 1.44°C). It was, of course, not possible to simultaneously control the distribution of rates of cooling among the therapies. This exhibits a range of 0.41°C/hr (from 0.44 to 0.85°C/hr). The three therapies for which mean rate of cooling is somewhat lower than the rest are trunk immersion, inhalation + plumbed garment and body-to-body heat exchange.

One final convention was adopted to censor nonrepresentative results from the analysis. Rewarming data was used from an experiment only if at least 0.5°C cooling was experienced by the subject prior to the initiation of rewarming. This level of cooling was selected, based on the results of early experiments, as being a reasonable cutoff point for evaluating the treatment of hypothermia. This restriction resulted in rewarming data being obtained in only 72 of the 90 cold-immersion experiments performed.

3.3 Instrumentation

The instrumentation used to monitor temperature data in this study was all manufactured by Yellow Springs Instruments. Skin temperatures were measured with a Model 44TD, 12-channel monitor (50°C face sweep) using Model 409 probes (1.1 second time constant) taped to the skin. Rectal and esophageal temperatures were measured with a Model 46TUC, 6-channel monitor (11°C face sweep) using Model 401 probes (7.0 second time constant).

4.0 RESULTS AND ANALYSIS

4.1 Basis of Evaluation

The evaluation of theperformance of the selected rewarming therapies is based on three descriptive parameters of thermal response illustrated, for a typical experiment, in Figure II-3. The parameters are the following.

1. Afterdrop
2. Recovery period
3. Rate of rewarming

Afterdrop is taken to be the magnitude of the maximal depression in rectal temperature occurring after the initiation of rewarming. The "recovery" period is defined to be the time required for the rectal temperature to return to the level that it exhibited at the initiation of rewarming. The determination of the "rate of rewarming" is based upon the response during the first 30 minutes after the occurrence of the minimum temperature, or, if less than 30 minutes data was obtained, it was based upon the entirety of this data. These three parameters are regarded as adequately describing the response of core temperature (as approximated by rectal measurement) to rewarming treatment.

4.2 Experiment Results

The results of the rewarming experiments are summarized in Table II-6. This table gives, for each of the three descriptive parameters, the mean value and standard error of the mean (S.E.M.) occurring with each of the therapies.

As expected, trunk immersion exhibited the smallest mean afterdrop and mean recovery period and the largest mean rate of rewarming. Of the "portable" therapies, the afterdrop occurring during spontaneous rewarming was essentially as small as any. By comparison, body-to-body heat exchange exhibited a 61 percent increase in afterdrop and a 19 percent increase in recovery period, but also a 35 percent increase in rate of rewarming. Of the 8 subjects indicated in Table II-4 to have received both spontaneous rewarming and body-to-body heat exchange, 5 experienced more afterdrop and 5 experienced a longer recovery period with body-to-body heat exhcange, but 6 experienced more rapid rewarming with it.

FIGURE II-3
TIME-TEMPERATURE PROFILE:
LATE COOLING AND EARLY REWARMING

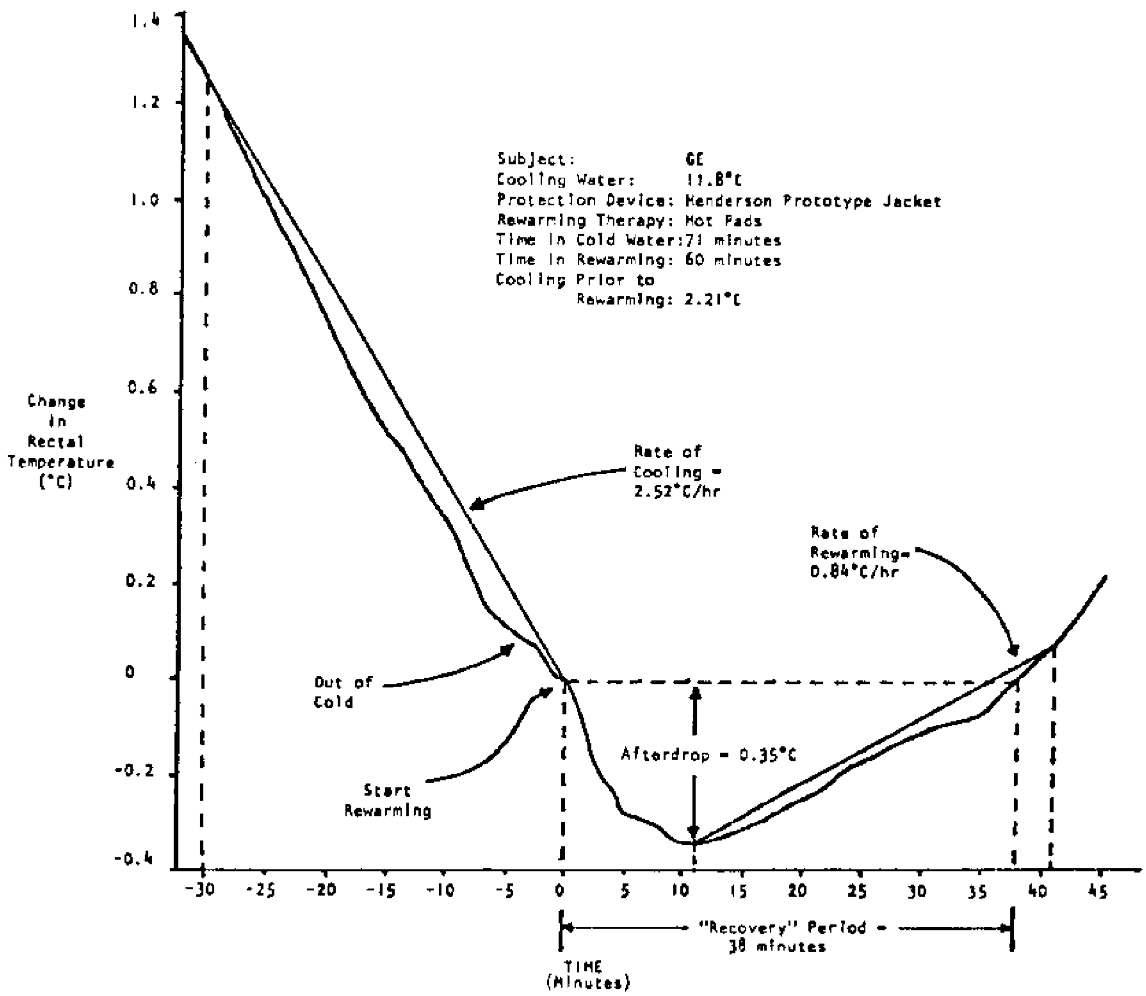


TABLE II-6

SUMMARY OF REWARMING RESULTS

Therapy	Afterdrop (°C) Mean	Afterdrop (°C) S.E.M.	Recovery Period (MIN) Mean	Recovery Period (MIN) S.E.M.	Rate of Rewarming (°C/hr) Mean	Rate of Rewarming (°C/hr) S.E.M.
Spontaneous	.18	.04	43	8	0.57	.11
Trunk Immersion	.09	.03	4	1	4.47	.46
Inhalation Therapy	.16	.04	40	14	1.03	.27
Heating Pads	.36	.11	36	9	1.03	.21
Plumbed Garment	.34	.07	38*	8	0.99	.14
Inhalation + H. P.	.18	.06	31	8	0.75	.10
Inhalation + P. G.	.17	.09	26	9	1.11	.27
Body-to-Body	.29	.11	51	16	0.77	.11

*ONE RECOVERY NOT COMPLETED IN 120 MINUTES NOT INCLUDED

Inhalation rewarming also produced as little afterdrop as any portable therapy. This was not improved by augmenting it with the heating pads or the plumbed garment. Augmenting inhalation therapy with the plumbed garment shortened the recovery period by 35 percent and increased the rate of rewarming by about 8 percent. Five subjects received inhalation therapy and inhalation in combination with the plumbed garment. With the combination, 3 experienced less afterdrop, only 1 experienced an increase in the recovery period and only 2 experienced a decrease in the rate of rewarming. Augmenting inhalation with the heating pads shortened the recovery period by 10% but also exhibited a reduction in mean rate of rewarming of about 22 percent. Seven subjects received inhalation therapy and inhalation in combination with the heating pads. With the combination, only 3 experienced less afterdrop, only 3 experienced shorter recovery periods and only 3 experienced increases in the rate of rewarming.

Comparing inhalation combined with the heating pads to spontaneous rewarming, the active rewarming results in the same afterdrop as spontaneous rewarming but it affects a 28 percent reduction in the mean recovery period and a 32 percent increase in the mean rate of rewarming. Of the 7 subjects who experienced both spontaneous rewarming and inhalation combined with the heating pads, 5 experienced less afterdrop with the active rewarming, 6 experienced shorter recovery periods but only 3 experienced an increase in rate of rewarming.

Finally, comparing inhalation combined with the plumbed garment to spontaneous rewarming, the active rewarming is seen to affect essentially no change in mean afterdrop but a 40 percent reduction in mean recovery period and a 95 percent increase in the mean rate of rewarming. Of the 5 subjects who experienced both spontaneous rewarming and inhalation combined with the plumbed garment, 4 experienced less afterdrop with the active rewarming, 3 experienced shorter recovery periods and 4 experienced greater rates of rewarming.

4.3 Significance of Differences Among Therapies

Many comparisons among the therapies are possible for each of the three performance parameters. A common approach to investigating these differences is analysis of variance (ANOVA). The ANOVA would reveal whether or not any significant differences exist among the therapies. If significant differences are indicated to exist they may then be identified by applying one of several post-ANOVA techniques. One of the requirements for ANOVA to be used is that the parameter variances within all therapies must be the same. Because of the uniformity of sample sizes, examination of the standard errors of the means given in Table II-6 indicates that this assumption is not warranted. Therefore, to assess the significance of the differences among the therapies all possible pairwise comparisons among them were examined with the Behrens-Fisher t-Test. This yields a test statistic which is known to be approximately distributed according to the Student's-t distribution and it yields an estimate of the degrees of freedom corresponding to the test statistic. These could be used to determine whether or not the differences are significant at some given level of significance. But this conveys less information than is available. The level of significance at which each difference is significant has been computed. This is often referred to as the "probability of a larger t".

The levels of significance (one-tail rejection region) are shown for comparisons in afterdrop in Table II-7, for comparisons in recovery period in Table II-8, and for comparisons in rate of rewarming in Table II-9. The appearance of a number in a cell of these tables indicates that the therapy corresponding to the cell's row is superior to the therapy corresponding to the cell's column at the level of significance given by the number in the cell. For example the .08 in the first row of Table II-7 indicates that trunk immersion is superior to inhalation therapy (with regard to afterdrop) at the .08 level of significance. This means that if the afterdrop associated with these two therapies are identical, the probability of getting the experimental results obtained with them due to randomness is .08. To find highly significant differences, one should scan these tables for small numbers. For convenience, the cells containing significance levels of about 10 percent or less have been circled. Levels above 10 percent are generally not regarded as truly significant.

It is a positive indication for a therapy to have many circles in its row and a negative indication for a therapy to have many circles in its column. Thus in regards to afterdrop, Table II-7 indicates spontaneous rewarming, inhalation rewarming, inhalation combined with the heating pads and inhalation combined with the plumbed garment to be the best of the portable therapies and heating pads and the plumbed garment are indicated to be the least attractive among the therapies. Similarly, Table II-8

TABLE II-7

COMPARISON OF AFTERDROPS AMONG THERAPIES

SUPERIOR THERAPY \ INFERIOR THERAPY	TRUNK IMMERSION	INHALATION THERAPY	INHALATION + PLUMBED GARMENT	SPONTANEOUS REWARMING	INHALATION + HEATING PADS	BODY-TO-BODY	PLUMBED GARMENT	HEATING PADS
TRUNK IMMERSION	-	.08	.20	.04	.09	.05	.01	.02
INHALATION THERAPY		-	.45	.34	.36	.13	.03	.06
INHALATION + P.G.			-	.45	.45	.19	.08	.10
SPONTANEOUS REWARMING				-	.48	.18	.05	.09
INHALATION + H.P.					-	.20	.07	.10
BODY-TO-BODY						-	.37	.33
PLUMBED GARMENT							-	.43
HEATING PADS								-

TABLE II-8

COMPARISON OF RECOVERY PERIODS AMONG THERAPIES

SUPERIOR THERAPY \ INFERIOR THERAPY	TRUNK IMMERSION	INHALATION + PLUMBED GARMENT	INHALATION + HEATING PADS	HEATING PADS	PLUMBED GARMENT	INHALATION THERAPY	SPONTANEOUS REWARMING	BODY-TO-BODY
TRUNK IMMERSION	-	.03	.00	.00	.00	.02	.00	.01
INHALATION + P.G.		-	.34	.23	.18	.21	.08	.09
INHALATION + H.P.			-	.35	.28	.29	.14	.13
HEATING PADS				-	.44	.41	.28	.20
PLUMBED GARMENT					-	.45	.31	.23
INHALATION THERAPY						-	.42	.30
SPONTANEOUS REWARMING							-	.32
BODY-TO-BODY								-

TABLE II-9

COMPARISONS OF REWARMING RATES AMONG THERAPIES

SUPERIOR THERAPY \ INFERIOR THERAPY	TRUNK IMMERSION	INHALATION + PLUMBED GARMENT	INHALATION THERAPY	HEATING PADS	PLUMBED GARMENT	INHALATION + HEATING PADS	BODY-TO-BODY	SPONTANEOUS REWARMING
TRUNK IMMERSION	-	.00	.00	.00	.00	.00	.00	.00
INHALATION + P.G.		-	.42	.41	.35	.13	.14	.05
INHALATION THERAPY			-	.50	.45	.18	.20	.08
HEATING PADS				-	.43	.12	.15	.04
PLUMBED GARMENT					-	.09	.12	.02
INHALATION + H.P.						-	.44	.13
BODY-TO-BODY							-	.11
SPONTANEOUS REWARMING								-

indicates that regarding recovery period, inhalation combined with the plumbed garment is attractive. No particular therapy of the portable ones is indicated by Table II-9 to be attractive regarding rate of rewarming. However, while the significance levels are not small, inhalation combined with the plumbed garment is superior to more of the other therapies (all but trunk immersion) than any other portable therapy.

4.4 Correlations of Results with Experiment Initial Conditions

To determine the role that variation in rewarming initial conditions (amount of cooling and rate of cooling) plays in determining the outcome of the rewarming experiments, the correlations between each of the three rewarming performance parameters and each of the initial conditions was investigated. Pearson's product-moment correlation coefficient was calculated for each combination of performance parameter and initial condition for each rewarming therapy. Table II-10 shows the correlation coefficients resulting from correlating afterdrop with each of the initial conditions. None of the r values has magnitude exceeding 0.71. Table II-11 gives the results for correlations between recovery period and each of the initial conditions. The magnitudes of these coefficients are also limited to 0.71. The correlations involving rate of rewarming, shown in Table II-12, range to larger values with 2 of them having magnitudes above 0.8.

Based on the 48 correlation coefficients in Tables II-10 through II-12, only 2 of which have magnitudes above 0.8, it is concluded that the results of the rewarming experiments were not materially influenced by variation in the rewarming initial conditions. As a consequence of this finding it is concluded that the integration of the rewarming experiements into the protection equipment tests did not materially detract from the validity of the rewarming results. It should be recalled that the rewarming experiment design balanced the amount of cooling among the therapies such that valid results could have been obtained even if this initial condition had been found to correlate reliably with one or more therapy performance parameters.

TABLE II-10
CORRELATION COEFFICIENTS FOR AFTERDROP

THERAPY	INDEPENDENT VARIABLES AMOUNT OF COOLING	RATE OF COOLING
Spontaneous Rewarming	.70	.71
Trunk Immersion	.56	.25
Inhalation Rewarming	-.22	.22
Heating Pads	.12	.44
Plumbed Garment	.16	.63
Inhalation + H.P.	.08	.27
Inhalation + P.G.	-.22	-.50
Body-to-Body	-.49	.13

TABLE II-11
CORRELATION COEFFICIENTS FOR RECOVERY PERIOD

THERAPY	INDEPENDENT VARIABLES AMOUNT OF COOLING	RATE OF COOLING
Spontaneous Rewarming	-.07	-.07
Trunk Immersion	.27	-.17
Inhalation Rewarming	-.43	-.25
Heating Pads	-.19	.23
Plumbed Garment	-.36	.10
Inhalation + H.P.	-.21	.05
Inhalation + P.G.	-.46	-.71
Body-to-Body	-.67	-.43

TABLE II-12
CORRELATION COEFFICIENTS FOR RATE OF REWARMING

THERAPY	INDEPENDENT VARIABLES AMOUNT OF COOLING	RATE OF COOLING
Spontaneous Rewarming	.08	.03
Trunk Immersion	.64	.03
Inhalation Rewarming	.92	.85
Heating Pads	.41	.42
Plumbed Garment	.59	.41
Inhalation + H.P.	.23	.01
Inhalation + P.G.	.72	.73
Body-to-Body	.37	.74

5.0 ADDITIONAL EXPERIMENTAL OBSERVATIONS

Late in the sequence of experiments, one took place in which only about 0.3°C net cooling occurred during the 3-hour cold immersion. Because this did not meet the 0.5°C minimum cooling criterion, no attempt was made to obtain data using one of the 8 rewarming therapies included in this research. Since the hot bath had been prepared and was not going to be used for a rewarming experiment, the subject was invited to sit in it to rewarm for comfort. Before entering the 35°C (95°F) water, his skin temperatures were as follows.

Great toe	16.9°C
Thigh	31.4°C
Groin	35.0°C
Subscapular	23.6°C
Bicep	29.1°C
Forearm	28.7°C

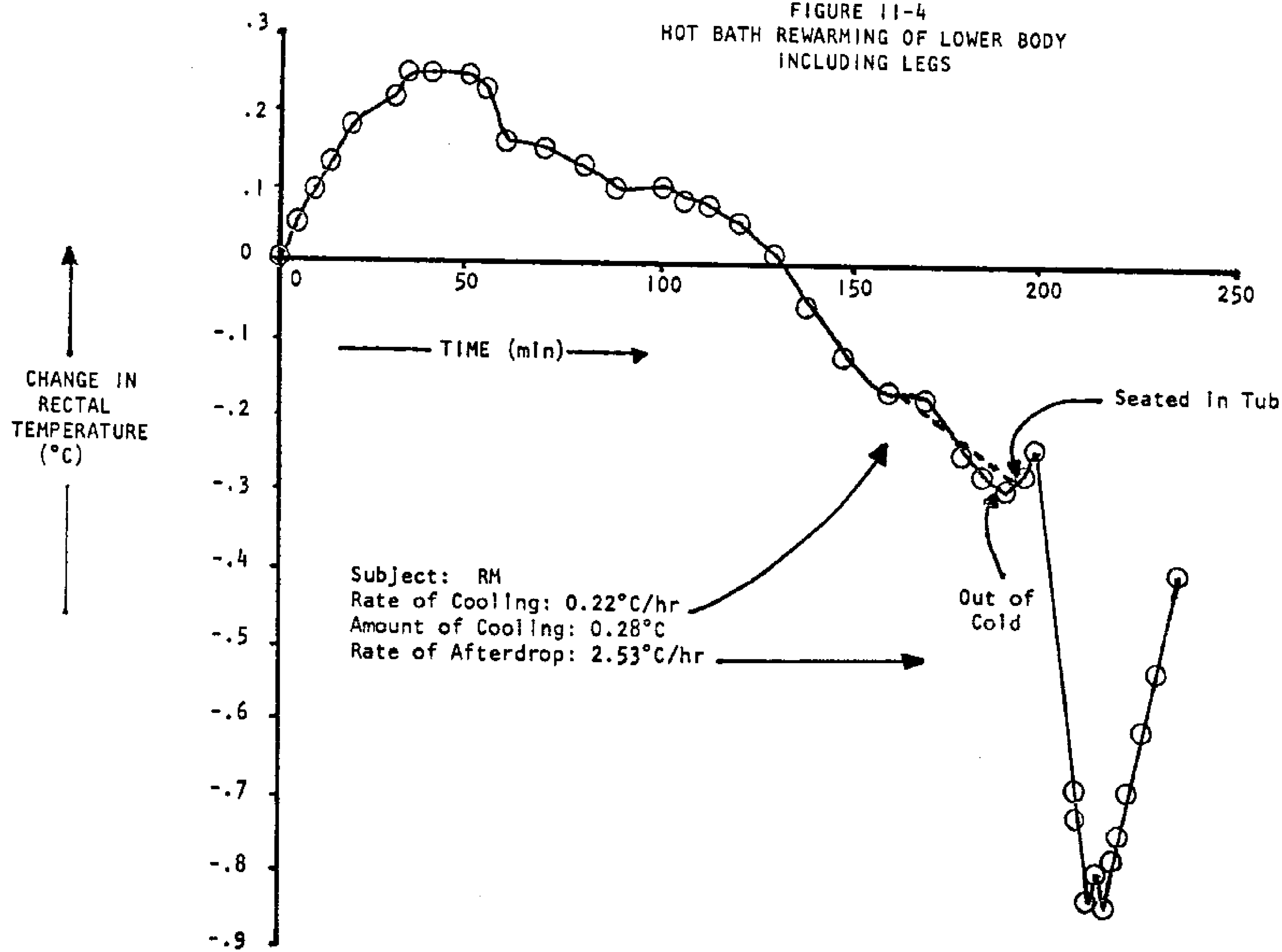
The subject entered the tub unassisted and assumed a seated position. His feet, legs and torso up to the waist level were immersed in the hot water. The surface temperatures of his toe and thigh immediately warmed to 33.0°C.

Following an initial small rise, rectal temperature fell by 0.59°C in a 14 minute period. As shown in Figure II-4, this represents an increase in the rate of rectal temperature reduction of an order of magnitude as compared to the last 30 minutes before entering the tub. After some fluctuation near the minimum temperature, a recovery of 0.44°C occurred in a 19 minute period for a rewarming rate of 1.39°C/hr.

If afterdrop was a manifestation of a conductive heat transfer phenomenon, as was suggested by Golden and Hervey (1977), one would expect to see afterdrop proceed initially at the same rate as did cooling late in the cold immersion. The rate of afterdrop, when measured rectally and with legs and lower torso immersed in warm water, should then begin to decrease in a continuous fashion until it is smoothly reversed. The rise in rectal temperature should proceed initially at an increasing rate followed by a period of slowing in the rate of warming as the temperature approaches its normal level (it is assumed that the warm water would be at a temperature near normal core temperature).

This response is, of course, idealized and normal "biological variation" is to be expected. However, the precipitous increase in the rate of rectal

FIGURE II-4
HOT BATH REWARMING OF LOWER BODY
INCLUDING LEGS

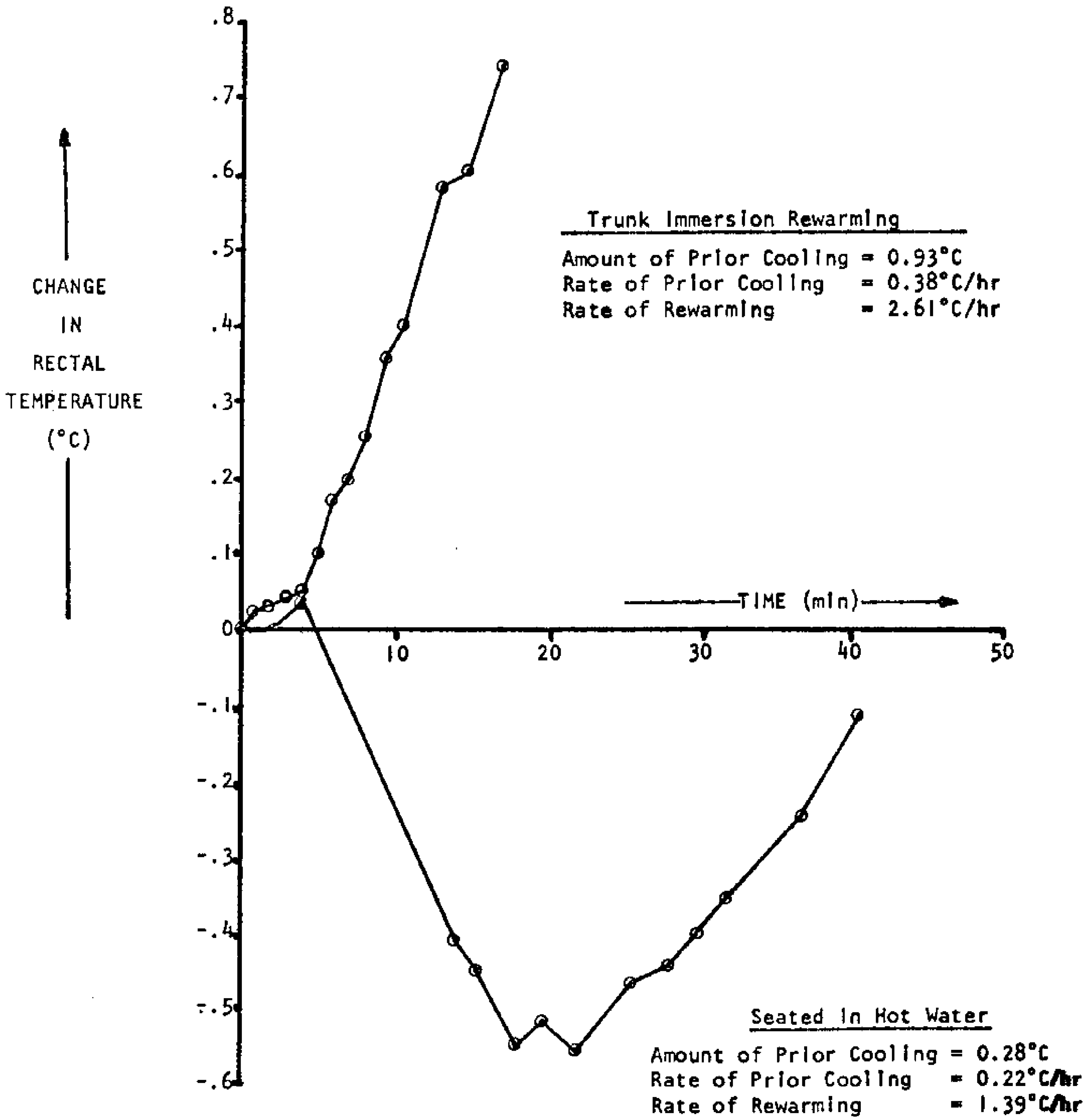


temperature reduction (while initially sitting in the hot water) as compared to the rate prevailing prior to entering the hot water, transcends one which can easily be explained as a biological variation of a conductive heat transfer phenomenon. It probably resulted from the increased return of blood to the body core (rectum) after having yielded much of its heat to peripheral tissues (legs).

Two weeks later, a proper trunk immersion rewarming was done with the same subject following a 191-minute cold immersion. The protocol described in Section 2.2 of this paper was followed. The net cooling prior to rewarming was 0.93°C and the rate of cooling over the last 30 minutes prior to rewarming was 0.38°C/hr. Figure II-5 compares the course of rectal temperature during this trunk immersion to that occurring while the subject was seated in the hot water. It may be seen that during the trunk immersion no afterdrop occurred. This is taken as an indication that the immersion of the legs during the earlier rewarming played a causal role in promoting the precipitous afterdrop seen at that time.

FIGURE II-5
COMPARISON OF LEGS IN AND OUT OF HOT WATER

Subject: RM



6.0 INTERPRETATION OF RESULTS OBTAINED WITH MILD HYPOTHERMIA

There exists a need to make certain compensations in evaluating the results of these experiments since only mild hypothermia was addressed. The subjects were all healthy, conscious and shivering vigorously at the time rewarming was initiated. Victims of profound hypothermia may be expected to exhibit reduced or extinguished shivering thermogenesis and a very much reduced respiratory minute volume (RMV). Compensations are necessary in selecting treatment methods for the differences between this laboratory condition and the real world of profoundly-cold patients. These compensations may be imperfect but they are unavoidable since rewarming-therapy research is restricted to mild hypothermia as a concession to subject safety. The primary compensations are discussed in the following paragraphs.

6.1 Reduced Respiratory Minute Volume

The reductions in a patient's RMV may be expected to reduce, more or less proportionally, the ability of inhalation therapy to introduce heat into the patient's core. This might degrade the recovery period and rate of rewarming aspects of its performance more than its afterdrop avoidance. But this is uncertain since it is not clear whether the afterdrop-avoidance property of inhalation therapy derives more from the amount of heat imparted or the manner in which it is imparted.

The most serious implication of the reduced RMV is the doubt it casts on the performance of the combination therapies (inhalation plus some mode of selective surface heating). As the inhalation components of the combination therapies take on diminished roles in treatment, the combination therapies begin to resemble conceptually the heating pads and plumbed garment therapies. The question is, would the combination therapies continue to perform relatively as well as they did with mildly-cooled subjects or would their relative performances more closely resemble those of the selective surface heating therapies.

6.2 Depressed Shivering Thermogenesis

In these experiments shivering thermogenesis was a major contributor to the uptake of heat involved in rewarming. There are some indications that therapies involving surface heating were negatively effected by their propensity to diminish shivering thermogenesis earlier than occurred without the surface heating. For example, the 7 subjects who experienced both spontaneous rewarming and body-to-body heat transfer, and for whom oxygen uptake rates were measured early in rewarming (first 10 minutes), 5 subjects exhibited larger rates when rewarming spontaneously. One might expect that if no shivering had been present during <u>any</u> of these rewarmings, the opportunity would not have existed for this relative penalty to occur. The specific effects of the diminution of shivering should have included reducing the rate of rewarming and lengthening the recovery period. Therefore, in compensating for the depression of shivering thermogenesis, one would expect with surface heating, improvement in recovery period and rate of rewarming relative to those therapies involving no surface heating.

However, the primary deficiency with surface heating was in afterdrop, not recovery period or rate of rewarming. Shivering probably tends to promote afterdrop through its stimulation of blood supply to the musculature involved. Some of this musculature will be in the extremities. This shivering-induced component of afterdrop was present in the rewarmings performed with all therapies in this research. However, to the extent that surface heating reduces shivering, this component should have been smaller with the therapies involving surface heating. Even so, the therapies consisting only of surface heating exhibited the largest mean afterdrops of all. If no shivering had been present (and therefore no shivering-induced afterdrop had occurred) with any of the therapies, then the afterdrops observed with surface heating only, should have compared even less favorably to those with other therapies. There certainly is no reason to expect the absence of shivering to improve the afterdrop performance of surface heating relative to the other therapies.

7.0 SUMMARY AND CONCLUSIONS

Reviewing the experimental results presented in Section 4, it may be seen that of the portable therapies, spontaneous rewarming, inhalation therapy, inhalation combined with the heating pads and inhalation combined with the plumbed garment afford superior performance with respect to afterdrop avoidance. The only one of these four therapies affording a statistically-significant advantage with respect to the next most important criterion (recovery period minimization) is inhalation combined with the plumbed garment although inhalation combined with the heating pads is nearly as good. The results relating to the last criterion (rate of rewarming mazimization) weakly support a selection of inhalation combined with the plumbed garment.

The question arises as to the real benefit of augmenting inhalation therapy with a plumbed garment as opposed to heating pads. Reviewing the comparisons between these two therapies in Tables II-7, II-8, and II-9, one sees that inhalation combined with the plumbed garment affords slightly smaller afterdrop and shorter recovery periods but that these differences are not significant, statistically or subjectively. The plumbed garment affords a more significant improvement in rewarming rates. It therefore seems likely that inhalation could be augmented with any <u>selective</u> surface heating modality to produce afterdrops and recovery periods generally similar to those seen in this study with the plumbed garment. By "selective" it is meant that the surface heating is aimed at the same general areas addressed in this study. The rate of rewarming may be subject to more control through selection of surface heating modality, since a relatively large difference was seen between the rates resulting with the two modalities used in this study when combined with inhalation therapy.

It is important to notice that the heating pads and the plumbed garment, when applied without inhalation therapy, were associated with the greatest mean afterdrops observed in these experiments. Also their recovery periods were not significantly shorter than the longest ones seen. This indicates that surface heating, even when done selectively as in this study, is not the most efficacious approach.

The combination therapies were found in these experiments to be most attractive in the context of all three performance parameters. Therefore, one could select one of these therapies and achieve top performance in terms of afterdrop avoidance without having to make concessions in recovery period and rate of rewarming. This fortuitous result would relieve the necessity for concern over imperfections in rectal estimates of deep core temperature if consideration of the differences between mild and profound hypothermia were not necessary. The behavior of a combination therapy is unknown in treating hypothermia of various severities and with various levels of respiratory disfunction. If the relative contribution of the inhalation component diminishes as RMV decreases then the performance of the combination therapy might closely resemble that of selective surface heating alone. The corresponding changes in afterdrop avoidance would, on the basis of these experiments, deteriorate from the best to the worst achievable. The problem of choosing would not be so troublesome if the surface heating alone had not performed so poorly regarding afterdrop. Therefore, inhalation therapy alone seems to be the prudent choice for treatment when afterdrop can not be tolerated (profound hypothermia).

However, the use of inhalation therapy alone when RMV is depressed can be expected to result in reduced rates of rewarming and possibly protracted recovery periods as compared to a combination therapy. The afterdrop encountered would depend much more upon the manner in which the patient is handled than upon intrinsic aspects of the inhalation therapy. This is indicated by the similarities of the mean afterdrops observed in thses experiments with spontaneous rewarming and inhalation therapy. Therefore, while inhalation therapy alone does not increase rates of rewarming and may not reduce recovery periods (compared to spontaneous rewarming) as much as it does when combined with the plumbed garment, its use alone with very low RMV's would not promote afterdrop, as the combination therapies likely would.

Anticipating the cardiac irritability normally associated with profound hypothermia, consideration should be given to leaving such patients clothed to avoid the mechanical irritation involved in undressing them. Their surface is probably at thermal equilibrium with their wet clothing by the time they are rescued from the cold water and treatment can be initiated. However, it would be extremely important that they be wrapped in a material capable of doing the following three things.

1. Providing effective thermal insulation from the patient's environment.

2. Preventing evaporation from the wet clothing which would affect further heat drain from the patient.

3. Maintaining its thermal insulation property while exposed to water.

A normal blanket would not possess properties 2 and 3 and most sleeping bags would not. The device surrounding the patient would have to be resistent to water impinging upon it from the inside and the outside. If any of these three properties can not be satisfied, then all wet clothing should be removed. In any case, outer garments holding large quantities of water should be removed.

If inhalation therapy is used alone, provisions should be made for careful handling for a protracted period of time (until core rewarming is well underway). Selective surface heating could be added to the inhalation therapy once rewarming is underway and the threat of serious afterdrop has passed. But this would be minor participation in the treatment after the critical period has passed.

One would expect that most hypothermia victims are recovered before experiencing severely depressed RMV's. For these individuals the combination therapy is to be preferred. The exact RMV below which the use of a combination therapy is contraindicated can not be determined from these experiments.

The use of body-to-body heat exchange, which has been widely recommended for use in circumstances where no other treatment is feasible, must be discouraged in treating profound hypothermia. The moderate surface heating would be expected to promote greater afterdrop than might occur if the victim were well insulated from his environment, handled with great care and transported to a facility capable of rendering treatment. With hypothermia known to be mild, body-to-body heat exchange might offer desirable shortening of total rewarming time (by increasing the rate of rewarming) and some subjective improvement in the patient's condition but some additional afterdrop can be expected. If uncertainty exists concerning the severity of the hypothermia, it would be prudent not to risk precipitating an afterdrop that could be dangerous.

An additional problem that exists with body-to-body heat exchange is the potential for it to be applied differently than was done in this research and, in the process, to promote even greater afterdrop than has been indicated here. In this research, body contact was restricted to the upper-body region of the subject. An over-zealous heat donor might reason that if a little contact is good, then a lot is better. The resulting increase in the surface warming of arms and legs could promote even more afterdrop than results with upper-body contact. This potential for misapplication of body-to-body heat exchange is perhaps the most troubling aspect of even a qualified recommendation for its use.

The question arises, might the body-to-body heat exchange treatment be more effective if it is applied to parts of the patients body other than the back. It could easily be applied to the chest, for example. The thermographs of Hayward, et al. (1973) showed the chest of a normothermic man to radiate more heat than his back. Thus a chest-to-chest arrangement might offer some heat transfer advantage after the recipients chest-surface vasculature had dilated. However, the thermographs show the back and chest of a man who had held still for 15 minutes in cold water to radiate the same amount of heat. Therefore, one would expect no heat transfer advantage during initial rewarming for the chest-to-chest arrangement. It is quite possible that one could accurately regard the heating pads therapy as indicating a limit to performance which may be achieved by improvements to body-to-body heat exchange. The heating pads were placed on the areas thought to maximize heat transfer. In terms of recovery period and rate of rewarming there is abundant potential indicated for refinement of the body-to-body heat exchange approach. However, afterdrops avoidance is the single most important consideration in the treatment of profound hypothermia. The potential for afterdrop avoidance through refinements to body-to-body heat exchange is not indicated, by the results seen with the heating pads, to be attractive.

A final comment on trunk immersion therapy is in order. This therapy has been used only as a standard of comparison for the evaluation of therapies thought to be candidates for use in the field. Trunk immersion is impractical for such use. However, serious attempts should be made to design and evaluate special equipment to allow trunk-immersion-like treatment in the rescue environment. If these attempts are successful, widely different results would be achievable depending upon the water temperature used. Research would be required to refine techniques for using such equipment to minimize risk of afterdrop and hypovolemic shock. Inhalation therapy should be used in combination with this equipment for its ancillary benefits and, in the interim, inhalation therapy represents the treatment of choice for use in the field.

8.0 REFERENCES

Cooper, K. E., and J. R. Kenyon, (1957), "A Comparison of Temperatures Measured in the Rectum, Esophagus, and on the Surface of the Aorta During Hypothermia in Man", British Journal of Surgery, 44: 616-619.

Golden, F. St. C., and G. R. Hervey, (1977) "The Mechanism of the After-drop Following Immersion Hypothermia in Pigs", Proceedings of the Physiological Society, 8-9 July 1977 Journal of Physiology, 272, 26-27 P.

Harnett, R. Michael, Sias, Fred R., and James R. Pruitt, (1979) "Resuscitation from Hypothermia : A Literature Review", Final Report Task V, Contract No. DOT-CG-72074-A, Clemson University, Clemson, South Carolina, February 14, 1979.

Hayward, J. S., Collis, M. and J. D. Eckerson, (1973), "Thermographic Evaluation of Relative Heat Loss Areas of Man During Cold Water Immersion", Aerospace Medicine, 44 (7): 708-711.

Keatinge, W. R., (1969), Survival in Cold Water, Blackwell Press, Oxford.

POSITION STATEMENT: Airway Rewarming and Afterdrop

R. Michael Harnett
Clemson University

AFTERDROP

The occurrence of fatalities among victims of hypothermia soon after their rescue and removal from the cold has been described in the literature. Explanations for this so-called "post-rescue collapse" have been sought to provide a basis for refining methods of treatment to eliminate these presumably-avoidable deaths. Probably the best explanations are

1. Cardiac fibrillation resulting from afterdrop in the temperature of the myocardium promoted by peripheral vasodilatation

2. Hypovolemic shock resulting from peripheral vasodilatation and secondary to cold-induced reductions in blood volume

Post-rescue collapse is generally cited during the first half hour after rescue and is probably distinct from fatalities reported to occur during the latter stages of rewarming.

The occurrence of afterdrop in "core" temperature has been reported to occur at the heart site following surgical hypothermia. The details of one such report suggest that the afterdrop results from the blood-vascular redistribution of heat. Many observations of afterdrop in rectal temperature have been reported following mild, experimental hypothermia. Since core temperatures at various sites (rectum, esophagus, stomach, right atrium) are known not to respond to cooling and rewarming in a concerted way, the significance to cardiac fibrillation of afterdrops in rectal temperature is questionable.

Rewarming experiments with deeply cooled, lightly anesthetized pigs have indicated that rectal measurements overestimate the afterdrop in temperature at the right atrium when rewarming is accomplished by hot bath. It was also shown that rectal and gastric afterdrops occurred even when circulation was stopped at the beginning of rewarming. On the basis of these results, some have claimed that afterdrop does not affect the temperature of the myocardium and that rectal afterdrop is a conductive heat transfer phenomenon.

The inference is drawn that peripheral vasodilatation is of no real concern and that surface heating may be practiced with impunity.

The results of these pig experiments should be interpreted cautiously. The hot bath rewarming is widely recognized to minimize afterdrop as compared to other techniques of rewarming. Therefore, it makes a weak case against the occurrence of afterdrop at any particular core site. Furthermore, the pig is a particularly poor analog for man with respect to peripheral vascularization. It has only about 15 percent of its mass in its limbs compared to 40 percent for man and the difference between hoofs and hands and feet are obvious. Therefore, the pig makes a weak case against the occurrence of afterdrop promoted by peripheral vasodilatation.

A better understanding of the nature of afterdrop is a prerequisite for selecting proper methods for managing profound hypothermia, particularly early in the post-recovery period. Its propensity to occur at the heart site and the causal involvement of circulatory heat transport must be learned. Of course this is made difficult by the need to investigate thermal events at the heart site during profound hypothermia. Even if humans volunteer to accept the small risks due to instrumentation, profound hypothermia may not safely be induced. Experiments with primates present an opportunity to obtain data with a more faithful human analog than has previously been used. This research approach should be pursued.

AIRWAY REWARMING

The conclusions of published experimental work with airway rewarming vary radically. These conclusions are generally based on afterdrops and rewarming rates observed in experiments with mildly hypothermic volunteers or profoundly cold animals. Variations among experimental conditions and techniques for performing rewarming may explain much of the difference in results and conclusions. These are too many and too detailed to be reviewed here.

An extremely important consideration in treating profound hypothermia is the minimization of afterdrop at the heart site. Hot bath has been shown to be very effective in minimizing rectal afterdrop. However, its inherent lack of portability and concern over the effects of very rapid rewarming of profoundly cold victims deter its use during the early stage of treatment. Moderate applications of surface heat have been shown to be counterproductive, even when selectively applied. Peritoneal irrigation is beyond the capability of EMT's.

The afterdrop accompanying airway rewarming has been indicated to relate variously to that seen during spontaneous rewarming of vigorously-shivering subjects. The benefit of the airway rewarming has been shown to range from insignificant to significant. Additional concern is raised by the prospects for reduced effectiveness in treating profound hypothermia, with its associated depressions of respiration. No serious negative effects are known to accompany airway rewarming. The best case for its use may be based upon the following:

1. Cessation of respiratory heat loss and some warming of pulmonary vasculature.

2. Thermal stimulation of mucociliary transport and vapor treatment of pulmonary congestion.

Dr. John Hayward
Department of Biology
University of Victoria
Victoria, BC V8W 2Y2, Canada

A pioneering leader in hypothermia research and cold water survival, Dr. Hayward has been involved with physiological responses and survival techniques of man in cold water for 7 years. He earned his Ph.D. in comparative physiology from the University of British Columbia and currently serves on the faculty of the University of Victoria. His research interests include studies on rewarming methods, effects of behavioral variables on the cooling rate of man in cold water and the thermal balance and survival time prediction of man in cold water. He has also designed a thermal protection jacket (Mustang Coat) for which he holds patents in several countries.

ABSTRACT

Cardiac Temperature During Rewarming From Hypothermia

Dr. J. Hayward
Department of Biology
University of Victoria

Core rewarming is now advocated for victims with severe hypothermia. Experimental evaluation of techniques to accomplish such rewarming has been limited by the difficulty of measuring the temperature of the most important core tissue, namely the heart. This report describes the findings on the temperatures of the heart (by catheterization of the pulmonary artery), esophagus, gastrointestinal, auditory canal, and rectal regions during three rewarmings of a conscious subject from mild hypothermia. Rewarming methods were: shivering alone; airway rewarming; and hot bath immersion. The results show:

1. Cardiac temperature is closely approximated by esophageal temperature no matter which rewarming technique is used.

2. There is a considerable differential between cardiac temperature and rectal temperature during rewarming.

3. Airway rewarming shows the least afterdrop of core temperatures, and rewarms the heart faster than shivering alone.

Although it is not recommended that esophageal temperature be used for monitoring of core temperature of severely hypothermic persons in the field or during transport to hospital, this site is most appropriate for experimental evaluation of core rewarming procedures.

A perspective regarding the large differential in temperature of various core regions during rewarming from hypothermia will be presented by the example of arousal from hibernation.

Richard C. Hiscock
Chatham, MA 02633

ABSTRACT

LIAISON COMMITTEE ON EMERGENCY RESCUE EQUIPMENT
STUDIES OF EXPOSURE AND EXPOSURE SUITS 1943

Richard C. Hiscock

The interest of the past decade in hypothermia (exposure) and anti-exposure clothing is of great interest to me.

We are indebted to Dr. John Hayward and others for making "hypothermia" part of the language of survival. But, until last year he was unaware of the studies that were done on exposure and exposure suits by US and Canadian military during the final years of WWII. It would appear that this research was "lost" at the end of the war. It is fortunate that a member of my family saved much of the original information on these studies and also on the committee that was responsible for them.

During early 1943 the Liaison Committee on Emergency Rescue Equipment (ERE) was established by the Joint Chiefs of Staff (JCS) under the direction of the Navy Department Coordinator of Research and Development, the Office of Strategic Services (OSS) to furnish the funds and personnel to operate the committee. The purpose of the committee was to "coordinate the work concerned with methods, techniques and procedures for emergency rescue or with research, development and production of emergency rescue equipment". Further ERE was to promote the use of this equipment among the various military and civilian services, and to maintain liaison with other Allied agencies involved in similar efforts.

At the second meeting of the committee the "light-weight exposure unit" was established as a priority need. Several major conferences were held on the increasing loss of life due to exposure (hypothermia) among downed fliers. Subsequently tests were conducted on exposure suits that were developed to meet this crisis and the growing crisis in the merchant marine and Navy. The most significant tests were performed at Halifax NS (with the cooperation of the Royal Canadian Armed Forces) in November 1943. Much was learned regarding: the affects of cold water emersion on survival time, types of clothing and their relative merit, and design and materials for exposure suits.

As the war came to a close the functions of ERE were transferred to Air Sea Rescue and in September 1944 Air Sea Rescue became part of the Coast Guard.

By piecing together the information that I have, along with the recollections of several participants, I hope to fill in some of the gaps in the history of our understanding of exposure and efforts to develop clothing to mitigate its affects. It will also be important to understand the nature of the ERE committee and the role it played in this important effort. Although it existed for less than one year it made some very significant contributions not only to our understanding of exposure, but other areas of survival.

Some questions that occur: Why was all this information "lost", or was it, and what other significant and historically valuable information was "lost"? I hope that by piecing together this information, it will spark the curiousity of others who can help answer these and other questions. It may be that in learning the accomplishments and failures of the past we can save more lives in the future.

DEVELOPMENT OF EXPOSURE SUITS
BY THE
LIAISON COMMITTEE FOR EMERGENCY RESCUE EQUIPMENT
1943

RICHARD C. HISCOCK

INTRODUCTION

The interest of the past decade in exposure (hypothermia) is of great interest to me, for the lethal effects of exposure and the development of "exposure suits", during World War II, have been known to me all my life.

We are indeed indebted to Dr. John Hayward and others for rekindling our concern. However, when discussing with him the work done during World War II, I was intrigued that he was unfamiliar with the extensive research and development that was done then. It appeared that much if this information was, or is, "lost". We are fortunate, however, that members of my family, who participated in those past efforts, saved much of the original documentation concerning the research and development that was carried out in 1943 by The Liaison Committee for Emergency Rescue Equipment. It is for this reason that I am here today.

What I propose is to give you some background on the reasons for, and the development of, The Liaison Committee for Emergency Rescue Equipment and its eventual evolution into Air Sea Rescue; and specifically, a discussion of their concern, research, and development that led to the production of exposure suits for military personnel.

My effort has been to bring together information that heretofore has apparently been unavailable to many of you, who are experts in the effects of hypothermia and its prevention, in the hope that some may find this discussion fascinating enough to justify further investigation into the recent history of emergency rescue equipment.

PART I

THE LIAISON COMMITTEE FOR EMERGENCY RESCUE EQUIPMENT

Today it is assumed in the United States that the Coast Guard has always been the primary service involved in air and sea rescue. While it is true that the Coast Guard has carried on rescue work since its inception, it was not until 1944 that the Coast Guard (then under the Navy Department) assumed command of Air Sea Rescue (33).

To fully appreciate the development of exposure suits during World War II, an understanding of the events preceeding the consolidation of Air Sea

Rescue in the Coast Guard is necessary, for it was between April 1943 and early 1944 that much research and development was carried out by The Liaison Committee for Emergency Rescue Equipment.

The urgent need for air sea rescue was a direct result of the military conflict of World War II. This was the first time in history that so many ships and planes operated under such adverse weather and battle conditions.

The British military learned, during the Battle of Britain, that a coordinated effort was necessary to retrieve downed fliers. In February 1941 they established an Air Sea Rescue Service (33).

In late 1941, when the United States entered the conflict, British developments in Air Sea Rescue assisted the U.S. rescue effort; however, the U.S. had no consolidated command for air sea rescue. In early 1943 there was a concentrated effort to overcome the U.S. deficiency. It is this effort that we will examine now.

Recognizing the necessity for a more coordinated effort, the U.S. Joint Chiefs of Staff on April 15, 1943 issued Memorandum for Information No. 58: "Plan for Organization of Committee on Emergency Rescue Equipment", which directed the Navy Department to coordinate the efforts of all services and agencies with regard to research and development of emergency equipment, to evaluate and disseminate information pertaining to emergency equipment, and to maintain a liaison with other "United Nations" rescue efforts. A liaison committee was appointed with representatives from the Navy Department, the Army Air Forces, the Maritime Commission, the Office of Scientific Research and Development, and the Office of Strategic Services (3).

On April 20th the Navy Department directed its Office of Coordinator of Research and Development to head the Liaison Committee authorized in Memorandum No. 58 (4).

On April 26th Assistant Coordinator of Research and Development, Captain Lybrand Smith, requested all the agencies named in Memorandum No. 58 to appoint a representative to the "Liaison Committee on Emergency Rescue Equipment" (5).

The substance of the first meeting of The Liaison Committee, held on May 4th, is contained in a letter of May 5th from Captain Smith to the Commandant of the U.S. Coast Guard (6). Several important considerations were outlined. The Committee agreed to the need for:

-a Technical Aid to the Coordinator
-a Secretariat
-a Technical Literature Research Section and
-an Exhibit Section

The Office of Strategic Services (OSS) was requested to furnish personnel (except the Technical Aide), office and exhibit space, equipment and funding for the Committee.

The choice of the Technical Aide was given special consideration. It was agreed that "because of the vast experience of the Coast Guard in connection with emergency rescue" that a Coast Guard officer "would be most fully qualified to cover the whole broad subject." Further, since the outbreak of the war, the Coast Guard had been developing special protective and emergency equipment.

In his letter to the Commandant, Captain Smith requests that "Lieutenant Commander Hiscock (be) ordered to report for duty to the Coordinator of Research and Development as Technical Aide for Emergency Rescue Equipment" (6). Earle F. Hiscock is my father; it is through him that I am able to compile this report.

Lieutenant Commander Hiscock had a varied career before joining the Emergency Rescue Equipment Section (ERES) in May of 1943. He was born in Maine in 1903, grew up in Quincy, Massachusetts, spent much of his childhood experimenting with ham radio. During World War I he served as a radio operator in the U.S. Navy. Later he served in the same capacity aboard fishing and merchant vessels. He attended Harvard College and graduated from MIT in 1932 with a degree in Naval Architecture and Ship Operation. During the depression he was a steamboat agent office manager in Portland, Maine.

In 1935, after the Morro Castle and other passenger ship disasters, he joined the Commerce Department, Steamboat Inspection Service (later the Bureau of Marine Inspection and Navigation), Technical Division. He pioneered the development of new standards for U.S. passenger and merchant vessels, applying modern principles of subdivision and fire protection.

In 1936 he transferred to the Inspection Division to serve as Assistant Chief. Later he was released, by mutual agreement, to the Maritime Commission to supervise the construction of the first large passenger/transport vessels to be built under the new government regulations. When construction was completed in 1940, he returned to the Bureau as Chief of Inspection.

At the outbreak of the war he drafted safety regulations for all American merchant vessels, including special equipment and installation requirements, and authored (1): <u>Wartime Safety Measures for Merchant Marine</u> for the U.S. Coast Guard.

In March of 1943 before the establishment of ERES, Commander Hiscock conducted, for the Bureau, tests in Miami, Florida on lifesaving and rescue equipment, including: signal mirrors, florescent dye, kites, night distress signals, reflective buttons, life preserver lights, color visibility, and the desirable angle for best visibility (2).*

It was because of his background in safety and his experience at sea that Commander Hiscock joined ERES. Others, who assisted in the Miami tests were also assigned to the ERES staff:

Lieutenant N. S. Bartow, from Navy Air Force Training Center, Jacksonville, Florida;

*Note: At the beginning of the war the Bureau of Marine Inspection and Navigation was transferred to the Coast Guard, where it remains today. This explains the change to military rank.

John Bader, Special Forces Section, Army Quartermaster Corps; and
Dr. Henry Field, as liaison for OSS.

Others who joined the staff were:

Lieutenant Colonel George W. Holt, Army Air Flight Surgeon;
Captain C. M. Murphy, Air Transport Command;
Julia McWilliams (now Julia Child) to head the Secretariat Staff; and
Alice M. Carson (now Mrs. Earle F. Hiscock) to head the Exhibit Staff.

When the Liaison Committee held its second meeting on May 15th, several developments had already transpired. Classification of the work of ERES was changed to "unrestricted" to allow for the widest possible distribution of information concerning emergency rescue equipment. A notice to all services and agencies outlining the responsibility of ERES and requesting their cooperation had been published and given wide distribution (7, 8).

The most significant decision reached at the second meeting was the realization that the efforts of ERES would require definitive recommendations "that certain equipment be adopted". Candidates for immediate recommendation bulletins were: life preserver lights, rescue signal mirrors, and light-weight exposure suits (8).

The Committee held a third meeting on June 5th (9) and approved one INFORMATION bulletin (10) describing the purpose of the RECOMMENDATION bulletins and the three RECOMMENDATIONS (11, 12, 13) discussed at the second meeting. RECOMMENDATION Number 3 (13) is of the most interest to us: "substitution of Protective Exposure Suits for 'Lifesaving suits' on Merchant Vessels and Military Transports". The so-called "lifesaving suits" had proved dangerous and ERES strongly recommended replacement with the "protective exposure suit" developed for the U.S. Coast Guard by the B. F. Goodrich Company. The suit had a neoprene coating and weighed less than six pounds packed in a bouyant bag. ERES advised (13) "that the primary need of survivors is for an overall garment which will protect them from exposure and which is of such character that it may be comfortably worn in boats and on rafts and of such weight as to be readily accessible and available in time of emergency". This is the first reference by ERES to exposure suits, for naval and merchant seamen. Soon ERES's will turn its efforts to providing exposure protection for fliers.

On July 27th the Liaison Committee held a Special Meeting to discuss (14) "recommending the formation of a land-air-sea rescue force under one command and operational group". Despite some concern by the Army Air Force that "the transition to a single command organization at the present time would necessarily be slow..." it was unanimously agreed that because of the Coast Guard's background and experience in the rescue field that they should assume command for all land-air-sea rescue operations.

On July 29th the Coordinator of Research and Development (Navy Department) wrote a letter to The Joint U.S. Chiefs of Staff with the recommendation from the Liaison Committee (15): "that immediate steps be taken to place the responsibility for the organization in the Navy Department under the immediate command of the U.S. Coast Guard".

It was not until February 1944 that The Joint U.S. Chiefs of Staff requested the Secretary of the Navy (33) "establish in the Coast Guard the Air Sea Rescue Agency to coordinate studies conducted in these fields by the various United States services, and to maintain liaison with services of Allied governments".

On September 9, 1944 the Coast Guard's new role was announced in a press release issued by Vice-Admiral Waeshe; Commandant, U.S. Coast Guard (31): "coordinating war time Air Sea Rescue and organizing a peacetime agency for rescue work with expanding commercial and private flying has been made a U.S. Coast Guard responsibility...the 'know how' for the job has been developed by (the Coast Guard) from 150 years of rescue experience ...Development of Air Sea Rescue has been an interesting story".

Thus the role of the Coast Guard and Air Sea Rescue is confirmed for the remainder of the war and the beginnings of their peacetime purpose is established.

The next part of this paper will concentrate on the development of "lightweight exposure suits" for airborne personnel carried on by ERES, prior to the establishment of the Air Sea Rescue Agency.

PART II

THE DEVELOPMENT OF THE EXPOSURE SUIT BY ERES

The Emergency Rescue Equipment Section (ERES) and the Liaison Committee developed many survival equipment items (16) which we take for granted today. An investigation of all these developments would be illuminating; however, the primary concern of this paper is the development of "lightweight exposure suits". It is of particular interest that of all items developed by ERES exposure suits were the most critical to successful rescue (19). Unfortunately, exposure suits received little attention in the civilian world after the war.

That we are here, years after the end of the war, at an international conference on hypothermia indicates a new urgency. It is distressing that a great deal of research on exposure and exposure suits was done during the war, and apparently ignored when that crisis of survival ended.

The information that I have compiled is by no means complete; however, there is sufficient documentation to demonstrate the effort of ERES to develop and provide lightweight exposure suits for airborne and naval personnel.

What follows is a brief examination of the material available regarding ERES and exposure suits. I hope this will excite the interest of others who may have access to additional records that may still exist.

As we have seen, ERES expressed a concern regarding protective exposure suits for naval and merchant seamen in mid-1943 (13). However, there is evidence that in 1917 Walter L. Fry developed a "lifesaving suit" that was tested by the U.S. Navy in January of 1918 at the Brooklyn Navy Yard. Fry's consideration for construction of his suit was (20, 26, 27):

1) A man had to be an individual unit in himself.

2) The suit had to be so constructed that it could be worn all day long and still be ventilated and comfortable. When closed, it has to be as hermatically sealed as (it) could get.

3) Simplicity.

Similar considerations are still discussed today, and were discussed again in 1943.

Prior to the establishment of ERES, there were several references to the problems of exposure and the use of exposure suits. In Wartime Safety Measures for Merchant Marine (1) there is a discussion for the use of "lifesaving suits" as exposure suits, and the treatment of "immersion foot" and "prolonged exposure to cold." As noted earlier, it is these "lifesaving suits" that later proved to be unsafe and should be removed from all vessels (13, 18, 21, 23).*

It was not until ERES was established that any concentrated effort was made regarding exposure or protective clothing to mitigate its effects.

In August, 1943 ERES held a conference in Washington, D.C. on: Rafts, Survival Equipment, and Seasickness (17). Attending the conference from ERES staff were: Commander Hiscock, Mr. Bader, Lieutenant Bartow, Colonel Holt, and Major Murphy. In addition, representatives of Naval Medical Research (particularly Dr. L. H. Newburgh), the Army Air Forces, the Royal Air Force, Trans-World Airlines and Boston City Hospital. The report of this conference, which details many aspects of sea survival, reveals the urgent need for exposure suits.

Dr. Newburgh's experimental work at the Naval Medical Research Institute in Bethesda, Maryland had demonstrated that fliers were subjected to a double hazard: first, when emersed in water, they rapidly lost body heat, and secondly, after climbing into a raft, wind vaporized the water in their clothing causing further loss of body heat. His data also indicated that personnel emersed in water of 60°-70°F "could not survive many hours in the absence of an exposure suit". His most surprising revelation was that water of less than 92°F would cause significant slow body cooling.

The conference unanimously recommended (17):

(a) That there exists a general and immediate need for a light weight exposure suit for all airborne personnel as a part of the sea survival equipment.

---

*Note: There is no evidence that these "lifesaving suits" are related to Mr. Fry's efforts of 1918 and 1943.

(b) That this need is such as to necessitate giving serious consideration to immediate production of such suits for use in existing rafts.

(c) That an exposure suit of the most improved design, construction, and light weight (maximum weight approximately 26 oz.) be provided for all new rafts.

(d) That the exposure suit provided for use on existing rafts should be of such character as to be packed in bouyant containers or otherwise readily accessible for jettison when rafts are thrown out of the plane.

(e) That on new rafts provision be made to pack the exposure suits as part of the raft equipment.

It was further recommended that new rafts be provided with insulated (inflatable) bottoms "to provide protection against cold water".

In late October 1943, ERES held a conference specifically devoted to Exposure Suits for Aircraft (19). Chairmen for the conference were Colonel Holt of the ERES staff* and Dr. Louis H. Newburgh of Naval Medical Research Institute. Also attending, in addition to Commander Hiscock from ERES, were Wing Commander M. M. Foss, Royal Canadian Air Forces and other members of the Canadian Joint Staff, the Canadian National Research Council, and the U.S. Office of the Quartermaster Corps textile and plastics division.

All agreed that the primary need was to design an exposure suit that could be used by both bomber and naval personnel, realizing that the problems presented by fighter pilots would have to be dealt with at a later date, as fighter pilots would need a suit that could be worn continuously. What was needed immediately was a suit that was: as light as possible for the least amount of bulk; as simple as possible, without watertight zippers; had the hands free, with adequate wrist closures; used separate floatation jacket underneath; and could be stowed on the back of a life vest or jacket.

There follows a fascinating discussion, particularly considering limited availability during war, of new materials and design considerations for prototype exposure suits, summarized here:

-The virtues and drawbacks of using nylon (a new material) versus cotton; how many layers of material to use; and whether the material should be coated with neoprene, one or both sides, with how many coats, was discussed at length. The flamability of nylon was a major concern, a coating of neoprene seemed to solve this problem; and whether a nylon suit could be packaged tightly enough to reduce bulk were other concerns with regard to materials to be used.

---

*Note: Dr. Holt is now a practicing neurologist in Denver, Colorado.

-Zippers versus drawstrings were discussed, with many opposed to zippers because of skepticism regarding mass production of a truly watertight zipper.

-The suits were being designed to be worn over winter flight clothing and boots; however, it was felt that the hands must be free to allow survivors to abandon the craft and use other survival equipment. Possible wrist closures discussed were: an inflatable tube around the cuff; a still cuff, so that gloves could be pulled over the cuff; or a watertight zipper at the sleeve opening.

-The use of additional floatation was ruled out as most services felt that their personnel would be, or should be, wearing floatation equipment during combat; therefore, additional bouyancy in the suits would not be necessary.*

-Quick donning and proper placement of the suits was discussed; also the possibility of having additional suits in life rafts for survivors who had to abandon their craft before donning a suit.

Wing Commander Foss expressed at the afternoon session of the conference the urgent and immediate need for exposure suits (19): "Why didn't we realize before, that without this item (exposure suits) all our elaborate items are not worth a darn. We (the RCAF) have come to the conclusion that without this item we might as well leave out the equipment we carry during the winter season. It is embarrassing to say that the emergency equipment doesn't mean anything without the suit".

The immediate need for prototype exposure suits, to conduct field trials, and obtain the necessary result needed to "sell" exposure suits to the various services was expressed by many of the conferees. It must be pointed out here that although ERES and members of RCAF were well aware of the lethal effect exposure was having on downed naval and airborne personnel, not all the service "brass" were convinced that exposure was a primary killer of those who survived the initial catastrophy.

It was understood, as the conference concluded, that Goodrich would have two dozen suits ready for testing by mid-November. Plans were made with Wing Commander Goss to conduct trials at a Canadian base near Halifax, Nova Scotia.

On November 17-19, 1943 the Joint United States-Canadian Air Sea Rescue Equipment trials were held near Halifax for the purpose of testing prototype light-weight exposure suits produced since the October conference in Washington (20, 25, 28).

---

*Note: The manufacturer of the prototype suits, the B. F. Goodrich Company, was attempting to add a small amount of floatation across the chest and arms of the new suits.

Colonel George W. Holt of ERER was chairman of the trials. Also traveling to Halifax for ERES were Commander Hiscock and Mr. Bader. Other United States representatives included representatives of Army Air Forces and the National Defense Research Committee. Wing Commander M. M. Foss led the Royal Canadian Air Force team of thirteen, in addition to two members of the Canadian National Research Council.

The principal purpose of the trials was expressed by Colonel Holt (20): "to determine the course of events following an individual's immersion in the North Atlantic with and without a watertight protective exposure suit".

At the time of the trials (1500 hours on the 17th to 0600 hours on the 18th) the sea temperature was 42°F, air temperature 36°F, winds from the North and West at 18 to 25 MPH, with moderate snow at times during the night.

At least thirteen Canadian airmen participated in the trials. All were checked by the Medical Officer prior to the tests and found to be in excellent physical condition. Vital signs, particularly body temperatures, were recorded for later comparison.

Six subjects entered the water and climbed aboard rafts dressed in flight clothing with exposure suits; two other similarly dressed without exposure suits. Two other subjects were transferred directly to rafts wearing only normal flight clothing. To simulate a ditching procedure, and to test the exposure suit neck closures and valves, three subjects jumped in the water; two with exposure suits, one without.

In all cases the subjects without exposure suits failed to complete the tests and had to be removed to the sick bay.

The first entered the water and swam 35 yards to a rubber raft and had to be pulled aboard. He had great difficulty donning his exposure suit and forty minutes later was ordered to the sick bay. His rectal temperature had dropped 3°F, he had marked redness (erythema) of the hands and feet, and decreased superficial sensitivity to pin prick and deep pressure in both feet.

The second entered the water, swam 25 yards and with some difficulty climbed aboard a raft and donned his exposure suit (without shearling lined flight boot). He was able to play cards; however, after a total of fifty minutes he was removed to the sick bay. His rectal temperature had dropped 1.8°F. It was noted that the foot which had been in the wet shearling lined boot showed marked redness (erythema), while the other foot showed no change.

Two subjects wearing winter flying clothing but no exposure suit were transferred directly to rafts.

The first remained in the raft for nine hours; however, during the night, while asleep, his right foot dropped into the water. When he awoke thirty-five minutes later, his foot was numb with no sensation, nor could he feel pressure when standing on the foot. When examined, the foot was found to be markedly reddened (erythematous), pronounced in the digits. His rectal temperature had dropped .8°F.

The second subject requested to be removed from the raft in less than nine hours. His clothing was wet through from spray. He was shivering with cold hands and feet. When examined, he showed mild reddening (erthema) of the feet, otherwise the extremities appeared normal. His rectal temperature had dropped 2.6°F.

Three men jumped into the water; two wearing exposure suits over winter flying clothing, one with only flying clothing.

The subject without the exposure suit was unable to remove his parachute harness or open the dinghy and had to be rescued in four minutes.

In neither case, of the subjects who jumped using exposure suits, did the neck closure rupture and the valves freely expel air. One jumped from a height of sixteen feet, swam with ease 40 yards to a raft and stayed there for fifteen hours. Although he showed a rectal temperature drop of 2.4°F, he did not complain of the cold and was completely dry at the end of the trials. The other subject jumped into the water from a height of five feet, opened the dinghy and boarded in ten minutes.

Six personnel wearing various combinations of winter flying clothing and exposure suits entered the water and swam to and entered rubber rafts. All remained in the rafts for the duration of the trials; up to fifteen hours for some subjects. Their rectal temperature drops ranged from 1.2° to 3.2°F. All felt that they could have stayed in the rafts much longer, up to several days, if necessary. Some even slept through the snow squalls during the night.

Of the six, three used single-ply nylon suits, which seeped some water causing a greater temperature drop than in those using suits which did not leak. In addition, the completely watertight suits provided greater bouyancy and allowed easier boarding of the rafts.

The medical officers made some additional observations regarding shivering and the observed temperature drops in some of the subjects.

It is not uncommon, they note, to observe a temperature drop of up to 2°F in a normal subject during early morning hours (the trials ended at 0600) when compared to early evening hours; the fact that subjects were resting could effect rectal temperature as could a change from an upright to a sitting position; further, that the effect can be even greater if an individual lies down after mild activity.

With regard to the shivering observed in some subjects they note that shivering: indicates a great increase in the rate that the body is producing heat; that violent muscle contractions can increase heat production up to three to four times that found in a resting state; shivering is a clear indication that the subject is attempting to compensate for repeated heat loss, which may prevent body cooling; however, if the conditions are severe, there will continue to be a fall in internal body temperature, despite violent shivering.

Other related observations were recorded by the participants following the trials, which answered many of the questions raised by earlier discussions (20), summarized here:

-When an exposure suit was worn over winter flying clothing, subjects floated at the nipple line, could maintain a vertical position, and if desired, could float in a horizontal position for up to three hours (probably longer, if necessary); that the additional bouyancy provided by the air trapped in dry clothing made swimming and boarding rafts much easier.

-That a single-ply nylon-neoprene suit allowed too much seepage and was therefore unsatisfactory.

-That neck closures must be reasonably, but not absolutely, watertight.

-Loose fitting exposure suits were easier and quicker to don over wet or dry clothing; however, they would be difficult to wear while flying. The close fitting suits were particularly difficult to don over wet flying clothing.

-Even with wet winter flying clothing, it was possible to survive longer if an exposure suit was used.

-Without the additional floatation provided by an exposure suit, it was very difficult to board a raft. (The addition of a stirrup ladder and knotted lines was recommended to assist exhausted men in boarding rafts.)

-That in further developments of exposure suits "the incorporation of an inflatable chamber in the head and neck region to keep the neck closure above water when the subject is floating on his back" be considered and "provision for draining the suit through the feet may also be desirable in the event of considerable leakage".

When all the reports were compiled, the following conclusions were put forth by the joint group (20):

A. The major problems of a castaway are exposure, dehydration and rescue.

B. Exposure is a highly lethal hazard to military and civilian personnel operating in northern latitudes. A human body cools when immersed in water of a temperature of less than 92°F. The warmest open ocean water in any latitude at any time of the year is 84°F.

Individuals exposed to water of this temperature undergo significant cooling, and need the protection of a waterproof suit in the water. Individuals, even in such warm climates, while sitting on life rafts, loose body heat rapidly due to evaporative cooling, unless provided with a waterproof suit. The rate of loss of body heat increases rapidly as the temperature of the air and water falls. For example, personnel in Aleutian areas survive less than thirty minutes.

C. Severity of exposure to cold as a lethal factor is dependent on such variables as wind velocity, temperature of both air and water, degree of wetness of clothing, humidity, physical activity of the individual, duration of exposure and variation in individual susceptibility.

D. Long exposure, though not severe enough to kill, to water and a general chilling of the body does act locally causing gangrene.

E. It is exceedingly difficult and sometimes impossible for personnel to climb into a life raft after heavy flying clothing has become water soaked. Moreover, even if such sodden individual manages to get into the life raft, he will shortly be incapacitated through evaporative cooling, and will be unable to operate his emergency equipment.

F. An exposure suit of the type tested when worn over a flying suit, or similar clothing, will protect an individual for many hours in cold water or in life rafts.

Additional conclusions are found in a report written by Commander Hiscock for ERES (20):

-The principle demonstrated...completely justifies the adoption and immediate procurement of such an exposure suit.

-A joint development program should be inaugurated to bring about improvements in the efficiency of the present type of suit, but that this should not delay the procurement of one or other of the present types, or of a basic type which incorporates the best features of each type tested.

-The following definition of Aviation Exposure suit was adopted. 'THE AVIATION EXPOSURE SUIT IS ONE WHICH WILL PROTECT PERSONNEL WHO ARE IMMERSED IN WATER, OR ON RAFTS, AGAINST LOSS OF BODY HEAT.'

-It was further agreed that an immediate effort be made to adopt a general specification governing the type of exposure suit to be used by all airborne personnel.

This concludes the discussion of the "Halifax Trials".

---

*Note: The author is attempting to secure a copy of the film taken by the U.S. and Canadian team (20, 24), if successful, viewing should prove interesting.

A recent conversation with Dr. Holt confirms the conclusions of the trials of 1943; he recalls some other observations not found in the written reports of the time (34):

-In water of 32°F., mental activity stops in eight minutes and death occurs in ten minutes.

-During World War II, Sir Thomas Lewis, a British heart specialist, concluded that in many cases of rapid hypothermia, death is due to ventricular fibrillation.

-That at the time of the "Halifax Trials" over 1500 men were in Canadian hospitals suffering from "trench" or "immersion foot".

-At the height of the bombing of Germany only 20% of the airmen downed in the English Channel were saved. An average of 800 men per day were lost, most to the effects of exposure.

-There was a cold chamber built at Wright Field (Dayton, Ohio) by the Army Air Forces; however, the largest chamber was built at Orlando, Florida where temperatures could be dropped to -75°F. and simultaneously pressures the equivalent of 60,000 feet simulated.

The efforts of ERES in the development of exposure suits that culminated in the "Halifax Trials" ultimately led to the production of aviation exposure suits for the Navy and Army, Air Forces (32). These were not produced until very late in the war. It is not known how many were manufactured or by whom. It is significant that they were produced at all considering the lack of interest demonstrated, early on, by some services, particularly the U.S. Army Air Forces (22). However, by May of 1944 the U.S. AAF was doing their own testing on exposure suits at Wright Field and were preparing to authorize production (30).

In February, 1944 the Air Sea Rescue Agency was formed (33). The Liaison Committee continued for some time after the formation of the new agency; however, some ERES staff went on to other projects, while some transferred to Air Sea Rescue (29). ERES had by this time demonstrated the need for and had pioneered the development of exposure suits in the United States.

It is indeed unfortunate that recent investigators and designers of the modern "survival suit" did not have the benefit of this information. Despite my life long knowledge of the hazard of exposure and the need for protective clothing, I hever dreamed that I would be the one to put this information together. It has been an interesting project for me. I hope that you have gained as much from the presentation as I did from assembling the information and talking to some of the participants.

I am sure that I have posed as many questions as I have answered. I will answer, as best I can, any you may have.* My hope is that others of you will pursue missing information, not only regarding exposure suits, but

*Note: I have xerox copies or originals of all the reference materials listed, with me today.

other items of emergency rescue equipment as well which ERES developed thirty-seven years ago. Some of them are just being rediscovered today. It may be that in examing the accomplishments and failures of the recent past, we can save more lives in the future. That is after all why we are here.

POSTSCRIPT

It is interesting that the recent interest in hypothermia is, in part, the result of the realization that in many marine accidents victims succumb to "drowning" because they were first the victim of hypothermia. This is born out by the Coast Guard's recent concern for "level floatation" in recreational craft and the development of "float coats" and "survival suits".

That exposure was a primary killer of maritime "accident" victims was realized at least thirty-seven years ago. Why did it take so long to again realize that without protection from hypothermia "all our other (safety) items are not worth a darn" (19)?

In addition, I would note the fact that we are gathered here today to discuss hypothermia leads me to propose the need for a new liaison committee for emergency rescue equipment, with international participation, to coordinate all efforts, not only with regard to hypothermia, but in the development of emergency rescue equipment items necessary to successful survival.

ACKNOWLEDGMENTS

To Earle and Alice Hiscock, and George Holt for their remembrances, and for the material they saved; to Dr. John Hayward, for encouraging me in this endeavor of "historical perspective to keep up humble"; to my wife, Lynn, for her encouragement and suggestions; and to Sabra Ramsdell, for her tireless assistance in preparing the final manuscript.

REFERENCE LIST
(cronological order)

1] Wartime Safety Measures for Merchant Marine
United States Coast Guard, Educational Series No. 2
January 1943
U. S. Government Printing Office, Washington (D.C.) 1943
Pages: 82, 110-111

2] (U. S. Department of Commerce, Bureau of Marine Inspection and Navigation)
Copy of Memorandum
From: Lt. Comdr. Earle F. Hiscock, Principal Traveling Inspector
To: Chief, Merchant Marine Inspector
Subject: Tests on lifesaving and other rescue equipment at Miami, Florida, from March 22 to March (1943) inclusive.
Dated: 31 March 1943

3] (U.S.) Joint Chiefs of Staff (Washington, D.C.)
Copy No. 18
Memorandum for Information No. 58
Plan for Organization of Committee on Emergency Rescue Equipment
Dated: April 15, 1943

4] (U.S.) Navy Department (Washington, D.C.)
Office of the Chief of Naval Operations, Washington (D.C.)
Copy of Letter
From: The Vice-Chief of Naval Operations
To: The Coordinator of Research and Development
Subject: Committee on Emergency Rescue Equipment
Dated: April 20, 1943

5] (U.S.) Navy Department, Washington (D.C.)
Copy of Letter
From: Coordinator of Research and Development
To: Commanding General, Army Air Forces
Chairman, Maritime Commission
Director, of Scientific Research and Development
Director, Office of Strategic Services
Subject: Liaison Committee on Emergency Rescue Equipment
Dated: April 26, 1943

6] (U.S.) Navy Department, Washington (D.C.)
Copy of Letter
From: Coordinator of Research and Development
To: Commandant, U.S. Coast Guard
Subject: Emergency Rescue Equipment, Liaison Committee and Technical Aide.
Dated: May 5, 1943

7] (U.S.) Navy Department (Washington, D.C.)
Office of Coordinator of Research and Development
Copy of Notice re: Liaison Committee on Emergency Rescue Equipment
Dated: May 12, 1943

8] (U.S.) Navy Department, Washington (D.C.)
Copy of Minutes of Second Meeting, May 15, 1943
Liaison Committee on Emergency Rescue Equipment
Dated: May 22, 1943

9] (U.S.) Navy Department, Washington (D.C.)
Copy of Minutes of Third Meeting, June 5, 1943
Liaison Committee on Emergency Rescue Equipment
Dated: July 24, 1943

10] Coordinator of Research and Development, U.S. Navy
Liaison Committee on Emergency Rescue Equipment
Emergency Rescue Equipment-Information (Bulletin) Number 1
Dated: June 5, 1943

11] Coordinator of Research and Development, U.S. Navy
Liaison Committee on Emergency Rescue Equipment
Emergency Rescue Equipment-Recommendation, Number 1
Subject: Lenses, color of, life preserver lights.
Dated: June 5, 1943

12] Coordinator of Research and Development, U.S. Navy
Liaison Committee on Emergency Rescue Equipment
Emergency Rescue Equipment-Recommendation, Number 2
Subject: Signaling mirror, tempered glass type.
Dated: June 5, 1943

13] Coordinator of Research and Development, U.S. Navy
Liaison Committee on Emergency Rescue Equipment
Emergency Rescue Equipment-Recommendation, Number 3
Subject: Substitution of protective exposure suits for "lifesaving suits" on Merchant Vessels and Military Transports.
Dated: June 5, 1943

14] (U.S.) Navy Department, Washington (D.C)
Copy of Minutes of Special Meeting, July 27, 1943
Liaison Committee on Emergency Rescue Equipment
Subject: Consolidation of land-air-sea rescue under one command
Dated: 28 July 1943

(U.S. Navy Department, Washington, D.C.)
Copy of Letter
From: Commander-in-Chief, United States Fleet and Chief of Naval Operations
To: oint (U.S.) Chiefs of Staff
Subject: Consolidation of Air-Sea Rescue under one command
Dated: No Date

15] (U.S. Navy Department, Washington, D.C.)
Copy of Letter
From: Coordinator of Research and Development, U.S. Navy
To: Joint (U.S.) Chiefs of Staff
Via: Vice Chief of Naval Operations
Subject: Land-Air-Sea Rescue Operations
Dated: 29 July 1943

16] (U.S. Navy Department, Washington, D.C.)
Copy of Agenda and Minutes of Forth Meeting, August 2, 1943
Liaison Committee on Emergency Rescue Equipment
Dated: August 2, 1943

17] Office of Coordinator of Research and Development, U.S. Navy
Emergency Rescue Equipment Section
Report of Conferency, August 3,4 and 5, 1943
Subject: Airborne Rubber Rafts and Sea Survival Equipment and Seasickness.
Dated: 20 August 1943
Pages: 1-2,4,6.

(U.S.) War Department
Headquarters, Army Air Forces, Washington (D.C.)
AFF Memorandum No. 20-10
Subject: Organization of AAF Emergency Rescue Branch
Dated: 25 August 1943

(Office of Coordinator of Research and Development, U.S. Navy)
Emergency Rescue Equipment Section
Memorandum to Personnel
Subject: Organization of AFF Emergency Rescue Branch
Dated: 6 September 1943

Coordinator of Research and Development, U.S. Navy
Emergency Rescue Equipment Section
ERE publication #2, Survival Hints
Dated: September 1943
(Reproduced from: Wartime Safety Measures for Merchant Marine
U.S. Coast Guard, January 1943 [1])

(U.S.) War Department
Headquarters, Army Air Forces, Washington (D.C.)
AFF Regulation No. 20-23
Subject: Organization: Air Communications Officer
Dated: 1 October 1943

18] Coordinator of Research and Development, U.S. Navy
Liaison Committee on Emergency Rescue Equipment
Emergency Rescue Equipment (Section)
Bi-Weekly Report No. 5 (Copy No. 12)
Dated October 16, 1943
Page: 12

(U.S. War Department)
Headquarter , Army Air Forces, Washington (D.C.)
AFF Memorandum No. 20-10A
Subject: Amendment to memorandum No. 20-10
Dated: 26 October 1943

19] (Coordinator of Research and Development, U.S. Navy)
Emergency Rescue Equipment Section
Report of Conference:
Exposure Suits for Aircraft, 27 October 1943
Dated: 27 October 1943

20] Office of Coordinator of Research and Development, U. S. Navy
Emergency Rescue Equipment Section
Royal Canadian Air Force Flying Clothing Committee
Reports of: Joint United States/Canadian
Air Sea Rescue Equipment Trials
Washington-Montreal-Halifax-Toronto
Dated: November 21, 1943; 25 November 1943; November 30, 1943;
December 6, 1943

21] Navy Department, Washington, D.C.
United States Fleet
Headquarters of the Commander-in-Chief
Copy of Memorandum for Mr. H. W. Jackson
Subject: "Vaco" rubber life saving suits.
Dated: 27 November 1943

22] (Emergency Rescue Equipment Section)
Copy of Memorandum for file
By: George W. Holt, Lt. Colonel, M-C
Subject: AAF and exposure suits
Dated: 27 November 1943

Office of Strategic Services, Washington, D. C.
Copy of Letter
From Earle F. Hiscock, Lieut. Comdr.,U.S.C.G.R.
Technical Aide for Emergency Rescue Equipment
To: Wing Commander M. M. Foss, Air Member, Air Staff
Director of Operational Requirements
Royal Canadian Air Force
Toronto, Canada
Dated: 29 November 1943

:3] (U.S.) Navy Department (Washington, D. C.)
Office of the Chief of Naval Operations, Washington, D.C.
Chief of Naval Operations Armed Guard Bulletin 25-43
From: Chief of Naval Operations
To: Armed Guard Officers
Subject: Rubber Life Saving Suits
Dated: 1 December 1943

:4] (Emergency Rescue Equipment Section)
Copy of Letter
From: Earle F. Hiscock, Lieut, Comdr., U.S.C.G.R.
Technical Aide for Emergency Rescue Equipment
To: Director of Photography
Photo Science Laboratory
Naval Air Station
Anacostia
Subject: Film of Halifax Trials on Exposure Suits
Dated: December 6, 1943

(U.S.) Navy Department, Washington, D.C.
Coordinator of Research and Development
Copy of Agenda, Seventh Meeting
Liaison Committee on Emergency Rescue Equipment
December 15, 1943

5] (Emergency Rescue Equipment Section)
Copy of Letter
From: George W. Holt, Lt. Colonel, M-C
To: Wing Commander M. M. Foss
RCAF, AMAS/DOR
3103 Lisgar ldg.
Ottawa, Canada
Subject: Neoprene treated nylon for exposure suits, with sample of same.
Dated: 23 December 1943

Dr. William R. Keatinge, Ph.D.
Department of Physiology
London Hospital Medical College
Turner Street, London, E128D, England

Dr. W. R. Keatinge

HYPOTHERMIA - PAST AND FUTURE

RHODE ISLAND 1980

The present energy crisis is historically only the latest of many involving cold stress and hypothermia. It is uncertain just how rapidly energy supplies in North America and Europe will decline. Events in the Middle East could produce sudden interruptions, but even without these, it is now clear that present sources of cheap fossil fuel will dwindle before new sources of cheap energy are available in sufficient quantity to replace them. This crisis is unusual in being gradual in onset but very wide in its effects. One unusual feature, which reflects credit of the organisers of this conference, is that thought is being given in advance to finding ways to handle it before it strikes in full severity.

Let us start by looking in a simple way at the kind of options open to us. A medium-sized family house with good insulation, in air at 0oC, needs more than 10 kw to maintain inside temperature at 25oC (72oF). If the heating energy available fell to 5% of this it would not do much to heat the house. People wearing warm clothing could survive in the unheated house but they would not be comfortable, and people used to heated houses would not willingly tolerate this. If they were provided with personal heating of 0.1 kw each under warm clothing, four people could be perfectly comfortable at little initial cost and at an energy cost of under 5% of the cost of heating the whole home. However, simple practical trials show that some systems of this kind are much easier to use during some types of activity than others. Any widespread and continuous use of low-energy systems will require a variety of carefully planned, researched, and practically tested, systems. Convenience of use will be as critical as physiological and thermal efficiency, and difficulties must be identified and recognised before attempts are made to put them into mass use. Once the systems are available, even an extreme cutback in heating energy could be perfectly tolerable. Without them there would be considerable hardship, and probably some illness and a little loss of life.

Previous crises of cold exposure have been caused by shortlived events such as sinking of ships, or military campaigns on land and sea (1). Measures to deal with them have usually been taken only after they were over. There are many examples - the sinking of the Titanic, with over a thousand deaths from immersion hypothermia as people floated with lifebelts in water at 0oC, was followed by regulations requiring ships to carry lifeboats for all aboard. The Second World War involved massive loss of life at sea from hypothermia. Naval lifesaving equipment at that time left people immersed to the shoulders in water, while lifeboats in civilian ships were often impossible to launch from listing ships. In the British navy alone, some 30,000 people died of hypothermia immersed in the North Atlantic and Arctic Oceans. This was followed by adoption of inflatable liferafts as standard equipment on both naval and civilian ships, which has greatly improved the situation at sea.

The closest parallels with the crisis we now face are more remote, and are less well documented from the scientific point of view. For example, Napoleon is recorded as having lost almost the whole of an army of half-a-million men from cold on his retreat from Moscow in 1812. Civilian casualties during that and the following winter across the whole of Northern Europe were heavier, though they receive less attention in history books. But although hypothermia due to exposure, damage to housing, and breakdown in fuel supplies, was the prime cause of these deaths it was not working alone. Hunger and disease due to breakdown of food supply and sanitation were also major contributors. The records do not allow the roles of these various factors to be assessed accurately, but modern work does make it possible to be fairly confident that failure of heating alone will at least not cause much loss of life among people who are young, fit, healthy, well fed, well housed and well clothed, even in a severe winter. This is a very limited statement but it is an important one to make on the positive side.

Let us remind ourselves of the consequences of really severe cold stress to people without external protection. They are best documented for immersion hypothermia. This is still a major cause of death after accidents at sea. When the Lakonia caught fire near Madeira, 112 people died of cold in water at $16-17^{o}C$. Water carries heat away by conduction so effectively that many people die of deep body cooling in water at quite moderate temperatures. There is first shivering and constriction of blood vessels in the skin. These increase heat production, and shut down blood flow in the skin to reduce heat loss. If these responses fail to stabilise body temperature there is a rather well defined series of mental changes as body temperature falls. There is first a stage of general apathy in which survivors become depressed, lethargic and unwilling or unable to take any active measures to help themselves. There is then a period of real confusion in which behaviour can become completely irrational and actively dangerous. As deep body temperature continues to fall, consciousness is lost at a body temperature of around 30oC. The heart can continue to beat as temperature continues to fall, but there is an increasing risk of serious irregularities of the heart; and below 25oC the output of the heart becomes insufficient to supply the body tissues with enough blood. Death then eventually takes place unless the patient is rewarmed.

The difficulty about recognising early hypothermia is still the fact that its early mental signs are so unspecific. There are many reasons why people can be apathetic and irrational, other than hypothermia. The only way to confirm that someone is hypothermic is to measure deep body temperature, and it is not easy to do this by a reliable method in cold conditions. Mouth temperature is extremely unreliable in cold air, mainly because cooling of the face, and the salivary ducts in the cheeks, causes cold saliva to enter the mouth (2). Rectal temperature is generally impractical in field conditions. Some new methods have made matters easier. Urine temperature can be used in any surroundings, and is very reliable when it can be obtained in conscious people (3). It requires 50-100 ml of urine, and lags behind the temperature of the heart when this changes rapidly, but for a single reading it is very valuable. Aural temperature with servocontrolled external heat to eliminate local cooling is a comfortable and reliable method for tracking body temperature after the existence of hypothermia has been established. Once the ear has been warmed, this provides a very accurate record and tracks deep temperature with virtually no lag.

As regards resistance to hypothermia by well clothed people in moderately cold air, we sometimes forget that much of the external protection and heating we use is there for our comfort rather than for our survival. In still air at 5oC almost anyone can survive wearing only scanty clothing. They are uncomfortable, with cold hands and feet and fairly continuous shivering, but deep body temperature is maintained at a safe level. Early in the last century, Darwin found the Indians of Tierra del Fuego living naked in these conditions, and we are capable of doing the same. However, in air below this level, and in water at higher temperatures, some normal people will die while others survive. Let us remind ourselves of the reasons for this. They were established by many people, including Carlson in the United States, Pugh and Edholm in Britain, and Hayward in Canada. I can make some main points from some experiments of ours made about twenty years ago (1). When people go into water at 15oC, blood flow in the skin virtually stops, leaving the skin and fat under it as a layer of insulation, so that the rate of body cooling depends closely on the thickness of this fat. Children are usually thinner and cool faster than adults, and men faster than women (4). Although subcutaneous fat is mainly responsible, the small size of children and their consequent high surface area to mass ratio also contribute to their rapid cooling. The main practical point is that small children, and particularly small boys, can cool very rapidly in cold water or air which presents no hazard to most healthy adults. Exercise can increase heat production as much as tenfold, but it also increases heat loss, because blood flowing to the active muscles carries heat from the body core to near the surface. In cold so that exercise then increases the rate of body cooling. So exercise hinders survival in water cold enough to threaten life. It can increase body temperature during exposure to less cold water, and increases body temperature under almost all conditions in cold air, since external insulation is then available. Even in air it can have some harmful effects; excessive exercise with sweating can soak clothing and so increase cooling when exercise stops, and in outdoor conditions prolonged exercise can cause exhaustion. It is for these reasons that standard advice if you are caught in severe conditions in snow-covered country and unable to reach buildings, is to stop and build a shelter quickly while you are still in condition to do so.

Clothes are still useful even when they are soaked. They do, for instance, cut down body cooling during full immersion in water by as much as 75%, though they are much less effective than in air. Grouping ('huddling') of survivors can also help (5). The partial loss of insulation on immersion can be prevented by sealing air into the clothing, as is done in foam rubber wet suits. This system only breaks down in diving, when the air bubbles compress and much of the insulation is lost. There are, of course, many other thermal problems in diving, when the diver breathes high pressure gas mixtures which both conduct and transport heat very rapidly, and present evidence indicates that they are probably the cause of most of the high rate of casualties in North Sea diving at present.

In any event, dry clothing in air can provide very effective insulation. With clothed people, the main ill-effects of cold exposure are due to local cooling of the extremities rather than general hypothermia. In very cold air frostbite is the commonest hazard of severe cold exposure, and unprotected skin can also freeze solid if it is immersed in liquid seawater near its own freezing point of -1.9oC. Skin freezes at -0.5oC, and even a few minutes' immersion in very cold seawater can produce frostbite. Non-freezing cold injury ('immersion injury') requires cooling of limbs to below 12oC in air or water for many hours. It can be a very destructive injury, but it is rare in peacetime. Chilblains are a much less serious form of local cold injury, which can be produced in susceptible people by quite mild peripheral cooling. They are common during winters in Britain where homes are generally heated less warmly than in North America. They are not generally dangerous but are painful, and will certainly become commoner if house temperatures are lowered without substituting energy-saving heating systems. Cooling of the limbs also, of course, causes considerable loss of manual dexterity and clumsiness and discomfort, even when it is insufficient in degree to produce any kind of lasting cold injury.

The reason that the limbs can cool even in the absence of a serious fall in central body temperature is that during cold exposure heat flow from the extremities is reduced much more effectively than heat loss from the skin of the trunk. Vasoconstriction is then more effective in the extremities, there are countercurrent heat exchange systems in their blood supply, and physical heat conduction is trivial over the long distances to the extremities. As a result, once vasoconstriction has taken place in the cold, heat flow through the extremities is so low that even effective insulation by mitts and footwear may be unable to keep them more than a degree or two above surrounding air temperature. The reaction known as cold vasodilatation can rewarm the extremities when their temperature falls below 12oC, but it is intermittent and is therefore inefficient. Its main effect is, in fact, an adverse one, of increasing overall heat loss during prolonged and severe cold exposure.

In practice the only reliable way of keeping the extremities fully warm and comfortable in cold surroundings without artificial heating is by a combination of exercise and insulation. If heat production is increased by exercise in a warmly clothed person central body temperature will rise. This will cause the vasoconstrictor tone to relax and blood flow will carry heat to the extremities. As long as the extremities are insulated so that the heat is not immediately lost, they will rewarm. Equivalent amounts of heat provided to the trunk by artificial heating instead of exercise can, of course, produce the same effect of indirectly rewarming the extremities.

There are situations in which exposure to moderate cold, as with a clothed person in an unheated house, can produce large falls in central body temperature as well as peripheral cooling. The most dramatic is consumption of quite small amounts of alcohol after exercise, and in the absence of food (6). 28 ml of alcohol is insufficient to cause drunkenness or to have any important direct effects on blood vessels and heat loss. However, in people who have exercised for an hour or two to use up their reserves of carbohydrate, this much alcohol will cause a profound fall in blood glucose level and consequent failure of temperature regulation. Simultaneous consumption of food prevents alcohol from producing these eff–

ects. We think that they are responsible for otherwise unexplained deaths of hillwalkers and hikers in quite mild conditions. They would certainly be a hazard to a population living in unheated houses without personal heating systems, and turning to whiskey to relieve their discomfort. Actual drunkenness leading to collapse in the open air is also a major cause of hypothermia. Some warnings not to drink in cold conditions without eating a meal are important in complete energy failures such as major electrical breakdowns.

Mild exposure to cold can also be a serious threat to people with particular diseases. Diabetics on insulin are liable to spells of low blood glucose, and can cool rapidly during these. People with thyroid deficiency can cool because of their low rate of heat production. There has been much debate about whether old people are liable to die of hypothermia in moderately cold surroundings. Early reports of a massive incidence of hypothermia in the elderly were misleading, because of the use of sublingual temperature in cold surroundings. Later studies have shown that old people at home, even during total heating failures such as occurred in a miner's strike, are very rarely hypothermic even at the minimal point of the diurnal fluctuation in the early morning (3). The preferred air temperature for old people sitting still, in winter clothing, is 21oc and is the same in younger as in elderly people (K. J. Collins, personal communication). Old people who have genuine hypothermia on admission to hospital usually have it as a result of some other serious underlying condition. Such hypothermia is, in fact, often little more than part of the process of dying of some other condition such as a cerebral haemorrhage, heart failure, malnutrition or drug overdose. Old people are probably on average a little more susceptible to cold than young adults (7,3). They tend to cool a little more readily than younger people, because they often have less fat, generate less heat, and do not detect temperature changes in the skin so easily, but these differences are slight. A very small proportion of old people have major specific defects in their temperature regulating systems which can allow them to become dangerously hypothermic in quite mild conditions (8). This minority almost totally fail to shiver or to vasoconstrict in the cold, and do not survive unless they stay in well heated surroundings. A few younger people have similar specific defects whose cause is usually obscure, such as a man who is a working engineer and is perfectly normal except that he fails to regulate his temperature and becomes unconscious from hypothermia if room temperature drops below 25oC for long. Such people at immediate risk in cool air are rare but need special attention if heating of houses is reduced or stopped.

There are some mild thermal conditions which can allow even normal young people to cool, not fatally, but enough to impair normal function during quite mild exposure to cold. Divers in the North Sea generally work in water colder than 9oC and they are usually kept warm by hot water pumped from the surface to flood the interior of the diving suit. The temperature of this at the diver is regulated largely by the diver asking for it to be made hotter or colder. Some working divers let their body temperature fall to, and even below, the hypothermic level without asking for the temperature of the water supply to be raised, and if we simulate this situation in the laboratory, normal people can cool to similar levels without shivering significantly or complaining of cold (9). The cooling can be sufficient for cardiac irregularities to develop and is obviously dangerous in a working dive. The reason for this type of hypothermic drift seems to be that in lukewarm water the cold temperature receptors of the skin adapt to the constant level of very mild cold and fail to signal any cold stimulus. In thin people heat loss is still substantial, and body temperature falls, but the deep receptors alone are insufficient to trigger effective vasoconstrictor and metabolic responses to cold. The result is progressive and almost symptomless mild hypothermia. We need to know more than we do about the factors that can make people prone to develop this; they probably include some kinds of acclimatisation to cold. What is clear is that a very similar situation to lukewarm immersion can be produced by wearing heavy clothing in cold air and keeping still, so producing a very constant level of mild cooling of the skin. Apart from producing lethargy and unwillingness to work or move about, there are indications that such hypothermia can be mildly harmful even to people sitting quietly at home. Cold exposure can certainly worsen the symptoms of many fevers, such as the common cold. More serious consequences of mild hypothermia are doubtful; the increase of deaths in cold weather (10,11) is mainly due to different factors, such as anginal attacks when people go out suddenly into very cold air, particularly if they shovel snow there.

We must not forget that at present most cold-related deaths of healthy people are immersion deaths. Some are due to straightforward immersion hypothermia. Others are indirect - for example, in very cold water at near 0°C the high viscosity of the water and the intense reflexes set up by cooling of the skin can prevent even good swimmers from swimming more than a few yards without some kind of flotation aid (1).

We have evidence that public campaigns can reduce deaths from cold immersion, but so far only in particular groups of people. In 1971 a major conference of water-sport associations in Britain gave detailed practical advice to water-sport clubs and schools throughout Britain. The BBC later ran a campaign on local radio stations. The main aim of that campaign was to broadcast warnings specifically when weather forecasts predicted fine weather at weekends early in the year when water temperatures are low. They, for example, urged people who were planning to take out a boat that weekend to make certain they had a lifejacket and to make sure their children did, and described multiple accidents in previous years to people who failed to do so. There was a significant fall in mortality of school-age children in the four years after these measures were taken compared to the four years before they were taken (12). Pre-school children showed a probable smaller fall. However, there was no change whatever in the incidence of immersion deaths in adults. We seem to have got through to school-age children, and probably to some parents of small children. Adults probably heard the advice but were too sure of their own abilities and experience to change their customs. We have to find better ways of persuading adults, if we can, and we may be able to discuss possible ways of doing this over the next few days.

As regards home heating, to come back to my first point, there will be no difficulty persuading adults of the desirability of changing to very low-energy heating systems if energy becomes much more expensive and more scarce. The problem is to provide a range of fully researched systems which will be acceptable for longterm use in different situations. In a small apartment with several people living in it, highly efficient insulation may be enough to keep the whole area warm at low energy cost per person. An elderly couple in a house may be comfortable in winter by heating one well insulated room, and having an electrical blanket in bed. A family with children in a house may manage with one heated room but may need personal energy heating systems for the adults so that they can sit in comfort in other parts of the house if the children play pop music at full strength. Some background heating might be needed throughout the house in severe weather. There are many variants on this, and on the design of personal heating systems which could be used. None of these need to be expensive, but even in a severe energy crisis people will only use them if the optimum system for particular situations is fully researched for safety and practical convenience as well as physiological and thermal efficiency. If this can be achieved we would be in the happy position of being able to contemplate even massive reductions in heating energy, if we have to face them, with few consequences except some loss of personal convenience. I have tried to review briefly the information available which could help in planning for this.

References

1. Keatinge W. R. (1969). Survival in cold water. The physiology and treatment of immersion hypothermia and drowning. Blackwell Scientific Publications, Oxford.

2. Sloan R. E. G. and Keatinge W. R. (1975). Depression of sublingual temperature by cold saliva. Brit. Med. J. 1, 718-721.

3. Collins K. J., Dore C., Exton-Smith A. N., Fox R. M., MacDonald I. C. and Woodward P. M. (1977). Accidental hypothermia and impaired temperature homeostasis in the elderly. Brit. Med. J. 1, 353-356.

4. Sloan R. E. G. and Keatinge W. R. (1973). Cooling rates of young people swimming in cold water. J. Appl. Physiol. 35, 371-375.

5. Hayward J. S., Eckerson J. D. and Collis M. I. (1975). Effect of behavioural variables on cooling rate of man in water. J. Appl. Physiol. 38, 1073-1077.

6. Haight J. S. J. and Keatinge W. R. (1973). Failure of thermoregulation in the cold during hypoglycaemia induced by exercise and ethanol. J. Physiol. 229, 87-97.

7. Wagner J. A., Robinson S. and Marino R. P. (1974). Age and temperature regulation of humans in neutral and cold environments. J. Appl. Physiol. 37, 562-565.

8. MacMillan A. C. et al (1967). Temperature regulation in survivors of accidental hypothermia of the elderly. Lancet 2, 165-169.

9. Keatinge W. R. and Hayward M. G. (1980). Hypothermia during saturation diving in the North Sea. Brit. Med. J. (in press).

10. Bainton D., Moore F. and Sweetnam P. (1977). Temperature and deaths from ischaemic heart disease. Br. J. Prev. Soc. Med. 31, 49-53.

11. Anon. (1980). Blows from the winter wind. Brit. Med. J. 1, 137-138.

12. Graham J. M. and Keatinge W. R. (1978). Deaths in cold water. Brit. Med. J. 2, 18-19.

M. B. Kreider
Worcester State College
Worcester, Ma.

ABSTRACT

CROSS ACCLIMATION BETWEEN SEVERE COLD EXPOSURE PRODUCING HYPOTHERMIA AND EXHAUSTIVE EXERCISE IN RATS

M. B. Kreider
Worcester State College
Worcester, Ma.

One short severe exposure to cold for a period as short as 100 minutes, where hypothermia developed, resulted in an increase of cold tolerance and an increase of oxygen consumption in successive exposures (Kreider, M. B. Stimulus for metabolic acclimation to cold: intensity versus duration. Proc. Internatl. Symp. of Environ. Physiol. FACEB 88-91, 1971). Likewise, acclimation to cold has resulted in an increase in the level of physical fitness (Kreider, M. B. Effects of cold acclimatization on physical fitness in rats. Fed. Proc. 22:341, 1963). In this study cold acclimation was produced by the standard long-exposure method and it is not known whether short severe exposures would do the same thing. Also the reverse is not known; whether short bouts of severe exercise could influence cold tolerance on another day. This study was designed to answer this question.

Twenty rats were exposed twice to severe cold (-10C, clipped) until the rectal temperature reached 29.4C (85F) with one day intervals between exposures, and 4 and 6 days later exposed to an exhaustive swim each day (Group 1). Another group was exposed to the same stresses in reverse order. It was found that a partial acclimation to cold existed after only one short exposure to severe cold confirming previous reports and similarly that improved physical fitness resulted from one swim to exhaustion. The time for rectal temperature to reach 29.4C during cold exposure following two swims in Group 1 (161 ± 6 min.) was 40 percent higher (significantly) than in the control (Group 2 not yet exposed to an exhaustive swim). Swimming time following two cold exposures in Group 2 (26.5 ± 3.9 min.) was no different from the control (Group 1 not yet exposed to cold). While the mechanism of cross acclimation is not known one hypothesis could be that previous exercise improves cold tolerance through increased availability of energy for skeletal muscles while previous exposure to cold increases energy availability for non-shivering thermogenesis but this energy is not available for skeletal muscles.

Dr. Evan LLoyd
Department of Anesthetics
Royal Infirmary
Edinburgh, Scotland

AIRWAY WARMING AS A METHOD OF TREATMENT FOR ACCIDENTAL HYPOTHERMIA

Dr. E. L. L. Lloyd
Edinburgh, Scotland

In the assessment of any method of treating accidental hypothermia there are three important factors which must be considered.

1. Heat gain. This must be considered not only in the aspects of absolute quantities of heat gain which will include both heat added and any heat loss prevented, but also from the aspect of where the heat acts.

2. Other effects of the body. These may be beneficial or adverse and should include consideration of cardiovascular, cerebral, respiratory and renal function.

3. Where the method can be used. This involves consideration of the whole medical sequence from discovery of the victim, through first aid treatment, transport, treatment at base or hospital, to ultimate recovery.

1. HEAT GAIN

Because of the very low thermal conductivity of air, ventilation with warm dry air will provide negligible heat gain and, being dry, may cause a net heat loss from the body. Ventilation with warm humid air will provide a greater quantity of heat from a condensation of water vapour plus an additional, though small, quantity of heat cooling of the gas and the condensed water. The total quantity is however still small. Heat is however also being lost during normal respiration by warming and humidifying cold dry inspired air and the humidification is responsible for about 60 to 75% of this loss. The air temperature has to be minus 50 degrees centigrade before the thermal heat loss equals the humidification heat loss. The quantities of heat lost through respiration vary according to the respiratory minute volume and the air temperature (Table 1). By substituting warmed humidified gas to breathe the respiratory heat loss is prevented and there is a slight gain and the net effect can be significant. It should be noted that shivering will increase the heat production to 500 or 1000 K. cal per hour, and therefore, in a shivering person the effect of the respiratory heat balance (20-40 K. cal/hr.) is small and there should be minimal benefit from airway warming. Despite this, though two reports claim no gain from the use of airway warming with shivering; other reports show significant benefit. However, airway warming is worth considering in non-shivering subjects. In the experimental situation using sheep, provision of airway warming improved the rate of rewarming achieved by any particular level of body insulation (Table 2) but, as is also obvious, airway warming is no substitute for adequate insulation of the body surface. Table 3 shows the effect of airway warming in human cases treated in hospital. As can be seen the rate of rewarming during airway warming was always greater than the rate before airway warming was started. Despite the Q 10 effect, the rate of rise of core temperature during the period after airway warming was stopped, was also less than the rate of rise during airway warming. None of these patients were in fact shivering. In none of the cases treated did the core temperature fall as a result of the introductio of airway warming. In fact in most cases the after drop probably occurred before airway warming was started. These cases treated in hospital confirmed that airway warming can accelerate the rate of total body rewarming, while maintaining normal temperature gradients.

2. OTHER EFFECTS ON THE HUMAN BODY

There were no respiratory problems during or after the use of airway warming in those patients who survived and when post-mortem was carried out there was no evidence of damage to the larynx or trachea except in one case which had been ventilated with a humidifier set at 80°C with the delivery tube being lagged, which would give an endrotracheal temperature of almost 80°C, and yet even in this case there was only some laryngeal oedema and mild tracheal scalding. However, rate of rise of body temperature, theoretical or practical, is not the only factor in considering a rewarming method. Two aspects of cardio-vascular function important for the safe resuscitation of hypothermic patients, are cardiac out-put, and arterial blood pressure sufficient to maintain adequate perfusion of the heart and brain. In experiments with hypothermic sheep (Figure 1) the response to the initial rise in temperature was a rise in cardiac out-put whether the method of rewarming was the hot bath, spontaneous wrapped in blankets, or airway warming in addition to blankets. With both spontaneous rewarming and the hot bath, there was a marked fall in peripheral resistance which was still present when the sheep in the hot bath had reached normothermia. With airway warming, the peripheral resistance remained steady, and the arterial pressure could therefore rise after only a moderate rise in cardiac output. This contrasts with the hot bath where the rise in arterial pressure required a massive increase in cardiac output at a time when the heart was at its lowest temperature and therefore most vulnerable. This increase was greatly in excess of the base line values, even on return to normothermia, whereas with airway warming cardiac output varied around the base line values. With spontaneous warming, the increase in cardiac output was insufficient to compensate for the fall in peripheral resistance and there was therefore a fall in arterial pressure. This fall in blood pressure had been noted in man at a time when spontaneous rewarming could be expected and might be a possible cause of death during the transport of the victim. These experiments suggest that with regard to cardiovascular stability airway warming appears to be as safe as any other standard method of rewarming from acute hypothermia.

In the human cases treated the cardio-vascular status was examined. In all cases, however treated, the arterial pressure and pulse rate improved as the core temperature rose but airway warming had a specific beneficial effect on this. In six cases the blood pressure was unrecordable on admission and in a further six cases the blood pressure became unrecordable after having been present on admission. In all the cases treated with airway warming the blood pressure and skin colour improved rapidly whereas in the patient who rewarmed without airway warming the improvement was much slower. The cases of two elderly women will serve as an illustration. In one, previously absent blood pressure was restored within three hours by airway warming and at a core temperature of 27.5 °C whereas in the other, allowed to rewarm spontaneously, the blood pressure was not recordable for 22 hours and then only when the core temperature reached 33°C. Airway warming also has a beneficial effect on cardiac rhythm and one patient who at 24.3° C showed multi-focal supra-ventricular and ventricular extrasystoles was restored to sinus rhythm before her core temperature reached 27°C.

Cerebral function also improved as a result of airway warming. In six patients the respiratory drive which had been depressed by cold or drug overdose, was rapidly restored by airway warming before the core temperature had risen 1° C. In five patients the pupils were dilated and non-reactive when the patients were first seen. In the four treated with airway warming the pupils returned to normal size and reactivity very rapidly, two before any rise in core temperature could be recorded. This contrasts with a case which was allowed to rewarm spontaneously and the pupillary response did not return for several hours.

There is one hazard of airway warming. In cases with chronic hypothermia e.g. the elderly, airway warming is dangerous. If cases of chronic hypothermia rewarm too rapidly, even spontaneously, the fluid shifts can cause death through cerebral or pulmonary oedema, and because airway warming accelerates the rate of rewarming, it may be lethal. The only safe way to treat chronic hypothermia with airway warming is to use intermittent positive pressure ventilation (IPPV) which will prevent the onset of cerebral and pulmonary oedema.

There are two cases which illustrate the benefits of airway warming in human victims. In the first (Table 3, A2) (Figure 2) a 55 year old man took an overdose of Largactil on a cold night, and opened the window. He was found several hours later and was admitted to hospital unconscious with a core temperature of 27° C. He was wrapped in blankets in a hot room and because he was cyanosed with minimum respiratory efforts, ventilation was mechanically assisted with a bird ventilator. By replacing dry gas ventilation with warm humified gas, a zero rate of warming, which had been static for four hours was converted to a temperature rise. After three hours, active warming was discontinued and the body temperature continued to rise and showed the characteristic overshoot. The interesting comparison that during the three hours active warming was used, core temperature rose 3°C, whereas the next 3°C, without airway warming required six hours. Pulse and blood pressure improved with the rising temperature, and the active heating restored the respiratory drive. The patient regained consciousness and was discharged five days later. Figure 3 (Tab.3, A3) shows the progress of a young woman with severe overdose of distalgesic. She was unconscious though her core temperature was only 34°C. Her metabolism was so depressed by the drugs that she was unable to rewarm spontaneously despite being wrapped in blankets. The introduction of airway warming on two occasions caused the core temperature to rise and on each occasion the rise stopped when the airway warming was stopped. This is in contrast to the previous case where the initial heat stimulus was sufficient to start the rewarming process. When the patient was first seen, no pulses could be felt anywhere, breathing was impaired and being assisted, the pupils were dilated and not reacting to light, and indeed, the only definite evidence of life was an E.C.G. tracing on the oscilloscope. (If this patient had been found lying like that in her own home, she would probably be written off as dead). The first thing that happened after airway warming was started was that the pupils returned to normal size and became reactive. The pulses gradually returned and became palpable more peripherally, and after two hours, the blood pressure

Tab. 1

Body Temp. °C	Vent-ilation l/min	Basal Metabolic Rate Kcal/hr	Heat loss Kcal/hr	Heat left for rewarming Kcal/hr	Heat gain with air-way warming Kcal/hr	Heat available for rewarming Kcal/hr	% improve-ment	Rise in core temp. from available heat. without airway warming °C/hr	with airway warming °C/hr
37	5	72	- 8.0	64				1.8	
37	10	90	-16.0	74				2.1	
30	3	35	- 3.2	32.8	+ 6.2	39	19	0.9	1.1
30	10	35	-10.6	24.4	+ 20.5	55.6	128	0.7	1.6

Adapted from Guild (1978)

Environmental temperature of air = 0°C
Airway warming air temperature = 45°C with
100% relative humidity.

Tab. 2

Rates of rewarming achieved by the methods used in the treatment groups

Method	State of sheep	No.	Mean rate (and range) of rewarming (°C/h)	Projected interval for return to initial temperature
Control, non-cooled	Unshorn	3	0.5 (0.4-0.5)	-
Hot bath	Shorn	3	2.8 (2.0-3.4)	50 min
	Unshorn	2	2.0 (1.9-2.1)	1 h 20 min
Airway assisted ventilation	Unshorn	4	0.9 (0.3-1.3)	2 h 55 min
Airway spontaneous ventilation	Unshorn	5	0.7 (0.6-1.0)	3 h 20 min
	Shorn	1	0.1	31 h 30 min
Spontaneous wrapped in polythene and blankets	Unshorn	3	0.2 (0.1-0.3)	11 h 30 min
	Shorn	1	-0.7	-
Spontaneous no covers	Unshorn	11	-0.6 (-1.4-+0.6)	-
	Shorn	2	-0.6 (-0.4--0.8)	-

could be recorded. The respiratory drive was also stimulated. Despite a stormy convalescence this patient survived and eventually returned to work.

3. WHERE THE METHOD CAN BE USED

DEFINITION

Airway warming is a method by which the body gains heat mainly through prevention of the loss of heat and moisture which normally occurs during breathing. With some types of equipment there may also be some additional heat gain. As far as equipment is concerned every hospital will have a heated water bath humidifier which provides the necessary warmth and humidification, and the method can obviously therefore be used once the victim has reached hospital. The equipment, however, can be made portable and several cases have been treated in the field using a variety of designs of equipment. The initial design (Figure 4) utilized the well known reaction between carbon dioxide and soda lime which produces heat and moisture. A totally closed circuit was used to conserve all the expired heat loss and allow the use of a relatively small quantity of soda lime with a small priming dose of carbon dioxide. Unfortunately, there was the necessity for the use of oxygen. Equipment to this specification was carried by the successful Bonnington expedition in 1975 and worked effectively when tested at 20,000 feet. (It is of interest that in the first successful ascent of Everest in 1953 the use of closed circuit oxygen gave a better climbing performance than open circuit oxygen because of the heat and moisture generated. In fact this caused overheating in the "warm" still weather on the Western Cwm. The higher the altitude, the greater the heat loss from the lungs from warming and humidifying the air and therefore, the greater the benefit of the closed circuit. The fluid loss could amount to 3 1/2 pints per day, three to four times greater than at sea level.) Another configuration is to dispense with the oxygen and use air with a non rebreathing circuit but this, unfortunately, requires a larger quantity of soda lime and a larger priming dose of carbon dioxide, and also exposes the victim to the possible danger of the surge of heat from the initial chemical reaction being transmitted directly to the patient's face. However, equipment with this circuit has now been developed to a high degree of safety, and there should be very little to choose between the two methods, the ultimate choice depending on the operational requirements of any particular rescue service. As mentioned earlier there are a number of other designs which have been tried but these will not be discussed in this paper. The simplest method of producing some degree of airway warming effect is to use a condenser humidifier. The most efficient of these can conserve about 50% of the moisture, and therefore the heat, normally lost through respiration. It is a fortunate co-incidence that the best is also the smallest and lightest, weighing only a few grams. With the development of portable airway warming equipment the method can now be used from the moment the victim is found and during the transport to base i.e. times when no other method is available.

Finally though airway warming accelerates rewarming and does appear to have some other advantages, the ultimate decision about its use will have to depend on assessment by any individual rescue service as to whether the benefits justify the expense of purchase, manufacture and maintenance of the equipment and the added bulk and weight since to be of any use the equipment will have to be carried on many occasions when it may in fact only be rarely needed.

CASE	SEX	AGE	PRE-TREATMENT CHANGE			TEMP AT START OF TREATMENT °C	CHANGE WITH AIRWAY WARMING			TEMP AT END OF TREATMENT °C	CHANGE AFTER TREATMENT		
			TEMP. °C	TIME HOURS	RATE °C/hr		TEMP °C	TIME HOURS	RATE °C/hr		TEMP °C	TIME HOURS	RATE °C/hr
A 2	M	55	–	4	–	27	3	3	1.00	30	7	9	0.78
A 3	F	22	–	4	–	34	1.5	2.75	0.55	35.5	–0.75	5	–0.15
						34.75	3	4.25	0.71	37.75	–	2	–
A 7	F	23	-1	1	-1	29	7.5	13	0.58	36.5	1	11	0.09
A 8	F	39	-3.5	3	-1.2	30	6	12	0.50	36	2.5	8	0.30
A 14	M	50				33	1	2	0.50	34	4	15	0.27
A 17	M	56	–	1.5	–	28.5	7.7	4.5	1.70	36.2	1.5	3	0.50
A 18	F	39	-0.5	0.5	-1	30.5	2.5	4	0.63	33	4.5	8.5	0.53
A 1	F	61	-2	10	-0.20	34.8	1.8	2	0.90	36.8			
A 11	F	75	-6	24	-0.25	31	6	30	0.20	37			
A 13	M	38	-5	24	-0.21	32	4.5	12	0.38	36.5	-2.5	12	-0.21
A 5	F	75				28	3.3	5.5	0.60	31.3			
A 6	F	80	–	2	–	25.5	1.8	3	0.60	27.3			
A 15	M	84				23	4	6	0.67	27			
A 16	F	81				28	7	5	1.40	35			
A 4	F	57	–	7	–	28	0.6	1.5	0.40	28.6			
A 19	F	60				28	7	7.25	0.97	35	-3.5	9	-0.39
A 12	F	70	3	6	0.5	33	2.	2.5	0.80	35	2	5	0.4
A 9	F	75				32.5	1.5	1.5	1.00	34	3	4.5	0.67
A 10	F	88	0.3	2	0.15	24.6	11.2	11	1.02	35.8	1.75	19	0.09

Tab. 3.

Tab 4.

CASE	SEX	AGE	TEMP (°C) AT START	TEMPERATURE RISE		
				TEMP. °C	TIME HOURS	RATE °C/Hr
S 3	M	30	30.8	7	10	0.7
S 6	F	24	28.7	9.3	14	0.66
S 7	F	56	29.4	8	11.5	0.73
S 1	F	76	33.5	0.3	0.5	0.6
S15	F	79	25	5	10	0.5
				6	8	0.75
S 2	F	76	29.6	6	27	0.22
S 4	F	69	31	6.5	16	0.41
S 5	F	82	33.5	1.9	10	0.19
				0.6	23	0.03
S 8	M	83	33.2	4	29	0.14
S 9	M	69	33	3	9	0.3
S10	F	67	28	9	20	0.45
S11	F	77	25	11.4	43	0.27
S12	F	90	26.5	8.5	17	0.5
S13	F	75	33.75	3	11	0.27
S14	F	65	28	9	24	0.38
S16	M	old	31.8	3	21.5	0.14
S17	F	86	34.5	0.7	8	0.09
				3.3	14	0.24
S18	F	86	27.5	9.5	27	0.35

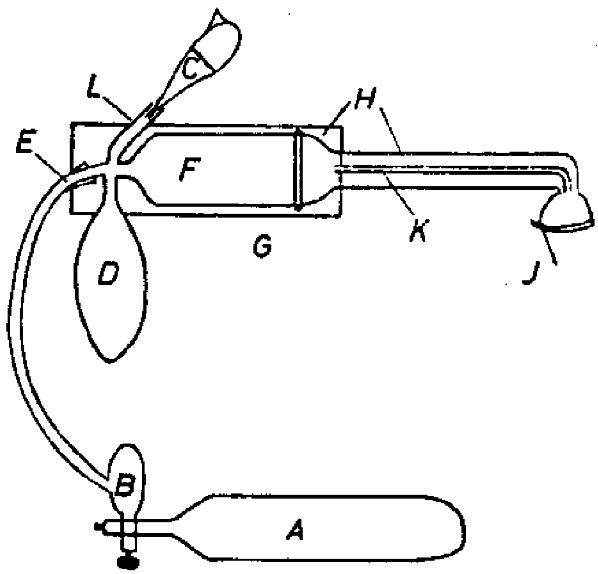


Fig. 4 Diagrammatic representation of portable resuscitation equipment.

A Oxygen cylinder.

B Demand reducing valve.

C Sparklets Corkmaster (BOC) with the distal portion of the needle removed and connected to the gas inflow limb of E. The oxygen supply is connected to the normal outflow part of the assembly.

D Reservoir bag of 6 l capacity.

E Normal Waters valve assembly with the Heidbrink valve removed and the reservoir bag connected. The arrangement is necessary to transmit the inspiratory negative pressure to the demand valve B.

F Soda-lime.

G Waters canister.

H Insulation-expanded polystyrene in the box and air in the delivery tube.

J Facepiece or mouthpiece and nose clip as used by mine rescue or skin divers or endotracheal tube.

K Double lumen delivery tube. The inner lumen is the respiratory tube while the outer is closed off and acts as insulation. The length of the tube is not critical since any build-up of carbon dioxide due to the deadspace would be beneficial in protecting the heart from the effects of hypothermia.

L Rubber tubing to give a flexible mounting for the Corcmaster C.

Fig. 2

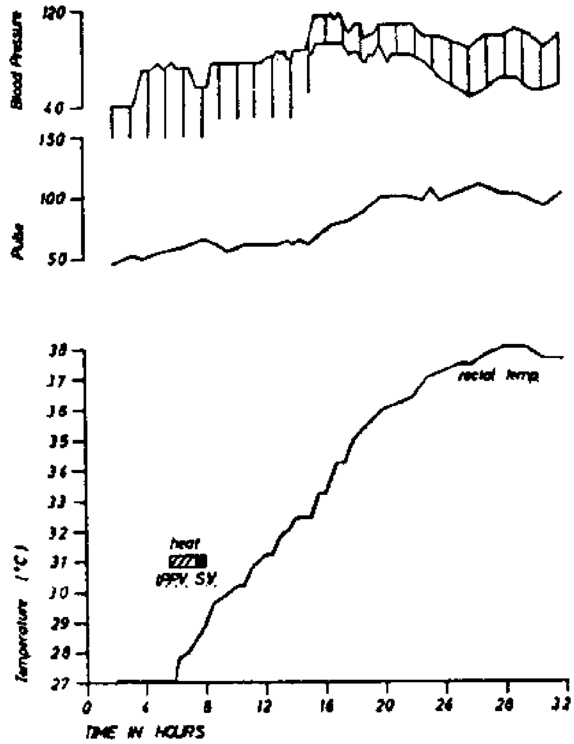


Fig. 3

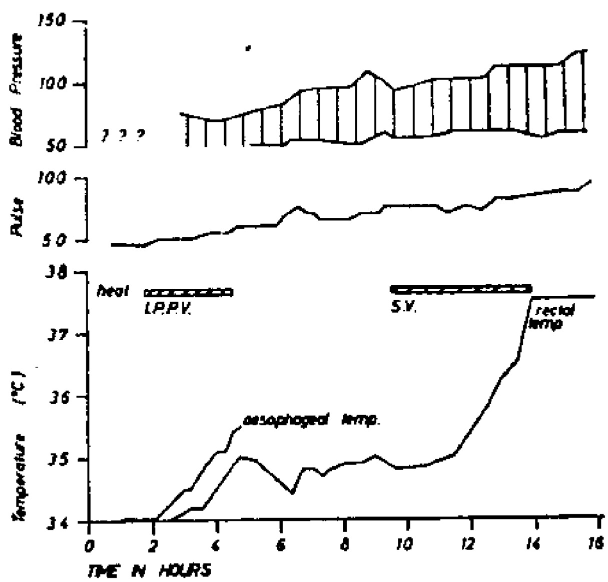
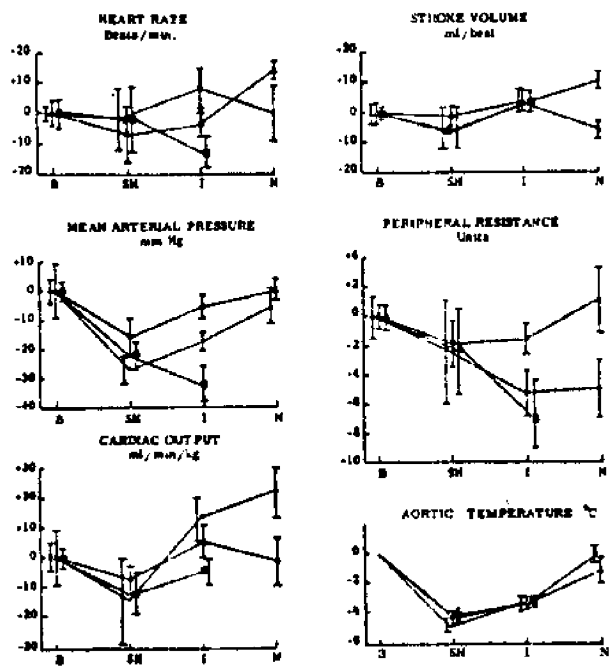


Fig. 1



CASE	SEX	AGE	PRE-TREATMENT CHANGE TEMP. °C	PRE-TREATMENT CHANGE TIME HOURS	PRE-TREATMENT CHANGE RATE °C/hr	TEMP AT START OF TREATMENT °C	CHANGE WITH AIRWAY WARNING TEMP °C	CHANGE WITH AIRWAY WARNING TIME HOURS	CHANGE WITH AIRWAY WARNING RATE °C/hr	TEMP AT END OF TREATMENT °C	CHANGE AFTER TREATMENT TEMP °C	CHANGE AFTER TREATMENT TIME HOURS	CHANGE AFTER TREATMENT RATE °C/hr
A 2	M	55	–	4	–	27	3	3	1.00	30	7	9	0.78
A 3	F	22	–	4	–	34	1.5	2.75	0.55	35.5	-0.75	5	-0.15
						34.75	3	4.25	0.71	37.75	–	2	–
A 7	F	23	-1	1	-1	29	7.5	13	0.58	36.5	1	11	0.09
A 8	F	39	-3.5	3	-1.2	30	6	12	0.50	36	2.5	8	0.30
A 14	M	50				33	1	2	0.50	34	4	15	0.27
A 17	M	56	–	1.5	–	28.5	7.7	4.5	1.70	36.2	1.5	3	0.50
A 18	F	39	-0.5	0.5	-1	30.5	2.5	4	0.63	33	4.5	8.5	0.53
A 1	F	61	-2	10	-0.20	34.8	1.8	2	0.90	36.6			
A 11	F	75	-6	24	-0.25	31	6	30	0.20	37			
A 13	M	33	-5	24	-0.21	32	4.5	12	0.38	36.5	-2.5	12	-0.21
A 5	F	75				28	3.3	5.5	0.60	31.3			
A 6	F	80	–	2	–	25.5	1.8	3	0.60	27.3			
A 15	M	84				23	4	6	0.67	27			
A 16	F	81				28	7	5	1.40	35			
A 4	F	57	–	7	–	28	0.6	1.5	0.40	28.6			
A 19	F	60				28	7	7.25	0.97	35	-3.5	9	-0.39
A 12	F	70	3	6	0.5	33	2.	2.5	0.80	35	2	5	0.4
A 9	F	75				32.5	1.5	1.5	1.00	34	3	4.5	0.67
A 10	F	86	0.3	2	0.15	24.6	11.2	11	1.02	35.8	1.75	19	0.09

Tab. 3.

Tab 4.

CASE	SEX	AGE	TEMP (°C) AT START	TEMPERATURE RISE TEMP. °C	TIME HOURS	RATE °C/Hr
S 3	M	30	30.8	7	10	0.7
S 6	F	24	28.7	9.3	14	0.66
S 7	F	56	29.4	8	11.5	0.73
S 1	F	76	33.5	0.3	0.5	0.6
S15	F	79	25	5	10	0.5
				6	8	0.75
S 2	F	76	29.6	6	27	0.22
S 4	F	69	31	6.5	16	0.41
S 5	F	82	33.5	1.9	10	0.19
				0.6	23	0.03
S 8	M	83	33.2	4	29	0.14
S 9	M	69	33	3	9	0.3
S10	F	67	28	9	20	0.45
S11	F	77	25	11.4	43	0.27
S12	F	90	26.5	8.5	17	0.5
S13	F	75	33.75	3	11	0.27
S14	F	85	28	9	24	0.38
S16	M	old	31.8	3	21.5	0.14
S17	F	86	34.5	0.7	8	0.09
				3.3	14	0.24
S18	F	86	27.5	9.5	27	0.35

Dr.Anthony F.Low
Department of Nautical Medicine
Bernhard Nocht Institute
Seewartenstrasse 9a, 2 Hamburg 11
Germany

Dr.Low is presently research assistant in hypothermia, diving medicine and SAR at the Dept.of Nautical Medicine. Prior to that he worked at the Institute of Aviation Medicine, Bonn, and the GKSS, Geesthacht, as deputy medical supervisor (1969-73) and then as supervisor (1974-77) of the German underwater laboratory "Heligoland" in its missions in the Baltic, North Sea and NW Atlantic. He is a certified engineer- and scientist diver in Germany, qualified in flight surgeon training in the German Air Force (1972) and in Occupational Medicine (1973).

Current Status of Hypothermia Therapy and Prophylaxis in Germany

by

Dr.Anthony F. Low

Dept.of Nautical Medicine, Bernhard Nocht Institute,
Seewartenstrasse 9a, 2 Hamburg 11, Germany.

Germany is bordered in the west and east by the North Sea and the Baltic Sea with average annual temperatures of about 9°C (48°F). Thus the threat of hypothermia is imminent for those who fall overboard. In the south, mountain ranges up to approx.3000 m height have abundant snow and low temperatures from fall to spring.

1. Hypothermia in coastal regions:

Last year, the German Lifeboat Society (DGzRS) rescued almost 500 casualties from the seas. Although the DGzRS does not differentiate between non-hypothermic and hypothermic cases in its statistics, we at the Dept.of Nautical Medicine consider the latter near to or equal to 50%. Hypothermic patients brought to shore are treated in coastal hospitals.

In 1976, we evaluated the hypothermia therapies at 30 hospitals and the number of patients treated [1]. Hypothermic patients were taken either to the intensive care units or to the internal medical departments. Our findings showed that

- 11 coastal hospitals had had no hypothermia cases during the last few years
- 14 hospitals dealt with not more than 1 - 2 cases per year with no deaths among the treated hypothermic patients, and
- 5 hospitals mentioned annual patient averages of 6 to 23.

Most of the above cases stem from swimming and sports boats' accidents and only a few from merchant marine ships. Knowledge of hypothermia therapies in general hospitals, internal medical clinics and ICUs differs considerably. Each hospital seems to have its own mode of treatment. In general, slow rewarming is prefered versus rapid rewarming (2 hospitals). Only one doctor mentioned increased oxygen needs during rewarming and only one warned of the dangers of hot water baths $\geq$ 40°C (skin burns and rewarming collaps
It is remarkable that the majority of coastal ICUs only have thermometers reading down to 31 - 32°C, whereas very few are equipped with those showing 20 - 22°C. Even hospitals with larger casualty numbers per year but without ICUs have only standard thermometers.

Some hospitals did not measure temperatures upon admission and quot 34 - 35°C after rewarming had been instigated. Thus the phrase "not below 35°C" is thermometer caused and masks eventual deep hypothermia. Only a few clinics had experience with casualties below 32°C core temperature. Several physicians became aware of the impossibility of low temperature measurements with the means at hand and asked for further advice from our department.

Treatment of hypothermia on board German merchant marine ships still is in accordance with the book "Health on board merchant marine ships"(1972) where rapid rewarming in a warm bath of initially 37°C and increasing its temperature to 40 - 42°C in a short time is recommended. Lacking a thermometer, bath water temperature should be monitored with the naked elbow. If no bath is at hand, pouring water of 40°C over the patient is advised therein.

2. Training of ship officers in hypothermia therapy

In Germany, merchant marine officers have to enlist for 2 or 4 week first aid courses of which one hour is devoted to hypothermia. Due to new research data in this field, we instruct them to rescue ship-wrecked persons from the sea with a minimum of manhandling, not to throw life-rings or similar devices to them if the water is very cold (numb fingers!) but to go to their help in the water, not to permit them to walk but to cover them with blankets --- especially head and neck region --- and to carry them into the ship and there, if the hypothermia is severe, to rather perform passive than active rewarming. We prefer passive rewarming due to the fact that ventr.fibrillation or rewarming collapse in a bath wil overburden the means and the knowledge (cardiac massage) of the crew If a hot bath is used, officers are instructed to start with 30 - 35°C (so-called reasonable rewarming) increasing the temperature to 40°C in 10 - 15 minutes while continuously stirring the water and checking its and the patient's temperatures. We urge the introductic of premature baby thermometers (27 - 28°C) on all German ships. Patients should be removed from the bath when body temperature has reached 35°C, and allowed to continue rewarming passively in bed while under a 24 hour observation. When available, O_2 inhalation is recommended as a supplementary therapy.

We do not recommend rapid rewarming in 40 - 44°C as proposed by the ILO "Resolution on hypothermia" (1973) and by the IMCO/LSA "Prevention of hypothermia" (1977) due to extreme pain for the pati-

Prophylaxis against hypothermia is emphasized as follows: Administer antiemetics as early as possible, don alternative layers of clothes (shirt-pullover-shirt etc.), cover feet and hands tying trousers at ankles and sleeves at wrists to reduce water circulatio protect head and neck, drink hot sugared beverages if available before abandonning ship.

3. Mountain rescue

3.1. General hypothermia:

In 1979, mountain rescue patrols saved approx.700 people and figures are rising each year. The majority of these casualties were hypothermic. The reasons were: over-estimation of one's capabilities, bad equipment and clothing, lack of basic survival knowledge. In this conference we have discussed several rewarming methods in the field, each with its advantages and inherent problems. In the southern German mountains , rescue groups have developed and perfected what they consider a highly effective core rewarming system and have been using it for the last 5 years with great success [2]. It is known as the HIBLER warming package (HIBLER Wärmepackung) and simply consists of: 1 linen sheet, a thermosflask with hot water and several blankets. Its application is as follows:

- fold the sheet 5 times and pour hot water onto it, wring sheet
- put folded hot sheet on underwear of chest and abdomen
- cover package with clothes and zip parka
- wrap aluminum foil or blanket closely around body alone
- then wrap several blankets around body, extremities and head
- pour fresh hot water on sheet package each following hour.

If used correctly, this method leads to an immediate rise in core temperature. In one case it enabled rectal temp. to rise from 29°C to 37°C in 7.5 hours [2]. This procedure is now used in the Garmisch-Partenkirchen hospital (a center for mountain casualties) instead of bath rewarming as it does not lead to a rewarming collap

According to NEUREUTHER (Garmisch) passive and active moving of hypothermic persons should be omitted as it has been observed that even by stretching flexed legs of a hypothermic patient a drop in core temperature from, for example, 30°C to 27°C can occur. If breathing stops, mouth-to-mouth resuscitation is prefered versus the Ambu bag as cold mountain air or cold oxygen would enter the lungs via the latter and eventually lead to further cooling.

If frostbite occurs together with general hypothermia in the field, the following first aid measures are used:

- central rewarming with hot, sugared drinks
- the HIBLER warming package
- rewarming the extremities by tucking them under rescuer's own clothing or armpits.

When frostbite is present without general hypothermia:

- patient is encouraged to move extremity actively and continuous
- if legs are only slightly frozen he is encouraged to walk.
- when larger parts are frozen passive transportation is used.
- if rescue doctor at scene warm (>37°C) 5% glucose infusions recommended, but no further medication.

Treatment in mountain cabin:
Administer hot sugared drinks, put frozen extremity into luke warm water (10°C!) and increase its temperature gradually within 30 min to 40°C if tolerable, otherwise slower. Then apply antibiotic powder and dry surgical dressings. Move extremities continuously. No vasodilatory drugs should be given as infusions.

Current German mountain rescue medical opinion does not favor rapid rewarming of frozen extremities [2].

4. Underwater hypothermia

The locations of Germany's Underwater Laboratory "Heligoland" during its missions from 1969-79 (North Sea, Baltic Sea, NW Atlantic) with water temperatures between 2°C and 14°C in depths of 10 to 42 m make protection against hypothermia imperative. Unisuits and full-face masks are compulsory. Wet suits perfused by water of 50°C have also been used. In the UW-habitat, therapy of hypothermia is possible by means of a hot shower (max.80°C) any time, hot drinks and warm meals with high caloric value. We have found that professional divers, paid by the time they spend diving are apt to overlook warning symptoms of impending moderate hypothermia more frequently than scientist divers (aquanauts). Among approx.150 aquanauts who have used our habitat between 1969 and 1979, no serious case of hypothermia has occurred.

In Germany, our Dept.of Nautical Medicine has been trying to make the warm, humidified air/O_2 therapy (CBRW) and its advantages more widely known but has met with resistance from several sides.

We hope that the opinions will change when our paper "Comparison between heat loss and heat gain via the skin and lungs during hypothermia and its therapy" (in press) appears.

5. Literature

[1]. H.Goethe and A.Low: Zur Praxis der Behandlung Unterkühlter - Erfahrungen in der Handelsschiffahrt und an der Küste.Teil I&II
Schlesw.-Holst.Ärzteblatt 31, 3, 206-209 (1978)
Schlesw.-Holst.Ärzteblatt 31, 4, 264-269 (1978).

[2]. G.Neureuther and G.Flora: Kälteschäden
Bayerisches Rotes Kreuz, Bergwacht (1978).

English translation of literature titles:

[1]. The treatment of hypothermic persons - experiences in merchant marine shipping and in coastal regions. Parts I and II.

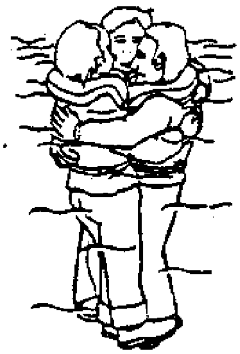
[2]. Cold injuries
Bavarian Red Cross, Mountain Rescue Section.

. . . .

Dr.A.Low

LOW GOETHE

MEDICAL PROBLEMS IN SEARCH AND RESCUE



Schiffahrts-Verlag „Hansa"
C. Schroedter & Co.

Medical Problems in Search and Rescue

Medizinische Probleme im Rettungswesen

— In englischer Sprache —

Verfasser: Dr. A. Low und Dr. H. Goethe, Bernhard-Nocht-Institut für Schiffs- und Tropenkrankheiten, Abt. für Schiffsmedizin (Wiss. Dir. Priv.-Dozent Dr. med. H. Goethe).

56 Seiten — ISBN 3-87700-0274 — Kart. DM 10,—

Medizinischer Ratgeber nach den neuesten Forschungen und Erfahrungen der Praxis für Kapitäne, Schiffsoffiziere, Schiffsingenieure, Schiffsärzte, Schiffseigner und Berater von Schiffahrtsbehörden in aller Welt.

Inhalt

Gefahren auf See
- Krankheiten, Verletzungen, Unfälle

Ortung von Schiffen und Besatzungen in Seenot

Erste Hilfe auf See

Rettungsausrüstung

Überleben auf See
- Psychologische Faktoren
- Physiologische Hilfen
- Durst
- Seekrankheit
- Lebensmittel
- Salzwasser

Unterkühlung und ihre Behandlung

Contents

Dangers for men at sea
- Diseases, injuries, accidents

Locating ships and survivors in distress

First aid at sea

Rescue equipment in distress

Survival at sea
- psychological factors
- physiological parameters
- thirst
- sea-sickness
- food
- salt-water

Hypothermia and its treatment

Prof. Dr. med. Hans Schadewaldt, Universität Düsseldorf, über dieses Buch:

„Es ist eines der wichtigsten auf diesem Gebiet, weil die Autoren die technischen, wissenschaftlichen und praktischen Probleme behandeln und auch auf neue pharmakologische Fortschritte hinweisen. Das Buch ist deswegen besonders relevant, weil die meisten Schiffe keine Ärzte an Bord haben; es informiert die Schiffsoffiziere ausführlich über die Gefahren bei Schiffbruch und über prophylaktische und therapeutische Maßnahmen in Seenotfällen."

Prof. H. Schadewaldt, University of Düsseldorf, said in a review of this book:

"It is one of the most useful books in this field, because the authors treat the technical, scientifical and practical problems and they include in their book new pharmacological propositions too. It seems very important that, because most ships have no doctor on board, the mates will be well instructed as regards the dangers of shipwrecking and the prophylactic and therapeutical methods to consider in emergency cases."

Bestellschein an Schiffahrts-Verlag „Hansa" C. Schroedter & Co., Postfach 11 03 29, 2000 Hamburg 11

Ich/Wir bestelle(n) .... Exemplar(e) **„Medical Problems in Search and Rescue"** zum Einzelpreis von **DM 10,—** inkl. MWSt. zuzüglich Versandkosten.

Name/Firma .... Datum ....

MEDICAL PROBLEMS IN SEARCH AND RESCUE

By Dr. H. Goethe and Dr. A. Low, MDs.
Department of Nautical Medicine
Bernhard Nocht Institute for Nautical and Tropical Diseases
Hamburg, Germany

WHAT DANGERS THREATEN MEN AT SEA?

Kinetosis can occur on planes, ships, and submarines in normal and adverse weather and sea conditions and depends on the individual susceptability. As the ship spends the longest time period on the water and is inclined to more yaw, pitch, and roll than the others, seasickness with its unpleasant side effects dominates here. This is especially so in small boats and during shipwreck. Time is an important factor for the outbreak of diseases and they therefore are also more frequent on ships than planes. Diseases and illness encountered most often on ships and requiring medical aid are dental and jaw diseases, acute and subacute appendicitis, bleeding and perforating gastric ulcers, kidney and gall bladder colics, acute psychosis. Accidents and injuries are seldom on jets and submarines due to the shortness of their journeys and the relative stability of their motion. In comparison, accidents and lethal injuries to seafarers are quite numerous.

Ship disasters, although decreasing in percentage of gross ship tonnage, are still continuing to rise after a 1956 low. With the changes in ship sizes, power, speed and purposes during the last decades, the prime causes of disaster also changed. It was found that between 1960 and 1969 the percentage of human lives lost at sea can be primarily attributed to foundering, collision, fire and finally groundings, in that order, although the reasons for disasters in former days were based on inadequate ship construction, inadequate seamanship, charts, weather information, navigational aids, or in general, on pure lack of knowledge. Human errors are still the main cause of maritime disasters.

As the number of oil rigs on the continental shelves (Gulf of Mexico, North Sea) increases, the risk of hazard on them rises and thus leads to new medical problems in rescue at sea due to their remoteness, i.e. far from regular shipping lanes, and their being occupied all year round even in the worst of weather by up to 60 men. While a mass disaster on land comprises 40-60 casualties in average, mass disaster at sea, for example on an oil rig, equals as few as five or six casualties. However, the other men are often at risk (explosion, fire) and would also have to be evacuated.

Plane crashes at sea occur each year and often many lives are lost either because the plane exploded before or on impact and sank immediately, or in any case it sank too fast for all the passengers aboard to be able to make their escape.

FIRST AID AT SEA

Except for large passenger ships, the great majority of cargo ships and tankers have no doctors on board. So, in the event of an emergency, e.g. injury or sickness of a crew member, they can only rely on a medically trained officer. If a catastrophe involving more than three seaman occurs, this officer, depending on his first aid training, might find himself unable to cope with the situation. Medical training differs from country to country and between ship agencies so it may be concluded that ships exist where none of the crew have received any medical training at all. This makes the situation even worse.

If the injury or disease on board is too difficult to treat, the next step would be to ask for radio medical advice from a physician well acquainted with nautical medicine. Several of these radio medical services have been in existence for many years. CIRM in Rome is without doubt the oldest and most well-known. It is on a 24 hour duty status in three to four languages and reaches around the world. The U.S. Coast Guard has its own system in connection with AMVER as do the Netherlands (radio Scheveningen) and the Federal Republic of Germany. Help and assistance is there whenever needed and these services make a high percentage of correct diagnoses. This can, of course, only be accomplished if the ship's officer, via the navigator, gives an exact description of the patient's symptoms, when they occurred, remedies so far, anamnesis etc., so that the doctor, maybe thousands of miles away, can form a correct mental picture of the case.

The third means of bringing medical assistance to ships without doctors is by flying so-called paramedics to the scene by either SAR or U. S. Coast Guard helicopters or amphibious planes/sea planes. These men have received special parachute training besides their medical education in order to be able to rescue people in the worst conditions.

The U. S. Air Force with its own rescue unit, known as the ARRS, can also assist in Search and Rescue missions at sea. Utilizing helicopters and a variety of specialized modified planes as well as paramedics, ARRS is well equipped for rescue operations together with SAR, U. S. Coast Guard, or other agencies, even in remote places. In a number of European countries with large deep-sea fishing fleets, radio medical advice and help is also available from so-called fishery protection boats. These follow the fleet in waters around Greenland, Iceland, Norway etc., have a doctor trained in nautical medicine on board, and also a well equipped sick bay and operating theatre.

Ships with doctors on board all the time, such as big military vessels, large passenger ships and the FPB's just mentioned, are in a far better situation should disaster strike. Casualties and diseases can be treated correctly and without any loss of time. Medical prophylaxis of crew members and the possibilities of daily consultations would decrease the probability of acute illness arising or being overlooked.

In accidents at sea we must also distinguish between those that occur near the coast and those that happen far out at sea. This is especially important in view of survival chances. When disaster occurs on ships and oil rigs near the shore, two advantages are at hand. First, the site of disaster lies within range of a helicopter (250 kilometers), rescue cruiser (45 km in 1 hour), and amphibious plane (350 km in 1 hour). Secondly, hospitals and airfields on the coast nearest the accident can be alerted for reception of casualties and can make appropriate preparations.

On ships far from land when in distress, e.g. mid southern Atlantic or Antarctic waters, prospects of rescue get worse. Survivors are usually out of range of SAR helicopters, the number of AMVER-registered ships in the vicinity will be smaller except if distress occurs on the main shipping lanes. Time till rescuers reach them gets long and the death toll would rise. Obtaining radio medical advice in cases of disease or injuries on board intact ships might or might not be possible depending on radio communication possibilities from and to these remote locations. This is an area where a number of medical rescue difficulties remain to be solved.

Personal rescue equipment includes warm clothing, life jacket, food, lamp, whistle, radio transmitter, and sometimes, in military aircraft, one-man rafts. The vital importance of warm clothing for survival cannot be stressed too much. It is essential that all people about to abandon ship put on as many warm clothes as possible: socks, shoes or boots, gloves, and protect their necks with scarves if the water temperature is below 25°C. Contrary to popular belief, a man fully dressed is not heavier in water and thus in no danger of sinking. Some studies indicate that even damp clothing provides considerable thermal insulation. Clothes should be fastened at wrists and ankles to prevent water circulation over the skin. Clothing shifts Molnar's survival-versus-time curve (1946) to the left. In water with an average temperature of 17-18° C. insulating clothing would put the survivor in the 21-22° C zone and thus prolong his survival greatly.

Life jackets are mandatory for each passenger. Of several models in use, the old types and those put on like jackets should be phased out as soon as possible as they are dangerous. The present optimal Uformed life jackets, e.g. Secumar 15, are stable and keep the heads of unconscious people above the water level. Only life jackets with a crotch strap should be used to prevent the life jacket from slipping upward and thus impairing free breathing and chafing the chin. The inflatable models should be inflated not before but after entering the water to prevent possible severe injuries to arms, neck, and chin, or knocking the person unconscious upon impact when jumping. It is recommended to use ladders or ropes to reach the water. Further requirements for life jackets are: easy donning, sufficient buoyancy, good fitting in wet and dry conditions, no restriction of freedom of movement, and self-righting tendency to a stable position. Life jackets should also have whistles attached to them and preferably some sort of light, e.g. on a cap so that they can be located in the darkness.

If a small radio transmitter is included in the personal rescue equipment it should perform automatically on contact with water or switches should be of the very large toggle switch type to facilitate use. Food supplies are at present hardly found in personal rescue equipment except in those of military jet pilots.

Group rescue equipment can be divided into life boats, life rafts, food, radio, water supply, and maybe primitive water desalting apparatus. For several years, life rafts have become more and more popular and have led to a decline in the number of life boats. Food on rafts or life boats should be ample for two to three days, a time span considered sufficient, in average, before rescue craft arrive at the location. Water is also a standard item (U.S. Coast Guard requires three quarts per person).

As regards passive or exterior rescue aids, these are in the first instance ships in the immediate (relative) vicinity of the distressed vessel. They either have received the SOS call or have been alerted by AMVER, U. S. Coast Guard or other similar agencies.

Further passive sea rescue aids are USCG, DGzRS, RNLI, FPB's, to quote a few national organizations that utilize specially equipped motor cruisers. Their inherent disadvantages are that they operate near the coast lines of their countries. The ranges of these rescue ships are limited by the time it takes to get to a specific disaster site from their base. Their range is approximately 45 km in one hour. Shore-based helicopters can cover a much larger area in a Search and Rescue operation having a range of about 250 km in one hour. They are also in a better position to locate single survivors in coloured life jackets and to hoist them up out of the sea. However, due to their relatively high gasoline consumption helicopters are not capable of long searching sorties.

Military SAR and ARRS helicopters and amphibious sea planes stationed on destroyers or aircraft carriers are the best means of bringing assistance to distressed ships in mid-ocean, for even shore-based long range rescue aircraft, e.g. C-130 Hercules, might arrive at the site too late to help, depending on prevailing weather conditions at the disaster location (cold, wind, rain). These aircraft can drop life rafts and other rescue items to survivors as need be. If the sea is not too rough, SAR/ARRS amphibious planes may try a sea landing or at least release paramedics to aid the survivors.

Although in use for several years now by modified ARRS C-130 Hercules planes, the STAR system (surface to air rescue) seems not to be as widely known as it should be. Utilizing STAR, it is possible to haul injured or distressed people (maximally two at a time) up into the C-130 from land, sea, ice floes, or jungle without the rescue plane having to land or to hover above those persons.

Psychological survival factors can be summed up as "the will to live." It is this will alone that has saved shipwrecked persons time and again in all epochs in situations where death was imminent. Persons in the situations, e.g. on life boats or together in the ocean, have died when they spiritually gave up, while their comrades lived on. Others have survived when all statistics proved they should have been dead. This "will to live" incorporates motivation and taking a correct mental attitude toward a certain situation. People who panic cannot survive for long in this case. Panic stems from fright or anxiety and this again usually from ignorance or incapability of doing certain tasks or using certain pieces of equipment when danger arises. Survival practice can do a lot to keep panic at a minimum and spirits high.

Physiological parameters influencing the duration of sea survival are numerous, the most important of them being thirst, immersion, seasickness, hunger, wounds, body weight, age, sex, and temperature, or more correctly hypothermia and clothing.

The human body requires 2.6 l. of water a day whereby 0.3 l. of this amount is produced by metabolism. During acute thirst the body decreases total water necessity to 0.8 l. per day, i.e. 0.5 l. from external sources. With this daily quantum per person in a life boat, indefinite survival is possible. Unfortunately, in many sea disasters this water quantum is either not at hand or the supply is only small and symptoms of thirst soon set in. Man loses 3% of body fluid a day. If 5% is lost physical collapse occurs, hallucinations between an 8-10% loss, and death at approx. a 20-22% loss of body fluids.

If a survivor replenishes his water needs by drinking sea water, even in diluted form, it will hasten dehydration because the kidneys need more water to eliminate the high sodium and chloride content (3.3 G % NaCl) yet can only concentrate it to max. 2 G %. Thus, thirst soon increases as NaCl levels in the body rise. Finally, thirst also increases when trying to eat dry and too sweet emergency foods, as water is needed for swallowing. All concentrated sweets cause thirst. Bitter chocolate is better than sweet chocolate.

An immersed survivor in a life jacket is equally in a very serious condition as regards accelerated dehydration and this fact is worth mentioning. Theoretically, immersion would minimize fluid loss if not for a striking water diuresis. Immersion aggravates water loss and according to Deforest leads to a rise in hematocrit of 3-4% in 8 hours in water of 34°C and to a 3% weight decrease within 10 hours instead of the usual 24 hours. The causes of immersion diuresis are:

1. Negative pressure breathing.
2. Vagal discharging activated by left atrial stretch receptors activated by diastolic filling levels.
3. Skin pressure, which leads to blood being forced centrally.

Diuresis, no doubt, would be minimized if the survivor were to take up a horizontal position in the water. This, however, stands in contradiction to the 45° angle assumed safe with modern life jackets.

When finally rescued, a survivor who spent the same time immersed as another on a raft without water would be in worse condition, even when not taking his heat loss and thermal failure into consideration. On being taken out of the sea, hydrostatic pressure would be removed from his skin and his reduced blood volume would be insufficient to fill the now available volume, thus leading to a condition similar to shock from an acute blood loss.

The effects of seasickness on survivors spending many hours or days on little life boats or rafts rocking in the waves can be very serious. Even the most experienced seamen are not immune from it and its devastating effects that may easily shorten survival time on an otherwise intact life craft. It is understandable then that everyone about to leave a distressed ship should take sufficient antiemetics and that they should be on stock in all life boats. Very great emphasis should be put on this point. Seasickness leads to yawning, general fatigue, locomotive insufficiency, apathy, hypotensive circulatory disturbances and depressions as well as to a considerable loss of body fluids.

Food is not as essential for life as water is for shipwrecked people, especially as the majority of survivors on shipping lanes can be expected to be found within 24-36 hours. Since we are used to meals at certain times a day, however, small rations of food would have a good psychological effect on anxious people. A problem in storage of canned foods on open life boats is the high corrosive effect of humid air and salty sea water on the food containers. Reports are on file of castaways having to abandon quantities of food that became inedible in a short time through water entering rusted cans, burst barrels, etc.

Salt water leads to a loss of the skin's natural moisture. The skin then begins to chap and becomes sore. Head, face, body, start itching and the eyes may get inflamed. If salt gets into a scratch it will become very painful and turn into a bad sore in one to two days.

Utmost care should be taken to use protective skin oils or cream. Any kind of skin wound will not heal if in contact with sea water.

A cardinal problem in sea survival has always been hypothermia and its treatment. Although death at sea was previously primarily attributed to drowning, this is not so. It is due to wet-cold. Several physiological factors, e.g., body weight, age, sex, water temperature and clothing, can have a positive or negative effect on the duration of survival time in the wet environment.

In the fight against hypothermia at sea, clothing can be a matter of living or dying. Emphasis should be put on making passengers don as many layers of warm and preferably woollen clothing as possible, before boarding the life rafts or entering the water. The insulating effect, though, does not only depend on the thickness of the material but on the amount of tiny air pockets or bubbles it contains. Clothes should fit well and be fastened at wrists, ankles, and neck and include some kind of neck protection. Body weight, subcutaneous fat-layers and skinfold thickness are also important parameters in sea survival. Fat people have a higher tissue insulation than thin ones and are able to stabilize their rectal temperatures at far lower water temperatures than lean people.

Almost all authors are against alcohol being issued prior to leaving the ship or on the life boats due to its vasodilatory effects and its increasing the heat dissipation from core to skin, thus encouraging hypothermia, besides its other side effects. At least one source, however, states that alcohol, even in substantial amounts, does not noticeably increase heat loss of persons in cold water though it greatly reduces their discomfort. Test subjects have been known to tolerate cold water immersions better with a little alcohol.

Therapeutic treatment of hypothermic survivors may be summed up as raising the core temperature of the body to its normal level as fast as possible. This can be achieved in several ways, depending on the degree of hypothermia and whether a doctor is on board the rescue ship or not. Nowadays, the prime method used is to put the patient in a hot bath of 37°C or even higher (max. 45°C) while keeping the four extremities outside the bath and bandaging their proximal parts so that their content of cool blood does not flow to the core before the central organs have regained their normal temperature. During this procedure the circulatory system should be monitored for eventual signs of impending collapse. It is also important that the back of the neck be rapidly re-warmed. Core temperature should be measured in short intervals.

Thauer then recommends infusions of warm glucose solutions and of $NaHCO_3$ or "tris" buffer to counteract acidosis and the possible occurrence of hypothermic edema of the brain.

Due to the increased sensitivity of the hypothermic heart to arrythmia, care must be taken to keep orthostatic loads to a minimum. A re-warming collapse can often be treated successfully by applying cold water to the face.

Wentrup recommends low molecular dextrose and hypotonic electrolyte infusions as well as analgetics, e.g. dolatin^R, tranquilizers, and, if need be, cortisone.

Souchon, besides advising rapid re-warming and the drugs just mentioned, includes strophanthin, cortisone derivates and drugs to reduce the fibrillation tendency of the heart (trophicard^R). After the survivor has been sufficiently re-warmed Souchon recommends antibiotics as a prophylactic measure against infections.

After re-warming, the survivor should remain under observation in bed for at least 24 hours. Alcoholic drinks must never be given to patients treated for hypothermia. Hot beverages, for example, sugar dissolved in warm water, may be taken but they are never a substitute for a hot bath.

REFERENCES

(1) *Souchon, F.:* Rettung aus Seenot – neuere ärztliche Aspekte. Mat. Med. Nordmark 26, 195-209 (1974).

(2) *Pfeiffer, W.:* Überleben auf See. Psychologische und physiologische Voraussetzungen. Ärztl.Prx. 17, 29, 1533-1537 (1965).

(3) *Wentrup, A.:* Flugunfälle über See und Überleben auf See. Wehrdienst und Gesundheit 16, 33-40 (1968).

(4) *Ayers, K.N.:* Marine disasters. Advanc. Sci. 25, 353-356 (1969).

John J. McAniff
University of Rhode Island Diving Safety Officer
University of Rhode Island
Department of Mechanical Engineering and Physical Education
Kingston, Rhode Island

As a diving safety specialist, Mr. McAniff, is known around the world for his contributions to this field. At URI he directs the National Underwater Accident Data Center which compiles information on underwater diving fatalities. He also conducts research in diving-related topics with researchers at URI, primarily with Dr. Hilbert V. Schenck of the Department of Mechanical Engineering and Applied Mechanics.

THE INCIDENCE OF HYPOTHERMIA IN SCUBA DIVING FATALITIES

by John J. McAniff*

The National Underwater Accident Data Center (NUADC) at the University of Rhode Island has operated over the last ten years on various federal grants and is presently supported by funds from the National Oceanic and Atmospheric Administration of the Department of Commerce, the U. S. Coast Guard in the Department of Transportation and the National Institute of Occupational Safety and Health of the Department of Health, Education and Welfare. The primary charge of the NUADC has been the investigation and statistical analysis of underwater diving fatalities involving United States citizens.

In the ten year period of 1970 through 1979 the NUADC has gathered information on approximately 1400 such fatalities. These have included case histories from the recreational or sport diving field, the occupational field including search and rescue divers, scientific divers etc. and the full time commercial diver field. The cases have included all types of situations; from the young snorkeler to the extensively trained professional diver working in the exotic helium-oxygen environment required in over five hundred feet of sea water.

A recurrent phenomena has surfaced in these investigations which we have called the "sudden death syndrome". This can be best described as an incident in which the victim has appeared to be alright at one instant and a few seconds or minutes later is observed laying face down in the

*Director, National Underwater Accident Data Center and URI Diving Safety Officer.

water with no physical response. Such instances are typically noted to involve a long and arduous dive in cold water. The victim depicts none of the classical signs of drowning such as thrashing or cries for help but appears to have spontaneously collapsed without warning. For quite some time the suspicion of possible hypothermia as a contributing factor to such cases has been present.

To investigate this possibility a search was made of the NUADC files covering the period 1970 through 1975. (Later years' cases were in varying degrees of incomplete computerization.) Of the 917 fatalities during this period, 33.4% (307) were found to be worthy of close examination. All cases within this sub-group had occurred in water temperature below 65°F (18.3°C) and were further limited to those cases in which we had sufficient information regarding the use or non-use of wet suit protection. Of the 307 cases examined it was determined that 85 (27.7%) had been possible hypothermia situations.

TABLE 1

POSSIBLE HYPOTHERMIA BY ACTIVITY AND SEX

	Male	Female
Scuba, Sport	69	8
Commercial	2	0
Snorkel Diving	6	0
TOTAL	85	

TABLE 2

POSSIBLE HYPOTHERMIA CASES BY STATE

STATE	1970 - 1975
Alaska	1
California	28
Florida	2
Hawaii	1
Idaho	1
Illinois	1
Iowa	1
Maine	5
Massachusetts	5
Michigan	4
Missouri	5
New Hampshire	3
New Jersey	2
New York	4
Ohio	4
Oregon	2
Pennsylvania	1
Rhode Island	1
Texas	3
Washington	11
Wisconsin	1
TOTAL	85

TABLE 3

POSSIBLE HYPOTHERMIA BY REGION

	Percent
Great Lakes	7
Pacific Northwest	15
New England	16
Mid-Atlantic	13
California	33
Missouri	6
Misc.	10

When the 85 cases were examined for activity and sex (Table 1), 77 of the cases involved non-professional (sport or recreational) activities and of these there were 69 males and 8 females. Of the remaining eight cases, two were considered to be commercial and six were snorkel diving and all eight were males. The incidence of females in the total sample was 11%, very similar to the estimated 10 to 12% female participation in the overall scuba diving population.

A tabulation of the cases by state (Table 2) reveals no significant trends but when examined regionally the following notes can be made. The Great Lakes region (Michigan, Illinois and Wisconsin) accounted for 6 cases (7%). The Pacific Northwest (Alaska, Washington and Oregon) had 13 cases (15%) while New England (Maine, Massachusetts, New Hampshire and Rhode Island) counted 14 cases (16%) and the Middle Atlantic group (New York, New Jersey, Pennsylvania and Ohio) accounted for 11 cases (13%). If the New England and Middle Atlantic group are combined, the total of cases is 27 (32%), almost identical to the count for the state of California which recorded 28 cases (33%). One other significant note concerned the state of Missouri which accounted for five cases (6%), all of these involved cold fresh water diving. The remaining 10% of cases were distributed among various other regions, each with numbers too small to be significant.

The incidence of cases occurring in salt water as opposed to fresh water situations was 61% versus 39% respectively. This is almost identical to our ten year average for all fatalities recorded.

Information was not available on 12 cases as to depth but of the remaining cases 50% occurred in water shallower than 30 feet. In nearly all cases deeper than 30 feet the water temperature was noted to be colder than 12.7°C (55°F).

It is difficult if not impossible within the scope of the investigations conducted through the NUADC to pinpoint hypothermia as the specific cause of death as the following scenario will indicate. A typical case involves a chartered boat with about twenty divers on board whose plan is to dive on a wreck in 90 feet of water 30 miles off the New Jersey coast in mid April. All divers have basic diver certification cards but no knowledge is available regarding their relative experience. (It is later determined that the victim is on his second salt water dive and has had only six dives prior to the accident dive. These were conducted in a 60 feet deep fresh water quarry.) One of the twenty divers is seasick so it is impossible to set up a one-on-one buddy program so three divers including the victim make up a three man team. Moving down the anchor line, the three men encounter a thermocline at about 40 feet which drops the temperature to about 4.5°C (40°F). This combined with the compression of the wet suit act jointly to cool the body.

The water visibility is less than six feet and in short order each of the three cannot find either of the others. The victim becomes more and more uneasy and distressed. As he begins to breathe harder and harder on the regulator, he thinks that he must be low on air. Along with this he starts shivering and decides to head to the surface leaving the others behind on the bottom. In his near panic state he probably swims up much faster than he should and once on the surface he finds that he has drifted far from the boat. The victim is now weak and disoriented and on the verge of unconsciousness. A few moments later he is spotted floating face down on the surface and though heroic efforts of CPR are conducted, he does not survive.

As can be observed from the above account, no one specific cause can be isolated for this tragedy but the conditions certainly implicate hypothermia as at least a contributing cause.

In a recent analysis of autopsies from the NUADC files, it was noted that 22% of all the victims over the age of 35 had died of heart attack or some form of cardiovascular disease. It is suspicioned that a sizable number of these also involved extreme stress and probable hypothermia.

In a conference such as this, one would be remiss not to call attention to another form of hypothermia which has been noted in commercial diving operations. In recent years the search for oil and gas supplies has reached deeper and deeper into the seas of the world. Divers working at such great depths are able to do so only by using exotic gas mixtures which rely on a high percentage of Helium mixed with Oxygen. Because of the very high thermal conductivity of the Helium, it is necessary to keep the divers' environment at 30°C (86°F) or slightly higher.

In the past few years two classic cases of helium hypothermia have been noted, both of which resulted in double fatalities. The first of these involved a lock-out submersible which became trapped by undersea cables and currents while examining a wreck. The two divers in the lock-out segment of the sub had a limited supply of heliox gas and no way to vent the build up of Carbon Dioxide. It was also not possible to maintain the necessary high temperature within the tiny compartment. Upon recovery of the submersible many hours later, the two men had expired while the two other men who had been in the one-atmosphere capsule of the sub survived with no ill effects. Ironically, one of the two deceased divers was the son of world famous inventor Edwin Link.

The most recent double fatality involving helium hypothermia occurred last year in the North Sea. Two American divers had completed their work excusion from a saturation diving bell at about 550 feet beneath the sea. Upon returning to the bell and sealing same, the word was passed for lifting to the surface. It was then discovered that the lifting cable was no longer attached to the bell and the men were trapped on the bottom for the next fifteen hours before recovery was accomplished. Both men had expired due to helium hypothermia. It was later noted that the main shackle to the diving bell which would normally have been both pinned and then wired, had worked loose due to the failure of someone to wire the pin to the shackle.

Some few observations can be made that do not necessarily rely upon statistical data but rather upon long years of investigation by the author. The activity of scuba diving can be very stressful especially in cold water which will require adequate thermal protection. Oftentimes adequate thermal protection for the diver at the surface will prove inadequate at depth due to the compression of the neoprene wet suit material with resultant faster cooling. Much of the cooling effect on the diver will be the result of breathing the cold compressed air from the scuba tank which has been constantly exposed to the very cold water. Some scuba fatalities can be prevented by simply practicing the proper one-on-one buddy system. Proper physical condition and conditioning is important.

When in doubt, use some common sense, it may be colder than you think.

References

Berkman, E.L. and Reeves, E., 1966, "Physiological Implications As to Survival During Immersion in Water at 75°F" Aerospace Medicin 37, 1136-42.

Burton, A.C. and Edholm, O.G., 1955, "Man in the Cold Environment", pp. 42-52, London, Edward Arnold.

Carlson, L.D., Hsieh, A.C.L., Fullington, F., and Elsner, R.J., 1958, "Immersion in Cold Water and Total Body Insulation", J. Aviat, Medicine 29, 145-52.

Craig, A.B. (1961A) "Underwater Swimming and Loss of Consciousness", J. Am. Medicine Assn. 176, 225-8.

Craig, A.B. (1961A) "Cause of Loss Consciousness in Underwater Swimming", J. Appl. Physiology 16, 583-6.

Golden, F. St. C. and Rivers, J.F., "The Immersion Incident, Anaesthesia 30: 364-373; 1975.

Ha dy, J.D. and DuBois, E.F., 1940, "Difference Between Male and Female in Response to Cold and Heat", Proc. National Academy of Sciences, USA 26, 389-98.

Keating, E.W.R., "Survival in Cold Water", Great Britain, Blackwell Scientific Publications, 1969, 131 p.

Molwar, G.W., 1946, "Survival of Hypothermia By Men Immersed in the Ocean", J. Am. Med. Assn. 131, 1046-50.

Talbot, J.H., Consolazio, W.V. and Pecora, L.J., 1941, Hypothermia Archives of Internal Medicine 68, 1120-32.

Anonymous: "Man in Cold Water", Aquanotes 6: 4; Mar. 1977.

United States Underwater Fatality Statistics 1975, Report No. URI-SSR-77-11.

United States Underwater Fatality Statistics 1976, Report No. URI-SSR-78-12.

Dr. James A. Miller, Jr., Ph.D., D.Sc.
Tufts University School of Medicine
c/o 307 Shorewood Drive
East Falmouth, MA 02536

Dr. Miller, now retired from full time research, is active teaching at Tufts University School of Medicine. His extensive research and publications on hypothermia and and hypoxia-hypercapnia have made him an international expert.

IV. Application of hyperthermia

IV. A) In anoxia

IV. A) 1. Physiology of hypothermic protection in anoxia

By J. A. Miller, Jr.

The fundamental rationale for the use of hypothermia in combating anoxia is its effects on the energy requirements of cells according to the van't Hoff-Arrhenius principle. This should reduce the depletion both of aerobic and of anaerobic energy stores and therefore irreversible cell damage. In neonatal puppies the reduction in over-all O_2 requirements between 37° and 15° C body temperature is 33% per 10° C. In 1-day old guinea pigs it is 28% per 10° C and in the human infant (one infant recovering from birth asphyxia) was reported by Auld (1962) at 40% per 10° C. Depression of O_2 uptake and increase in anoxic survival times were reciprocals in guinea pigs between 37° and 20° body temperature, but in puppies survival times between 37° and 15° were twice as long as predicted from depression of O_2 uptake [3]. This has been attributed to the increase in efficacy of the cardiovascular system in cold animals under hypoxia. Hypoxia-hypercapnia (H-H) and hypothermia tend to neutralize each other's deleterious effects [2, 3]. H-H counteracts the severe, generalized vasoconstriction caused by deep hypothermia. For example, it doubles cerebral blood volume at 15° C and increases liver pO_2 from near 0 to acceptable levels. Hypothermia counteracts the generalized vasodilatation of the shock-like anoxic state. In addition, H-H reduces the depletion of adrenal catecholamines and blocks shivering and non-shivering thermogenesis. Hypothermia during anoxia reduces the rates of increase in pCO_2, glucose, K, lactate and of decrease in pH, glycogen and pyruvate. These effects are proportional to the decrease in body temperature and therefore are delayed if cooling is slow. In clinical trials the first responses of asphyctic infants are: (1) increase in heart rate, (2) increase in pulse, and (3) change from pallid or blue to pink color [1, 4]. Except in the most deeply depressed infants these events occur before appreciable cooling of the core has taken place. It is suggested that in these cases the generalized vasoconstriction, which transports cooled, oxygenated blood from the periphery to the heart, may induce more vigorous contractions which break the vicious cycle of low cardiac $pO_2 \rightarrow$ weak contractions $\rightarrow$ decreased coronary perfusion $\rightarrow$ still lower pO_2 of cardiac muscle. If the early effects are inadequate, then falling core temperatures become more and more significant in protecting the brain. Hypothermia delays brain damage but cannot be expected to reverse damage which occurred before onset of cooling.

References

[1] Cordey, R., Chiolero, R., Miller, J. A., Jr., Resuscitation **2**, 169—181 (1973) — [2] Miller, J. A., Jr., Am. J. Obstet. Gynecol. **110**, 1125—1133 (1971) — [3] Miller, J. A., Jr., Miller, F. S., in: Neurohumoral and Metabolic Aspects of Injury, A. G. B. Kovách, H. B. Stoner, J. J. Spitzer Ed., p. 571—586, Plenum Publ. Corp. New York, N.Y., 1973 — [4] Westin, B., Nyberg, R., Miller, J. A., Jr., Wedenberg, E., Acta paediat., Suppl. **139**, 1—80 (1962)

IV. A) 4. Effects of hypothermia induced 2 min or more after last gasp upon resuscitation and brain damage from asphyxia in newborn Rhesus monkeys

By J. A. Miller, Jr., L. S. James, K. Adamsons, A. W. Brann, R. E. Myers, and F. S. Miller

Full term Macaca mulatta fetuses, delivered by cesarean section from anesthetized (pentobarbital) mothers were asphyxiated by slipping tightly fitting rubber sacs over their heads and then clamping the cords. Body temperatures were maintained during asphyxia (and during resuscitation in controls). Two minutes after time of last gasp (T.L.G.) resuscitation (clearing the airways, cardiac massage (CM) and artificial respiration with O_2) was begun. The experimental animals then were placed in a bath of circulating icewater (Temp. 0.0°—1.5° C) until breathing began or body temperature reached 25° C. Then they were dried and rewarmed on an electric hotplate at approx. 4° C per 10 min. Minimum body temperatures were between 17.2° C and 24° C. Acid-base determination and hematocrits were made before asphyxia, at 2, 10, 15—20, 30—40 min and on occasion later. The animals were in excellent condition at delivery (pH 7.32, buffer base 42, base excess —3.8 to —4.3, pCO_2 43, standard bicarbonate 19, and pO_2 30-36-mean values). When breathing was regular the infants were transferred to the nursery where they received intensive care during the first 12 h. At 100 h a neurological examination was made and then they were sacrificed by perfusion with 10% neutral formalin. After sectioning and staining, 11 areas were evaluated on a 0 to +++ scale for evidence of damage (double blind studies by R. E. M. and A. W. B.). Under these extreme conditions (= Apgar scores 0 or 1) the first effects of cooling (see IV. A) 1.) were not seen.

Cooling begun 2.5 min after T.L.G. resulted in delay of first breath, the stage of 5 breaths to 1 gasp, and the time when infants were transferred to the nursery. However, the brain studies showed that there were more than 5 times as much damage (as indicated by total numbers of pluses) in the brains of the controls as compared with the cooled animals. Animals for whom cooling was delayed for 4.5 min or more after T.L.G. showed increasing brain damage as time to the beginning of cooling increased. Thus, once irreversible damage has begun seconds are important.

These results disagree with the report of Daniel et al. (1966) that cooling failed to protect the brains of neonatal monkeys from asphyxial damage. However, their conclusions may be discounted since they studied only the brains of some of their cooled animals and none of their uncooled controls. Instead they compared these with brains of animals asphyxiated several years earlier (Dawes et al. 1964) whose body temperatures were not maintained during asphyxia and resuscitation. The current findings on monkeys agree with the demonstrated effects of hypothermia during asphyxia on a wide variety of neonates (Miller 1971).

References

[1] Dawes, G. S., Hibbard, E., Windle, W. F., J. Pediat. **65**, 801 (1964) — [2] Daniel, S. S., Dawes, G. S., James, L. S., Ross, B. B., Windle, W. F., J. Pediat. **68**, 45—53 (1966) — [3] Miller, J. A., Jr., Amer. J. Obstetr. Gynecol. **110**, 1125—1133 (1971)

Reprint from:

»ARZNEIMITTEL-FORSCHUNG«

(Drug Research)

Arzneim.-Forsch. (Drug Res.) 24, Nr. 6, 961—971 (1974)

Editio Cantor KG, Aulendorf i. W. (Western Germany)

IV. A) 5. Resuscitation of twenty neonates by hypothermia with acid-base studies on ten

By R. Cordey, R. Chiolero, and J. A. Miller, Jr.

Based on studies by Miller (cf. Miller 1971), infants have been cooled as a treatment for asphyxia neonatorum in several hospitals (Westin et al. 1962; Dunn and Miller 1969 and others), with uniformly good results reported. However, in none have acid-base studies been made.

Twenty neonates with low Apgar scores (average 2.8) after 5 min of resuscitation were cooled until the appearance of spontaneous respiration. The mean cooling time and lowest temperature was 4.8 min and 33° C, respectively. Their mean Apgar scores were 2.8 at the beginning of cooling and 7.1 at the end. All recovered. The rate of increase in Apgar scores during cooling was 4 times that during the first 5 min when the infants were resuscitated while warm.

In 10 infants acid-base determinations showed little improvement during the first 3 h in spite of the fact that in all but one case the clinical condition was good to excellent. By 24 h blood pH, P_{CO_2} and base excess had returned to normal. Thus, cooling was associated with greatly improved clinical condition without appreciably altering the acid-base status of the infants. Small doses of bicarbonate plus glucose given at the end of the cooling period improved the acid-base status slightly.

Follow-up studies on the 20 infants showed that with one exception all are normal, and free from evidence of cerebral lesions. The exceptional infant has a syndrome of malformations which appear unrelated to either asphyxia neonatorum or the hypothermic treatment.

In our service hypothermia has been used for treating thirty-five infants with refractory asphyxia pallida. There have been two deaths (5.7%) and only one case (2.9%) with neurological sequelae which might be attributed to the asphyxial insult. Thus, our results, using hypothermia with or without bicarbonate + glucose, compare favorably with those in which babies with low 5 min Apgar scores were treated with standard resuscitation methods (Drage and Berendes 1966).

References

[1] Dunn, J. M., Miller, J. A., Jr., Am. J. Obstet. Gynecol. **104**, 58—67 (1969) — [2] Miller, J. A., Jr., Am. J. Obstet. Gynecol. **110**, 1125—1133 (1971) — [3] Westin, B., Nyberg, R., Miller, J. A., Jr., Wedenberg, E., Acta Paed. Suppl. **139**, 1—80 (1962) — [4] Drage, K. S., Berendes, H., Pediat. Clin. N. Am. **13**, 635—643 (1966)

Jon W. Miller, M.D.
Daniel F. Danzl, M.D.
Donald M. Thomas, M.D.
Department of Emergency Medicine
University of Louisville
Louisville, KY

ABSTRACT

ACCIDENTAL HYPOTHERMIA: 103 CASES

Jon W. Miller, M.D.
Daniel F. Danzl, M.D.
Donald M. Thomas, M.D.
Department of Emergency Medicine
University of Louisville

We retrospectively reviewed 103 presentations (86 patients) of accidental hypothermia treated at the discretion of the emergency medicine staff and residents over an eight-year period. Rewarming treatment options included passive external, active external, and heated oxygen aerosol administered by mask or intubation.

The slopes of the rates of rewarming were statistically similar for passive external (0.86°C/Hr) and heated aerosol via mask (0.69°C/Hr). The rate of rewarming for active external methods was 1.06°C/Hr. Heated oxygen aerosol via intubation rewarmed the patient at a significantly greater rate than the passive external method (1.36°C/Hr) ($p < 0.01$).

The overall mortality rate for the series was 11.6%, but 47.8% if serious underlying disease was present. Individual mortality rates were 58% for active external (7/12), 10% for active core with a mask (1/10), 5.8% for passive external (3/52), and 3.6% for active core with an endotracheal tube (1/29). However, active core rewarming via intubation was selected more frequently with moderate and severe hypothermia ($p=.530$). The group of survivors had a higher mean arrival temperature (31.05°C) than the non-survivors (26.78°C) ($p < .001$).

Active core rewarming with heated aerosolized oxygen via endotracheal tube is a safe technique for the rapid rewarming of selected hypothermic patients. The arrival temperature and the presence of serious underlying disease appear to be major determinants of prognosis.

ACCIDENTAL HYPOTHERMIA: 103 CASES

Jon W. Miller, M.D.
Daniel F. Danzl, M.D.
Donald M. Thomas, M.D.

From the Department of Emergency Medicine, University of Louisville, Louisville, Kentucky.

INTRODUCTION

Hypothermia is defined as a core (tympanic, esophageal, or rectal) temperature less than 35°C (95°F). Accidental hypothermia is a spontaneous decrease in core temperature without intrinsic pre-optic anterior hypothalamic pathology.[1,2]

Multiple interacting variables may contribute to the development of accidental hypothermia via decreased heat production, increased heat loss, or direct thermoregulatory interference. Age, nutritional status, medications, intoxicants, previous CNS trauma or pathology, or exposure with conduction/convection/radiation/evaporation frequently are involved.[3,4] Therefore, no rigid prototypic "hypothermia protocol" can be developed.

A healthy patient may have physiologic compensatory mechanisms overwhelmed by exposure. Thermoregulation may be inefficient, impaired by acute or chronic pathology, or pharmacologically suppressed. The preexisting physiologic status is then in a dynamic state as the core temperature declines. Reasonable management must rely on accumulated reported experience while considering the patient's unique predisposing factors, the degree, and the duration of hypothermia.

Address for reprints: Jon W. Miller, M.D., University of Louisville School of Medicine, Department of Emergency Medicine, 323 E. Chestnut, Louisville, Kentucky 40202

MATERIALS AND METHODS

All hypothermic patients evaluated at the University of Louisville affiliated hospitals emergency departments from February 17, 1971 to February 15, 1979 were reviewed. Hypothermia was confirmed and monitored with a Yellow Springs Instruments[R] telethermometer model 431A electronic probe placed 5cm into the rectum.

Vital signs were obtained using a Doppler[R] if necessary and recorded on a flow sheet. Respirations were averaged over two minutes. Basic and advanced cardiac life support were initiated as indicated.

Contributing factors including pertinent cardiac, pulmonary, endocrine, or neurologic abnormalities were recorded.

All clothing was removed for the physical examination. The patient was insulated with blankets and placed on a cardiac monitor. Peripheral and central intravenous catheters were inserted as necessary and room temperature crystalloids administered.

Standard laboratory evaluation included an immediate Dextrostix,[R] CBC, SMA-18, amylase, prothrombin and partial thromboplastin times, and toxicologic screen. Cardiac enzymes, thyroid function studies, and cortisol levels were drawn on selected patients. Arterial blood gases were corrected for temperature.[5]

Electrocardiographic evaluation was obtained. Roentgenographic studies usually included skull, cervical spine and chest films.

Nasogastric intubation was performed unless the patient was alert with intact protective airway reflexes.

Indwelling foley catheters were inserted to obtain a urine specimen and monitor urinary output.

RESULTS

Eighty-six patients were involved in the 103 treatment episodes. Eight patients were admitted twice, one patient three times and one patient eight times. The mean age was 59.6 years with a standard deviation of 17.4 years. Average arrival temperature was 87.^{0}F with a standard deviation of 6.3^{0}F.

Forty of the one hundred and three cases (38.8%) were mildly hypothermic (95-90^{0}F), twenty-four (23.3%) were moderately hypothermic (90-86^{0}F) and thirty-nine (37.9%) were severely hypothermic ($<$86^{0}F). The mortality rates were 0.5%, 0.4% and 23.1% respectively.

Twenty-three of the cases (22.3%) had serious underlying organic disease resulting in eleven fatalities (47.8%). One fatality had no demonstrable disease. Mortality for the series was 11.7%.

Fifty-two of the cases (50.5%) were treated by Passive External Rewarming (PER), twelve (11.7%) by Active External Rewarming (AER), ten (9.6%) by Heated Oxygen Aerosol delivered by mask (HOA-M) and twenty-nine (28.2%) by Heated Oxygen Aerosol delivered by intubation (HOA-I) (Figure 1).

Table 1 displays the mortality for each of the four treatment methods. HOA-I has the lowest mortality (3.5%) and AER the highest (58.3%). Based on percentages the apparent differences in treatment efficacy are pronounced. It is not possible, however, to make a straight forward interpretation of these figures since patients were assigned through medical judgement rather than random chance. It is therefore possible that factors influencing mortality were confounded with treatment method. That is, patients with favorable survival profiles may have been assigned to HOA-I, and those with poorer survival factors to AER.

In order to deal with this problem, as well as the issue of true statistical "significance" of treatment differences, the data were submitted to stepwise multiple regression to "factor out" the effects of age, sex and presenting temperature before examining the residual effects of treatment method. While age and sex had no significant effect on mortality, presenting temperature did significantly ($p<.01$) influence mortality, with each additional degree in presenting temperature increasing survival chances by about two percent. After taking this relationship into account, a test of the effects of treatment indicated that AER was significantly ($p<.01$) more likely than other methods to be associated with mortality, while HOA-I was significantly ($p<.05$) less likely than the other methods to be associated with mortality. More specifically, estimates from the results suggest that survival is approximately 31 percent lower with AER and 18 percent higher with HOA-I (all other things being equal), when each is compared with its three respective alternatives.

The effect of treatment upon rate of rewarming was also examined within the same multiple regression framework described above. While sex had no effect upon the rate of rewarming, age did have a significant ($p<.01$) effect; each additional 10 years of age resulted in a rewarming rate than was approximately 0.3^{O}F per hour slower. Presenting temperature also significantly ($p<.01$) affected rate of rewarming; each additional degree in presenting temperature slows the rewarming rate by .02 degree per hours. Finally, after taking these effects into account, it was determinec that HOA-I resulted in a significantly ($p<.01$) faster rate of rewarming. The superiority of HOA-I over the average effect of the other three treatments is on the order of 0.74^{O}F per hour.

Laboratory analysis produced a variety of interesting results. Correction of pH for temperature reduced the incidence of acidosis to 24 of 70 samples (34.2%). Alkalosis was present in twelve patients (17.1%).

Sodium was decreased in eighteen cases (20.0%) and elevated in sixteen cases (17.8%) and decreased in sixteen cases (17.8%). Glucose was elevated in forty-one cases (48.2%) and decreased below 90 mg%/100 ml. in fourteen cases (16.4%). Amylase was elevated in 17 of 33 specimens (51.5%), cortisol was elevated in 8 of 11 measurements (72.7%).

Ethanol levels were measured above 100mg/100cc. in twenty-six patients (25.2%). Toxicologic screening yielded six drug ingestions in toxic ranges.

Patients were well oxygenated prior to any procedure. No induced dysrhythmias were monitored during tracheal or nasogastric intubation, or central venous or bladder catheterization.

Residents chose core rewarming (HOA-intubation) more frequently for lower temperatures; the study was not randomized (p=.530).

Sixty-two presentations were hospitalized.

FIGURE I

1) Passive (or physiologic) external rewarming with blankets at room temperature - PER

2) Active external rewarming with heating blankets or whirlpool - AER

3) Active core rewarming with heated oxygen aerosol via mask at 40°C - HOA-M.

4) Active core rewarming with heated oxygen aerosol via endotracheal or naso-tracheal tube at 40°C - HOA-I.

TABLE I

MORTALITY OUTCOMES FOR TREATMENT METHODS

	Number of Cases	Number of Deaths	Percentage of Deaths
PER	52	3	5.8%
AER	12	7	58.3%
HOA-M	10	1	10.0%
HOA-I	29	1	3.5%
TOTAL	103	12	11.7%

DISCUSSION

Passive external rewarming couples cessation of evaporation and convection with insulation against continued excessive heat loss. The patient is covered in an ambient temperature of at least 21.1^{0}C. This method has been advocated as the most physiologic approach for elderly patients who develop mild hypothermia over periods greater than 12 hours. It may be the only practical treatment in the field. A pre-requisite for success is the patient's ability to metabolically generate an "acceptable" rate of spontaneous rewarming. Peripheral vasoconstriction is maintained, diminishing the severity of the "rewarming collapse". This reduces core temperature afterdrop, rewarming shock, metabolic acidosis, and pulmonary edema, which can result from induced vasodilatation.[6]

Rewarming rates vary between 0.5 and 2.0^{0}C/Hr depending on the patient's physiologic status and age. The rate in the elderly should not exceed 0.55^{0}C/Hr if hypotension develops, but must be rapid enough to avoid prolonged periods of susceptibility to dysrhythmias.[6]

There were three deaths in 52 of our cases treated with PER, a mortality rate of 5.77%. This method rewarmed the patients at a significantly slower rate (0.86^{0}C/Hr) than HOA-intubation (1.36^{0}C/Hr). Although the mortality rates for these two methods were similar, the majority of the patients treated passively were mildly hypothermic. This group of patients did spontaneously rewarm at an acceptable rate. The three non-survivors had serious underlying diseases including sepsis and pneumonia.

Previously reported results with this method are in Table II.

TABLE II

PASSIVE EXTERNAL REWARMING (PER)

		Cases	PER	Survival	Success Rate
GREGORY[7]	1973 (1951-72)	201	121	67	55.4%
WEYMAN[8]	1974	39	7	7	100%
HUDSON[9]	1974	16	12	8	75%
O'KEEFFE[10]	1977	62	56	56	100%

Active rewarming, the addition of exogenous heat to the patient, is available by external or internal methods. Generally accepted factors necessitating active rewarming include cardio-vascular instability, certain cerebro-vascular accidents, or relative endocrinologic insufficiency (thyroid, adrenal, pituitary). Ethanol induced peripheral vasodilatation may also render the patient unable to generate sufficient endogenous heat.[6,11]

Active external rewarming can be accomplished by conduction of heat directly to the skin. Partial immersion in heated water or application of other heat sources have been successful.[12,13,14] The technique is uncomplicated. Generally, the rate of rewarming exceeds the spontaneous rate, but is slower than the core rewarming rate. Increased risk of core temperature "afterdrop", rewarming shock, and decreased ventricular fibrillation threshold secondary to myocardial thermal gradients have been reported.[6,7,15,16] Core temperature afterdrop was not prevented with mask inhalation rewarming in healthy mildly hypothermic patients experimentally.[17]

Thermal burns from blankets, and impaired patient access for monitoring and resuscitation when in water are considerations.[3,18] Healthy patients acutely hypothermic from immersion without pathophysiologic changes are optimal candidates for treatment with this method.

Our 12 cases treated with a thermal blanket rewarmed at 1.06^{o}C/Hr. The mortality rate was 58.3%. Of the seven deaths, six had serious underlying pathology.

Reported results of this method are noted in Table III.

TABLE III

ACTIVE EXTERNAL REWARMING (AER)

		Cases	AER	Survival	Success Rate
GREGORY[7]	1973 (1951-72)	201	73	29	39.7%
WEYMAN[8]	1974	39	32	24	75%
HUDSON[9]	1974	16	2	0	0%
SIEBKE[19]	1975	1	1	1	100%
CHINARD[20]	1978	2	1	1	100%

There are several methods of active core rewarming. Gastro-intestinal irrigation of the stomach or colon, peritoneal or hemodialysis, mediastinal irrigation, extracorporeal blood rewarming, heated intravenous fluids, and heated aerosolized oxygen inhalation are available. These techniques may decrease the incidence of rewarming collapse and dysrhythmias, especially below 30°C.[7,12,22,23,24] They require expertise, and have been reported to have associated morbidity.[25,26]

The inhalation of heated aerosolized oxygen has received recent attention.[21,23,27,28,29,30,31] The scanty experimental and clinical data available with this technique must be further subdivided. Those patients treated by mask rewarm at a slower rate than those patients intubated.

Lloyd demonstrated that a portable mask apparatus could deliver up to 30% of the heat production of a hypothermic patient, and Guild discussed the theoretical considerations at length.[29,32] However Hudson's calculations predict minimal heat gains with a mask.[33]

The mean rate of rewarming for our ten cases treated with HOA-mask was 0.69°C/Hr, inexplicably less than the rate for PER (0.86°C/Hr). The non-survivor was septic with a probable aspiration pneumonia.

The rewarming rate for our 29 cases treated with HOA-intubation was 1.36°C/Hr, significantly greater than PER ($p=.01$) with a similar mortality rate. However, the residents chose HOA-intubation more frequently for severely hypothermic presentations ($p=.530$). The non-survivor was septic.

We, like Ledingham,[34] noted no dysrhythmias during the intubation of pre-oxygenated patients. Translaryngeal anesthesia with 4% lidocaine was used as necessary. Cold induced bronchorrhea and depressed protective airway reflexes in the intoxicated or elderly could predispose to aspiration unless airway protection is provided.[35] No complications were attributed to this procedure.

Fisher calculated a "functional" value of hemoglobin, considering the effects of the shift of the oxyhemoglobin dissociation curve in hypothermic patients during cardiopulmonary bypass. The value was 4.2 gm/100ml blood. This, coupled with a decreased respiratory rate and tidal volume, suggest oxygen reserves are minimal despite decreased metabolic requirements.[36]

The results reported with active core rewarming are in Table IV.

TABLE IV

ACTIVE CORE REWARMING (ACR)

		CASES	ACR	METHOD	SURVIVAL	SUCCESS RATE
GREGORY[7]	1973 (1951-72)	201	7	1-inhalant 2-lavage 4-hematogenous	7	100%
SHANKS[23]	1973	1	1	heated IV plus intubation	1	100%
GROSSHEIM[37]	1973	4	4	peritoneal dialysis	4	100%
LLOYD[29]	1973	11	11	mask-heated	8	73%
TRUSCOTT[38]	1973	1	1	extra-corporeal circulation	1	100%
COUGHLIN[39]	1973	1	1	mediastinal irrigation	1	100%
DAY[40]	1974	1				
LLOYD[30]	1974	1	1	mask-heated	1	100%
HUDSON[3]	1974	16	2	1-peritoneal dial. 1-mask-heated	0 1	0% 100%
SHANKS[41]	1975	2	2	heated IV plus intubation	2	100%
WICKSTROM[42]	1976	3	3	Cardio-pulm byp.	2	67%
SOUNG[43]	1977	1	1	peritoneal dialy.	1	100%
PICKERING[44]	1977	1	1	peritoneal dialy.	1	100%
JOHNSON[45]	1977	1	1	AER plus periton. dialysis	1	100%
WOOD[46]	1977	1	1	AER plus heated IV	1	100%
BRISTOW[47]	1978	1	1	peritoneal dialy.	1	100%
JESSEN[48]	1978	3	3	peritoneal dialy.	2	67%
CHINARD[20]	1978	2	1	heated IV	1	100%

Interpretation and comparison of results to experimental data is difficult. Expecting the infamous Nazi experiments,[47] human experimentation on young volunteers has stopped at 34-35^{o}C. This is prior to the development of many significant physiologic changes. The subjects are healthy, while the majority of our patients are elderly, debilitated, and not acclimated.

Our temperature measurements were recorded rectally. A lag exists compared with esophageal or aural recordings which have other limitations.[6,17]

There are several factors which affected the probability of survival in our patients. These include as previously reported the absence of underlying disease, minimal depression of core temperature on arrival, and a rapid response to therapy.[4,8,9,10] Age did not correlate with arrival temperature or survival, although it did with the rate of rewarming. No consistent previously reported pH or electrolyte abnormalities were found.[50] As expected, the blood glucose and amylase were elevated in half the patients evaluated.[51,52] Hypoglycemia as a diagnostic aid to hypothermia or as a contributing cause was not noted.[53,54]

Prophylactic intracardiac pacing during rewarming was not necessary in our patients.[55]

No patients received steroids. Cortisol levels were obtained on eleven of our severely hypothermic patients, and elevated in eight. This was expected, since acute cold exposure stimulates cortisol secretion. Adrenal unresponsiveness to ACTH in hypothermia has been reported, thus the value of steroids is unknown.[56]

Active core rewarming with heated aerosolized oxygen via naso-tracheal tube is a safe technique for those patients who require rapid rewarming and airway protection.

REFERENCES

1. Duguid H, Simpson RG, Stowers JM: Accidental hypothermia. Lancet 2: 1213-1219, 1961.

2. Gale CC: Neuroendocrine aspects of thermoregulation. Annu Rev Physiol 30:641-710, 1968.

3. Reuler JB: Hypothermia: pathophysiology, clinical settings, and management. Ann Int Med 89: 519-527, 1978.

4. Whittle JL, Bates JH: Thermoregulatory failure secondary to acute illness. Arch Intern Med 139: 418-421, 1979.

5. Kelman GR, Nunn JF: Nomograms for correction of blood PO_2, PCO_2, pH, and base excess for time and temperature. J Appl Physiol 21: 1484-1490, 1966.

6. MacLean D, Emslie-Smith D: Accidental Hypothermia. Philadelphia, J B Lippincott Co., 1977.

7. Gregory RT, Doolittle WH: Accidental hypothermia. II. Clinical implications of experimental studies. Alaska Med 15:48-52, 1973.

8. Weyman AE, Greenbaum DM, Grace WJ: Accidental hypothermia in an alcoholic population. Am J Med 56:13-21, 1974.

9. Hudson LD, Conn RD: Accidental hypothermia: Associated diagnoses and prognosis in a common problem. JAMA 227: 37-40, 1974.

10. O'Keeffe KM: Accidental hypothermia: A review of 62 cases. JACEP 6: 491-496, 1977.

11. Freinkel N, Singer DL, Arky RA, et al: Alcohol hypoglycemia: J Clin Invest 42:1122-1133, 1963.

12. Fernandez JR, O'Rourke RA, Ewy GA: Rapid active rewarming in accidental hypothermia. JAMA 212:153-155, 1970.

13. Ledingham IM, Mone JG: Treatment after exposure to cold. Lancet 1:534-535, 1972.

14. Meriwether WD, Goodman RM: Severe accidental hypothermia with survival after rapid rewarming. Am J Med 53: 505-510, 1972.

15. Lloyd EL, Mitchell B: Factors affecting the onset of ventricular fibrillation in hypothermia. Lancet 2: 1294-1296, 1974.

16. Mouritzen CV, Anderson MN: Myocardial temperature gradients and ventricular fibrillation during hypothermia. J Thorac Cardiovasc Surg 49: 937-944, 1965.

17. Marcus P: Laboratory comparison of techniques for rewarming hypothermic casualties. Aviat Space Environ Med 49: 692-697, 1978.

18. Crino MH, Nagel EL: Thermal burns caused by warming blankets in the operating room. Anesthesiology 29: 149-150, 1968.

19. Siebke H. Breivik H, Rod T, et al: Survival after 40 minutes submersion without cerebral sequelae. Lancet 1: 1275-1277, 1975.

20. Chinard FP: Accidental Hypothermia-A brief review. J Med Soc NJ 75: 610-614, 1978.

21. Hayward JS, Steinman AM: Accidental hypothermia: An experimental study of inhalation rewarming. Aviat Space Environ Med 46: 1236-1240, 1975.

22. Lloyd EL, Mitchell B, Williams JT: Rewarming from immersion hypothermia: a comparison of three techniques. Resuscitation 5:5-18, 1976.

23. Shanks CA, Marsh HM: Simple core rewarming in accidental hypothermia. Br J Anaesth 45: 522-525, 1973.

24. Lewis Practice of Surgery 1978 Clinical Hypothermia, Accidental Hypothermia and Frostbite. Patton and Brantigan.

25. Welton DE, Mattox KL, Miller RR, et al: Treatment of profound hypothermia JAMA 240: 2291-2292, 1978.

26. O'Keefe, unpublished, personal correspondence.

27. Collis ML, Steinman AM, Chaney RD: Accidental hypothermia: an experimental study of practical rewarming methods. Aviat Space Environ Med 48: 625-632, 1977.

28. Lloyd EL, Conliffe NA, Orgel H, et al: Accidental hypothermia: an apparatus for central rewarming as a first aid measure, Scott Med J 17: 83-91, 1972.

29. Lloyd EL: Accidental hypothermia treated by central rewarming through the airway. Br J Anaesthesia 45: 41-48, 1973.

30. Lloyd EL: Accidental hypothermia: central rewarming in the field. Br Med J 4: 717, 1974.

31. Sereda WM: Treatment of hypothermia. Can Med Assoc J 112: 931-932, 1975.

32. Guild WJ: Central body rewarming for hypothermia-Possibilities, Problems, and Progress. J Roy Naval Medica 62: 173-175, 1976.

33. Hudson MC, Robinson GJ: Treatment of accidental hypothermia, Med J of Austral 1:410-411, 1973.

34. Ledingham IM: Accidental hypothermia. Lancet 11: 391, 1978.

35. Pontoppidan H, Beecher HK: Progressive loss of protective reflexes in the airway with the advance of age. JAMA 174: 2209-2213, 1960.

36. Fisher A, Foex P, Emerson PM: Oxygen availability during hypothermic cardiopulmonary bypass. Crit Care Med 5: 154-158, 1977.

37. Grossheim RL: Hypothermia and frostbite treated with peritoneal dialysis. Alaska Med 15: 53-33, 1973.

38. Truscott DG, Firor WB, Clein LF: Accidental profound hypothermia. Successful resuscitation by core rewarming and assisted circulation. Arch Surg 106: 216-218, 1973.

39. Coughlin F: Heart-warming procedure. NEJM 288: 326, 1973.

40. Day EA, Morgan EF: Accidental hypothermia: Report of a case following alcohol and barbiturate overdose. Anaesth Intensive Care 2: 73-77, 1974.

41. Shanks CA: Heat gain in the treatment of accidental hypothermia. Med J Aust 2: 346-349, 1975.

42. Wickstrom P, Ruiz E, Lilja GP, et al: Accidental hypothermia. Core rewarming with partial bypass. Am J Surg 131: 622-625, 1976.

43. Soung LS, Swank L, Ing TS, et al: Treatment of accidental hypothermia with peritoneal dialysis. Can Med Assoc J 117: 1415-1416, 1977.

44. Pickering BG, Bristow GK, Craig DB: Case History number 97: Core rewarming by peritoneal irrigation in accidental hypothermia with cardiac arrest. Anesth Analg (Cleve) 56: 574, 1977.

45. Johnson LA: Accidental hypothermia: Peritoneal dialysis. JACEP 6: 556-561, 1977.

46. Wood V: Case of hypothermia. Can Med Assoc J 117: 16-21, 1977.

47. Bristow G: Treatment of accidental hypothermia with peritoneal dialysis. Can Med Assoc J 118: 768-769, 1978.

48. Jessen K, Hagelsten JO: Peritoneal dialysis in the treatment of profound accidental hypothermia. Aviat Space Environ Med 49: 426-429, 1978.

49. Alexander L: Combined Intelligence Objectives Subcommittee, item 24, file no. 26-37, 1946.

50. McMillan IK, Melrose DG, Churchill-Davidson HC, et al: Hypothermia: some observations on blood gas and electrolyte changes during surface cooling. Ann R Coll Surg Engl 16: 186-194, 1955.

51 Curry DL, Curry KP: Hypothermia and insulin secretion. Endocrinology 87: 750-755, 1970.

52. Read AE, Emslie-Smith D, Gough KR, et al: Pancreatitis and accidental hypothermia. Lancet 2: 1219-1221, 1961.

53. Andrew PJ: Treatment accidental hypothermia. Br Med J 2: 1641, 1978.

54. Jaffe N: Hypothermia-a diagnostic aid to hypoglycemia. S Afa Med J 40: 569-572, 1966.

55. Br Med J 6149: 1383-1384, 1978.

56. Felicetta JV: False diagnosis of decreased adrenal reserve in the hypothermic subject (abstract) Clin Res 27: 20A, 1979.

Dr. William J. Mills, Jr., M.D.
742 K Street
Anchorage, Alaska

Dr. Mills is a world recognized authority on cold injuries and their treatment, primarily of frostbite and hypothermia. He has published numerous articles on the subjects in "Alaska Medicine" , "Current Therapy", "Patient Care," and is the author of the "Frostbite" chapter of the Encyclopaedia Britannica. Currently he heads a special cold injury clinic in Anchorage and is conducting research for the U.S. Navy.

Dr. William Mills, M.D.
742 K Street
Anchorage, Alaska

ABSTRACT

Accidental Hypothermia:

It is apparent that much controversy exists regarding the most effective and the least hazardous method of warming the victim of accidental hypothermia.

The elements of warming methods in controversy include "peripheral" as compared to "core warming," the development of reported phenomenon of afterdrop and its significance, and the etiology of cardiac irregularities, attributed to certain warming methods.

Fifty-one Alaskan case histories are studied. The temperature range as measured by both low reading and standard "clinical" thermometers was 96°F (36°C) to 70°F (23°C). The calculated range was from 93°F (34°C) to 65-70°F (19-22°C). Nineteen of the actual recorded initial temperatures (rectal) read 85°F (30°C) or lower, and 25 of the estimated values were in that range. The youngest victim was 24 hours old, the oldest 90 years. The 51 patients were warmed by six methods. These were:

I. Uncontrolled spontaneous warming, K-thermia pad, warm blankets, dry heat.

II. Spontaneous warming, controlled.

III. Rapid re-warming, warm water bath or whirlpool (external wet heat), uncontrolled.

IV. Rapid re-warming, warm water bath or whirlpool (external wet heat), controlled (90-106°F) 32-42°C).

V. Pertoneal dialysis, controlled.

VI. Gradual warming with warm fluids (I.V.) and the use of anesthetic breathing apparatus in surgery.

Four of the 51 patients died. In each case, the warming methods did not include full physical and chemical body monitoring, or control, and treatment of the underlying abnormalities of the hypothermic state.

The cardia irregularities are reported, and include four patients in ventricular fibrillation, 12 cases of atrial fibrillation, 24 patients with tacchycardia, or minor arrhythmias.

Most of the patients were dehydrated, demonstrated mild to severe acidosis, and after (and during) warming demonstrated evidence of hyperkalemia. The degree of awareness and consciousness is correlated with the level of hypothermia in both adults and children. It is noted that the optimum solution to the problem of hypothermia is dependent upon the time permitted to solve the complex metabolic and cardiac and chemical changes

as they appear. More time is obviously given by slower, spontaneous warming methods--three to eight hours-- and less rapid warming methods--thirty minutes to one and one half to two hours. Under controlled warming good results were demonstrated by all methods. However, the patient with associated freezing injury appeared to obtain better extremity anatomical and functional result when rapid thawing methods were utilzed.

The major immediate problems presented by the hypothermic patient included:

1. Loss of homeothermic control with the concomitant cerebral cardio pulmonary, renal and enzymatic dysfunction associated with low temperatures, especially under 85°F (30°C).

2. Metabolic acidosis

3. Dehydration and hypovolemia

If found alive by rescue personnel, the victim may be essentially in a "metabolic icebox," in a mid-lethal state, so that further exposure will result in death from vital organ cooling, and warming may, if uncontrolled, result in death because of uncorrected acidosis, and the sudden effect of released metabolities, increased serum potassium levels resulting in cardiac excitation and hypovolemic shock.

The "cold heart" is in a fragile state, and aggressive manipulation in CPR, or efforts to cardiovert a heart not metabolically prepared to accept such stimulation, may result in irreversible cardiac failure.

The major immediate solution appears to demand:

1. Immediate control of the patients rescue environment and immediate organization of the rescue and treating personnel.

2. A planned approach to the problem.

3. Careful patient handling, the establishment of a patent airway, through evaluation of the patient, and early monitoring of temperature, EKG, and urinary output.

4. Initiation, as soon as possible, of I.V. leads including central venous pressure, and evaluation of Ph, blood gases and electrolytes, and repetitive monitoring of these values.

5. Correction of hypovolemia utilizing glucose and H_2O solutions, or physiological saline, and once baseline blood gas and electrolyte values are obtained, sodium bicarbonate given for correction of acidosis and mannitol or lasix to develop renal profusion. Serum glucose values are obtained. Fluids given should be warmed to physiological levels. Do not assume acid-base values. The patient may be in a state of alkalosis.

Once the patient is under total system control, warming by the method best suited to the emergency area or hospital facility, is utilized. Whatever the method, the purpose of the treatment begun is to:

1. Restore a normal blood volume and overcome dehydration if present.

2. Restore the acid-base balance.

3. Restore a proper electrolyte balance and avoid a post-warming hyperkalemic state.

4. Encourage a normal renal flow.

5. Avoid serious cardiac arrhythmias and arrest of the heart.

6. Control respiration with an adequate airway, intubation if necessary, utilizing warm inspired air, an adequate respirator with temperature and humidity control, or the use of an anesthetic machine if total respiratory control is required.

The evaluation of this group of patients appear to indicate that spontaneous controlled warming of the trunk and head, with rapid rewarming of frozen extremities, and the use of a mechanical respirator or anesthetic gas machine, may prove to be the safest method of warming, allowing satisfactory time for continuous correction of any imbalance, as the patient approaches a normothermic state.

H. F. Nicodemus, M.D.
R. D. Chaney, M.D.
R. Herold, M.D.
Casualty Care Program Center
Naval Medical Research Institute
Bethesda, Maryland 20014

ABSTRACT

INOTROPES DURING HYPOTHERMIA AND RAPID REWARMING

H. F. Nicodemus, M.D.
R. D. Chaney, M.D.
R. Herold, M.D.
Casualty Care Program Center
Naval Medical Research Institute
Bethesda, Maryland 20014

Inotropes are drugs that influence myocardial contactility. Although effective during resuscitation at normothermia, their use is discouraged during hypothermia. The fear is that negative inotropes may further reduce an already decreased cardiac output leading to asystole; that the positive inotropes may precipitate ventricular fibrillation in the irritable heart. Electrical cardioversion and ventricular pacing are rarely successful during hypothermia.

The hemodynamic effects of propranolol, lidocaine and dopamine were studied in anesthetized, mechanically ventilated dogs, cooled to 25°C with a veno-venous shunt through a heat exchanger. After 1 hour at 25°C, in preparation for rewarming, the shunt was converted to an arterio-venous shunt which remained functioning until the study was completed. Before rewarming, each group of 8 dogs received the drugs intravenously, thus: Group 1 - 10 ml saline as control; Group 2 - propranolol 0.3 mg/kg; Group 3 - lidocaine, 50 mg initially followed with continuous infusion of 40-50 μg/kg/min; Group 4 - dopamine infusion at 12 μg/kg/min; and Group 5 - lidocaine as in Group 3 and dopamine as in Group 4. For the dopamine treated groups, 2 minutes of infusion was allowed, in all other groups 5 minutes elapsed after injection before hemodynamic data were recorded. The hemodynamic data were collected at 25°, 30° and 37°C.

The findings are: (i) hypothermia impairs cardiovascular function; (ii) lidocaine and propranolol have minimal hemodynamic effects during hypothermia, lidocaine being physiologically more desirable than propanol; (iii) dopamine, alone or combined with lidocaine reverses the cardiovascular depression from hypothermia, the improvement equivalent to rewarming by as much as 5°C; and (iv) at the completion of rewarming, cardiovascular recovery is more complete with dopamine/lidocaine compared to untreated and propranolol treated animals. Based on these findings, these inotropic agents are safe adjuncts to resuscitation during hypothermia.

Inotropes During Hypothermia and Rapid Rewarming

H. E. Nicodemus, M.D., R. D. Chaney, M.D. and R. Herold, M.D.

Casualty Care Program Center
Naval Medical Research Institute
Bethesda, Maryland 20014

From the Naval Medical Research and Development Command, NNMC, Department of the Navy, Research Task Number M0095PN001.1022

The experiments reported herein were conducted according to the principles set forth in the "Guide for the Care and Use of Laboratory Animals", Institute of Laboratory Animals Resources, National Research Council, DHEW, Pub. No. (NIH) 74-23.

Running Title: Inotropes During Hypothermia

Inotropes are drugs frequently used during resuscitation to influence myocardial contractility, some to control dysrhythmia and others to augment cardiac output. Based on little or no experimental evidence, their uses during hypothermia have been limited and in some instances discouraged[18]. On one hand, although effective in the control of ventricular dysrhythmia at normal temperature, the negative inotropic agents, lidocaine and propranolol, may have deleterious effects in a hypothermic patient. These drugs may further decrease and already depressed cardiac output (CO) and may lead to asystole. On the other hand, when increased CO is needed, positive inotropic agents are seldom used because they may precipitate ventricular fibrillation. Both asystole and ventricular fibrillation are difficult to manage, either of which may be the terminal event in profound hypothermia[6,19,24]. This study was specifically designed to test and compare the hemodynamic effects of two negative inotropic agents, lidocaine and propranolol; and a positive inotropic agent, dopamine, in acutely hypothermic dog model. Dysrhythmia is not a prerequisite to the study. We employed a surgical approach to rapid core rewarming, an arterio-venous shunt through a heat exchanger, because of its efficiency and simplicity[11]. Since the limit of hypothermia below which human survival is unlikely is 24-26° C, we choosed to test the drugs at 25° C[13,15].

Methods and Materials:

Male mongrel dogs (20-25 kg), anesthetized with pentobarbital (30 mg iv), mechanically ventilated with oxygen to $PaCO_2$ of 30-35 torr, were surgically prepared for the study. The ventilation was not readjusted for the temperature and carbon dioxide production.

The method of cooling was similar to that described by Warner[25], and rewarming similar to that described by Gregory[11]. Briefly, after anticoagulation (heparin 1 mg/kg iv), blood was pumped from a femoral vein, passed through a heat exchanger and returned to the superior vena cava via a canula (Bardic, 20-22 F) in the external jugular vein. For rewarming, the veno-venous shunt was clamped and an arterio-venous shunt opened to bring blood from femoral artery back to the superior vena cava through the heat exchanger, Fig. 1. Cooling the dog took about 1 hour followed by stabilization at 25°C for another hour. The temperature was assumed to have been reached if the difference between esophageal and rectal temperatures was no greater than 2°C. The arterio-venous (A-V) shunt had been functional for at least 5 minutes before baseline hemodynamic measurements were taken. With a functional A-V shunt, the drugs were administered intravenously in the following manner:

Group 1 - 10 ml saline as control (n = 8 in each group)

Group 2 - propranolol 0.3 mg/kg

Group 3 - lidocaine, 50 mg initially followed with continuous infusion, 40-50 μg/kg/min throughout the rewarming period

Group 4 - dopamine, 12 μg/kg/min, intermittent infusion.

Group 5 - lidocaine as in Group 3 and dopamine as in Group 4.

In the dopamine treated animals, 2 minutes of infusion was allowed, in the rest of the groups, 5 minutes elapsed after the administration of the drug before the data were collected. Rewarming was instituted after the initial response to the drugs were recorded.

The temperature of the blood during rewarming did not exceed 42°C. The pressures and the average of duplicate CO determinations by dye dilution technique were taken and recorded at 25°, 30° and 37°C. A third CO determination was taken if the first two CO curves were widely desimilar. The value of the two most similar curves were averaged and recorded. Balanced electrolyte solution was used to prime the heat exchanger in order to prevent broad variations in serum potassium[11]. Each dog received approximately the same volume of balanced electrolyte solution to flush in the dye for the determination of CO and to replace the visually estimated blood loss during the preparation of the vessels. Hematocrits were monitored at various points during the experiment. A five unit change in the hematocrit required recalibration of the densitometer. When the esophageal and rectal temperatures reached 37°C, rewarming was considered complete. All the blood from the system was returned to the animals and the anticoagulant was reversed with protamine (25 mg iv). The dog was sacrificed 24 hours following the completion of each experiment.

Arterial blood gases, serum electrolytes and blood glucose were also determined before cooling, at 25°C and at the completion of rewarming. Although no intergroup differences were expected[8,22], these parameters were monitored to insure that the individual changes in cardiovascualr function could not be attributed solely to changes in blood chemistry and pH. The means of the cardiovascular data are graphically presented in figure 2. Those that visually appeared different were subjected to t-test for unpaired samples. A probability of .05 was accepted as significant.

Results:

Cardiac Output (CO): The rapid core rewarming employed in this model reversed cardiac depression in the control animals in a step-ladder fashion, from 30% of CO of normothermic animals noted at 25°C to 70% at the completion of the study. As the dogs rewarmed, the increase in CO in the propranolol and lidocaine treated animals, Groups 2 and 3, were not different from the control. However, at the completion of rewarming, the CO in the lidocaine group recovered to 98% of the normothermic control value. Treatment with dopamine, singly or in combination with lidocaine (Groups 4 and 5) caused significant improvement in CO equivalent to that noted with a 5°C rewarming in Groups 1, 2 and 3. At 30°C, mean CO in Group 4 exceeded those of the completely rewarmed Groups 1 and 2, while in Group 5, combined therapy with dopamine and lidocaine resulted in complete recovery of the CO. Lidocaine and dopamine, singly or in combination have a sustained effect on CO up to the termination of the study, well within limits found in normothermic animals.

Stroke Volume (SV) and Heart Rate (HR): These two parameters are closely related so that at constant CO, they have an inverse relationship, i e, increased HR means decreased SV. In this study, HR and SV were the determinants of CO. Rewarming increased both HR and SV toward normothermic level. At 25°C, the increased SV in Groups 4 and 5 (Group 5 vs control, p .001) werelargely responsible for the higher CO. Dopamine at 25° C increased HR more than seen in any group (p .01).

HR appeared most sensitive to rewarming, almost complete recovery to normothermic values in all the groups at 30°C. In Groups 4 and 5, rewarming from 25-30° C increased SV (p .02) significantly, a level even higher than the normothermic value. At the conclusion of rewarming, SV in all groups were fully recovered seemingly unaffected by the drugs.

Mean Arterial Blood Pressure (MABP): Rapid rewarming increased MABP in all animals. At 25°C, dopamine increased MABP to normothermic level, significantly higher than any MABP at the same temperature (p .05). A 5°C rewarming coupled with dopamine therapy in Groups 4 and 5 caused significantly higher MABP than noted in Groups 1, 2 and 3. No intergroup differences were noted in the MABP at the completion of the experiment.

Pulmonary Arterial Wedge Pressure (PAWP): With hypothermia, PAWP fell to 50% in the control animals after rewarming. Presence of drugs made the response unpredictable; lidocaine tended to cause the highest PAWP although not significantly different from all the rest at anyone temperature. Propranolol caused the same directional change as control while dopamine alone seemed to stabilize PAWP against wide fluctuations.

Discussion:

We hypothesized that the negative inotropic agents might cause further depression of an already depressed cardiovascular state and that positive inotropic agents might increase myocardial irritability leading to ventricular fibrillation. Our experiments did not bear these out. The important findings may be summarized, thus: (i) hypothermia in this model impaired cardiovascular function; (ii) lidocaine and propranolol caused minimal changes in cardiovascular function, lidocaine having a physiologically more desirable effect than propranolol; (iii) when administered at 25° C, dopamine alone or in combination with lidocaine reversed the cardiovascular depression, the improvement being equivalent to rewarming by as much as 5°C; and (iv) at the completion of rewarming, cardiovascular recovery was more complete when the animals were treated with dopamine and lidocaine, either singly or combined, unlike the untreated or propranolol treated animals where recovery is incomplete.

Hypothermia caused depression of cardiovascular function in this model similar to the depression previously reported by others [5,6,11,21]. Rewarming from 25°C, there is a direct relationship between temperature and cardiovascular parameters except for vascular resistances which varied inversely with the temperature. Similar to those noted by Gregory et al[11], Patton et al[21], and others[14], rapid core rewarming in our model reversed all the cardiovascular effects of hypothermia, albeit at a slower pace in the absence of drug therapy. Gregory et al also reported an incomplete recovery at the end of rewarming although further improvement of CO occurred 12 hours later.

Cardiovascular reflexes, Starling phenomenon as well as adrenergic responses to catecholamines are readily recognizable and are more predictably modified by drugs during normothermia. However, there maybe less predictability in the direction as well as magnitude of hemodynamic responses during hypothermia. The negative inotropes showed surprisingly little hemodynamic effects. Lidocaine at normal body temperature is known to cause arteriolar dilatation[1] and mild pulmonary vasoconstriction[17]. Other than an increased

PAWP, insignificant in this study, there is little to suggest peripheral vascular effect of lidocaine. Propranolol also showed minimal beta blocking property both on the heart and on the peri-pehral vasculature. Reduced HR, a prominent sign of beta adrenergic blockade at normothermia, was transient, remaining sensitive to re-warming despite the large dose of propranolol administered at 25°C. The vascular effects of dopamine at the dose infused suggest mild vasodilatation of resistance vessels[10] since increased SV and CO had little effect on the MABP.

The minimal effect of the negative inotropes on CO is most surprising of all. An explanation for such an effect remains specu-lative, the possibility of adrenoceptor interconversion. Proponents of the theory aver that beta adrenoceptors become less specific during hypothermia, that the beta adrenoceptors become responsive to alpha agonists as well, perhaps a cellular adaptation to low meta-bolic state. Whether there is an actual change in configuration or only a change in receptor sensitivity is presently unclear[23]. In our study, CO remained unchanged after administration of propranolol as though the drug has no beta blocking effect, or that there were fewer functional beta receptors, or that the existing CO is not at all under the influence of beta adrenergic mechanism. No proof for any of these possibilities could be obtained from the data.

At the infusion rate of dopamine, no increase in ventricular irritability was noted, however, the increased HR was not at all unexpected since dopamine is known to increase HR[10]. Angelakos and Daniels[2] reported that dopamine at 10μg/kg/min, as well as norepinephrine lower to 12°C the temperature at which ventricular fibrillation occurs, in contrast, fibrillation occurs at 21°C with epinephrine. The stability of cardiac rhythm with dopamine or norepinephrine as well as other amines[7] could at least in part be explained on the basis of adrenoceptor interconversion. If the receptors are responsive to both alpha and beta agonists, then dopamine, (a direct precursor of norepinephrine) and the other alpha adrenergic amines could bind the beta receptors. When occupied, the receptors then become unavailable to the process that triggers ventricular fibrillation. Catecholamines, notably epinephrine are known to increase during hypothermia[25], and ventricular fibrillation generally coincides with the increased epinephrine level[4].

Covino and Beavers have shown increased myocardial contractility at low temperatures, they claim, a mechanism that is separate from the Starling phenomenon, or from the release of endogenous catecholamines[8]. Badeer et al claim an improvement in myocardial efficiency with hypothermia as evidenced by increased work without accompanying increase in oxygen consumption[3] It appears that dopamine, with or without lidocaine augments the effects of cold as shown by increased SV to levels much higher than seen during normothermia. Dopamine at 12μg/kg/min did not elicit similar effects at the completion of rewarming.

Induced hypothermia in the dog under controlled conditions is by no means similar to accidental hypothermia in man. We would, for example, hesitate to introduce a Swan-Ganz catheter into hypothermic patients for fear that the procedure may trigger ventricular fibrillation. However, others have inserted the cathether into the pulmonary artery of victims of accidental hypothermia without complication. The same investigators have also used isoproterenol during rewarming without inducing ventricular fibrillation[12]. Admittedly the temperature of their patients are above 30°C,outside the critical range for fibrillation.

The use of pharmacologic agents as adjuncts to rewarming have sound rationale. Prevention of fibrillation is logical because electrical cardioversion is difficult in a cold patient. In addition, if the cardiac output could be augmented pharmacologically, rewarming by any means becomes more efficient. Since there are evidence that lidocaine and dopamine, as well as other adrenergic amines could stabilize the cardiac rhythm, then they are indeed logical inotropes to use during resuscitation. The added benefit from dopamine maybe its splanchnic and renal vasodailating property[10] which will virtually assure good urine output, renal shut-down after all is a common complication of hypothermia[16, 20]. Based on the findings in the dog, propranolol, lidocaine and dopamine ought to be safe adjuncts to resuscitation in hypothermic patients.

ACKNOWLEDGEMENT: The authors wish to thank the crew and technicians of the Division of Experimental Surgery and its supporting laboratory for their assistance in this project.

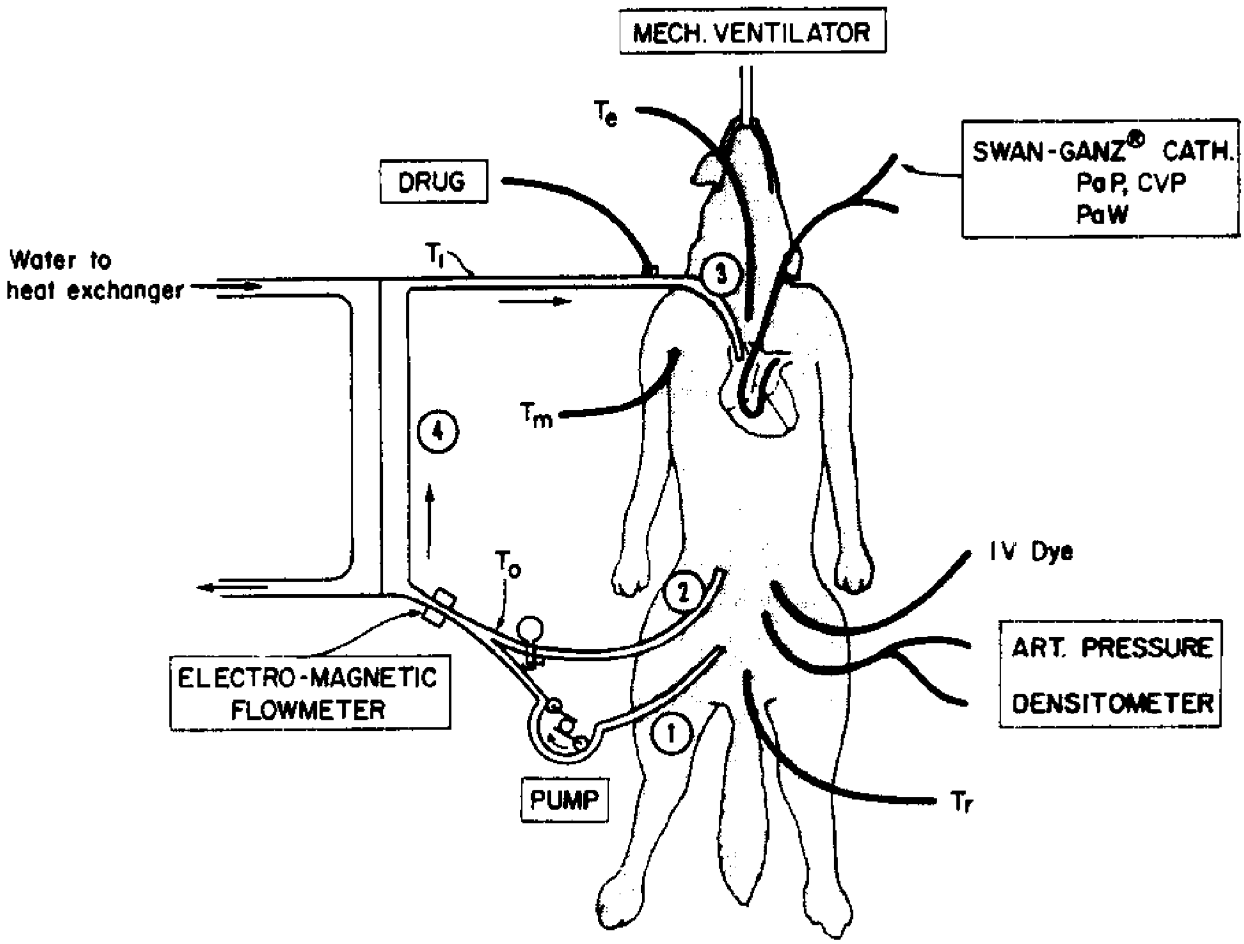


Figure 1. Schenatic diagram of veno-venous cooling and arterio-venous rewarming with the use of a heat exchanger.

Legend: 1 - femoral venous catheter

2 - femoral arterial catheter

3 - external jugular catheter

4 - heat exchanger

Te esophageal temperature probe

Ti temperature, inflowing blood

To temperature, outflowing blood

Tm temperature, triceps muscle

Tr temperature, rectal

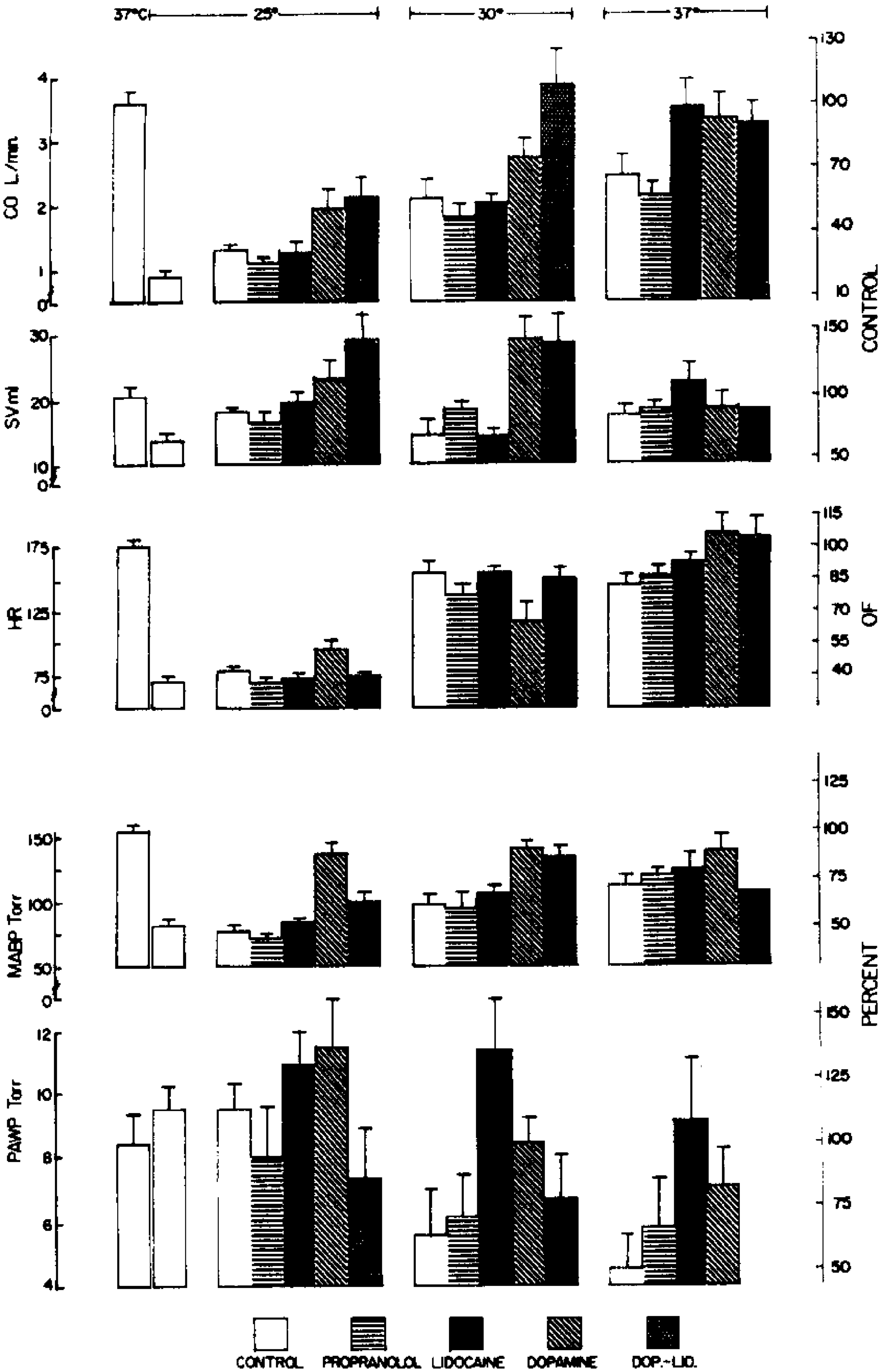


Figure 2. Hemodynamic changes during hypothermia, rewarming and the effects of inotropic agents.

References

1. Altura BM: Evaluation of neurohumoral substances in local regulation of blood flow. Am J Physiol 212:1447-1454, 1967.

2. Angelakos ET, and Daniels JB: Effect of catecholamine infusion on lethal hypothermic temperatures in dogs. J Appl Physiol 26(2):194-196, 1969.

3. Badeer H, and Khachadurian A: Role of bradycardia and cold per se in increasing mechanical efficiency of hypothermic heart. Am J Physiol 192(2):331-334, 1958.

4. Bennett CR, Smookler HH, and Buckley JP: Prevention of ventricular fibrillation during induced hypothermia by N,N-diisopropyl-N'-diethyl aminoethyl urea (P-286). J Pharmacol Exp Ther 159:115-122, 1968.

5. Bigelow WG, Lindsay WK, and Greenwood WF: Hypothermia: Its possible role in cardiac surgery: An investigation of factors governing survival in dogs at low body temperatures. Ann Surg 132:849-866, 1950.

6. Blair E: Generalized hypothermia. Fed Proc 28(4):1456-1462, 1969.

7. Cotten MdeV, and Brown TG, Jr: Effects of pressor amines and ouabain on the heart and blood pressure during hypothermia. J Pharmacol Exp Ther 121:319-329, 1957.

8. Covino BG, and Hegnauer AH: Electrolytes and pH changes in relation to hypothermic ventricular fibrillation. Circ Res 3:575-580, 1955.

9. Covino BG, and Beavers WR: Changes in cardiac contractility during hypothermia. Am J Physiol 195:433-436, 1958.

10. Goldberg LI: Cardiovascular and renal actions of dopamine: Potential clinical applications. Pharmacol Rev 24(1):1-29, 1972.

11. Gregory RT, Patton JF, and McFadden TT: Cardiovascular effects of A-V shunt rewarming following experimental hypothermia. Surg 73:561-571, 1973.

12. Harari A, Regnier B, Rapin M, Lemaire F, and LeGall JR: Haemodynamic study of prolonged deep accidental hypothermia. Europ J Intensive Care Medicine 1:65-70, 1975.

13. Hegnauer AH; Lethal hypothermic temperatures for dogs and man. Ann N Y Acad Sci 80(2):315-319, 1958

14. Hegnauer AH, Flynn J, and D'Amato H. Cardiac physiology in dog during rewarming for deep hypothermia. Am J Physiol 167:69-75, 1951.

15. Hervey GR: The physiology of cold/wet survival. J Royal Naval Medical Service 58(Winter):161-170, 1972.

16. Hudson LD, and Conn RD: Accidental hypothermia: Associated diagnoses and prognosis in a common problem. JAMA 227:37-40, 1974.

17. Hyman AL: Effects of lidocaine, hexamethonium and beta blocking agents on the pulmonary veins in intact dogs. J Pharmacol Exp Ther 174:489-499, 1970.

18. Johnson LA: Accidental hypothermia: Peritoneal dialysis. JACEP 6:556-561, 1977.

19. Kirby C, Jensen JM, and Johnson J: Defibrillation of the under hypothermic conditions. Arch Surg 68:663-665, 1954.

20. Krugelberg J, Schuller H, Berg B, and Kallum B: Treatment of accidental hypothermia. Scand J thor Cardiovasc Surg 1:142-146, 1967.

21. Patton JF, and Doolittle WH: Core rewarming by peritoneal dialysis following induced hypothermia in the dog. J Appl Physiol 33:800-804, 1972.

22. Rehder K, Kirklin JW, MacCarthy CS, and Theye RA: Physiologic studies following profound hypothermia and circulatory arrest for treatment of intracranial aneurysm. Ann Surg 156:882-889, 1961.

23. Sympossium: Drug and Hypothermia. Fed Proc 36:2569-2583, 1977.

24. Towne WD, Geiss WP, Yanes HH, and Rahimtoola SH: Intractable ventricular fibrillation associated with profound hypothermia _successful treatment with partial cardiopulmonary by-pass. N Engl J Med 287:1135-1136, 1972.

25. Warner WA, Anton AH, Andersen TW, and Swofford LJ: Ventricular fibrillation and catecholamine response during profound hypothermia in dogs. Anesthesiology 33:43-51, 1971.

Dr. Dennis Nixon, PhD.
Assistant Professor of Marine Affairs
University of Rhode Island
Kingston, Rhode Island 02881

Dr. Nixon is a member of the Rhode Island Bar Association, a practicing lawyer for coastal and marine clients, and teaches graduate courses in the Master of Marine Affairs Program at URI.

LEGAL ASPECTS OF HYPOTHERMIA TRAINING

Dennis Nixon*

Prepared for the International Hypothermia Conference and Workshop, University of Rhode Island, January 23-27, 1980

INTRODUCTION

It is a sign of our times that a conference examining an exciting new field of emergency medicine must also include an analysis of potential legal problems. But just as having the proper equipment used correctly can prevent hypothermia, knowledge of the legal issues involved in this field can prevent the chilling effect of a lawsuit. In law as well as in medicine, prevention is the key factor.

This paper is an effort to provide basic legal information for three client groups represented at this conference: organizations taking an active role in hypothermia training; individuals taking part in a hypothermia rescue; and manufacturers of products designed to prevent hypothermia. The focus is on United States law, although some foreign law is mentioned. The law may differ substantially from state to state, so that universal answers cannot be given on many of the questions posed. Both organizations and manufacturers should have local counsel to keep them advised of new developments in the law.

ORGANIZATIONAL/INSTITUTIONAL LIABILITY

The most likely theory of law that would be utilized in an action against an organization providing hypothermia instruction is negligence. Negligence can be defined as the failure to observe, for the protection of the interests of another person, that degree of care, precaution, and vigilance which the circumstances justly demand, whereby such other person suffers injury.[1] An act of negligence may be one which involves unreasonable risk of harm to others, even though it is done with reasonable care, skill, preparation, and warning. The negligence is inherent in the act. In other types of conduct, the act may become negligent through the lack of care, skill, preparation, or warning although the act in itself would not have constituted negligent conduct had reasonable care, skill, preparation, or warning been used.[2]

Focusing on the failure to exercise care, the negligence question is: "Did the defendant use such care as ordinarily prudent men would use under similar circumstances?" Whether

---

*Member of the Rhode Island Bar and Assistant Professor of Marine Affairs, University of Rhode Island

the facts of the case involve negligence is a question for the jury to decide. When planning a training program, keep that jury in mind when you consider how and where the course will be offered.

A recent case involving sailboat racing has had a dramatic impact on the sport. Claims in excess of $10 million have been brought against a boat owner and the Lloyd Harbor Yacht Club of Long Island by the widow of a sailor who drowned last year after being thrown overboard during a race sponsored by the club. The suit, alleging negligence by the yacht club, claimed that the wind speed was too high and the water temperature too low to safely conduct a race. In addition, the suit alleged that an inadequate number of rescue craft were available.

According to William Lynn, United States Yacht Racing Union Vice President, "Lloyd Harbor has created something of a panic in the Long Island Sound Area."[3] The club has zero assets, not even a clubhouse, and costs of legal defense arising from the lawsuit are proving to be significant. As a direct result of the suit, USYRU has decided to purchase an $11 million regatta liability insurance policy, which would give member yacht racing associations and yacht clubs the opportunity to purchase similar coverage for approximately $200 in annual premiums.[4] In addition, litigation is expected as an aftermath of the Fastnet race which claimed 15 lives in England last summer.

All of these suits may prove to be unsuccessful, but one point to remember is that they cost a great deal to defend. It is a virtual certainty today that any death or serious injury which appears to be even remotely related to an organization's activities will spark a Lloyd Harbor-style lawsuit. A training program must not include activities which might have "an unreasonable risk of harm." Keep in mind that that is a flexible term, which may vary from student to student. Activities which may be quite safe for trained lifeguards might be considered unreasonably dangerous for an older student. Thus your program must be flexible enough to meet the needs and abilities of different groups. In the zeal to "spread the word" about hypothermia training, safety standards cannot be relaxed--they must remain the most important consideration in every part of your program. Despite the best safety program possible, some injuries will probably still occur. But if you have exercised "that degree of care, precaution, and vigilance which the circumstances justly demand," your organization will be able to defend any resulting lawsuit based on negligence.

As an example of the many bases for liability suits, consider a typical indoor pool hypothermia training program.[5] A plaintiff could allege that you had failed to "provide safe facilities" and that his slip-and-fall injury was caused by your slippery decks, insufficient lighting, or steps and handrails which do not comply with government codes. Lesson: operate or rent only a very safe facility, with excellent safety equipment available. Another plaintiff could allege that his instructor "failed to perform properly" and that his near-drowning was the result of his instructor leaving the pool area to make a telephone call. Lesson: your instructors must be highly responsible and mature individuals who understand the dangers inherent in aquatic instruction.

Designing a completely safe training program can be compared to walking across a minefield loaded with exploding lawsuits. Hopefully, the information that has been provided will serve as an effective guide through those dangers. In addition, it is highly recommended that any organization involved in instruction protect itself further with substantial liability insurance to protect against unforeseen dangers.

INDIVIDUAL LIABILITY IN HYPOTHERMIA RESCUE

Under common law, there is no duty or legal obligation to come to the aid of another person who is in peril. This rule has long been criticized as anachronistic and outmoded. Most civil-law countries have changed this rule by statute, and many scholars have argued eloquently for its repeal in this country. Judeo-Christian philosophy has maintained that a man has a duty to aid his neighbor in peril, but courts faced with a breach of this moral duty have consistently refused to find that any legal duty was breached. Consider the following case: Albert Osterlind rented a canoe and paddled to the middle of a lake. He was drunk, and the boat overturned. He shouted for help for half an hour before he drowned. Standing on the shore, the owner of the boat heard the cries but did nothing. The court found that the owner was guilty of no crime or tort. "The failure of the defendant to respond to the intestate's outcries is immaterial. No legal right of the intestate was infringed."[7] Such decisions have been condemned by legal writers as revolting to any moral sense, but thus far they remain law.[8]

As with any rule of law, however, there are a variety of exceptions in which courts have found an affirmative duty to rescue. The first is when a special relationship exists between the rescuer and victim. Examples of this would be the relationship among family members, between innkeeper and guest, and between employer and employee. The second exception occurs if the defendant was at fault in causing the plaintiff's injuries or peril. He then has a legal obligation to go to the plaintiff's aid and is under a duty to exercise care in so doing. The next exception is statutory. Several states have statutes making it a criminal offense for the driver of an automobile to fail to go to the aid of any person in an accident with his car, even though the driver was in no way at fault in causing such accident. In addition, there is a federal statute recognizing that ancient law of the sea:

> The master or person in charge of a vessel shall, as far as he can do so without serious danger to his own vessel, crew, or passengers, render assistance to every person who is found at sea in danger of being lost; and if he fails to do so, he shall upon conviction, be liable to a penalty of not exceeding $1,000 or imprisonment for a term not exceeding two years, or both. 46 U.S.C. 728

Many other nations have turned this exception into the rule. Twelve civil-law countries recognize a legal duty to come to the aid of one in peril. The French Statute is typical--it imposes a jail sentence, a fine, or both, on "any person who willfully fails to render or obtain assistance to an endangered person when such was possible without risk to himself or others."[9]

Let us assume, however, that our potential rescuer does not need a statute forcing him to go to someone's rescue; his basic sense of humanity instructs him to take action. What legal relationship exists now? Our rescuer need not have acted at all, but if he does act, he must act with "reasonable care."[10] Courts have defined this "reasonable care" in a very flexible way by use of the so-called "emergency doctrine." Very simply, one confronted with a sudden emergency is not held to the same accuracy of judgment as would be required if he had time for deliberation; and if he exercises such care as an ordinarily prudent man would exercise in a like emergency, he is not liable for a resulting injury.

Widely recognized, this doctrine has provided substantial protection for the responsible volunteer rendering emergency assistance. The largest organization in this country sanctioning safety/instruction programs, the American Red Cross, reports that

> there has never come to our attention nor to that of our legal office, any case in which a student, who has been duly certified by the Red Cross, been made a party to a lawsuit or subject to a judgment for damages for any cause of action related to the rendering of volunteer emergency assistance.[11]

When a rescue in U. S. waters is taking place, more often than not the rescuer is the U. S. Coast Guard. The Coast Guard is authorized, though not obligated,

> "to render aid to distressed persons, vessels, and aircraft on and under the high seas and on and under the waters over which the United States has jurisdiction" and to "perform any and all acts necessary to rescue and aid persons and protect and save property." 14 U.S.C. 88 (a) (1)

The emergency doctrine applies to members of the Coast Guard, but since they are trained in emergency rescue operations, they must demonstrate a higher standard of care than those untrained in emergency operations.

Although the vast majority of Coast Guard rescues are handled in a professional manner, occasionally mistakes are made and the Coast Guard has been found liable for its negligence. In U. S. v. Lawter,12 a husband sued for the death of his wife who fell from a Coast Guard helicopter during rescue operations. The court found that where there was a Coast Guardsman aboard the helicopter who was trained in the operation of rescue equipment, but the officer in charge of the helicopter allowed an untrained man to operate the rescue equipment, the evidence was sufficient to support a finding that the Coast Guard was negligent.

Another class of individuals often faced with rendering emergency aid is doctors and other medical personnel. This country has, through the so-called Good Samaritan statutes, exempted doctors and other medical personnel from liability for negligence when they render unsolicited aid in an emergency. Over 30 states have adopted these statutes. Most of them exempt doctors and other medical personnel from liability for ordinary negligence when they stop at the scene of an accident to render aid. Three of the states, New Mexico, Tennessee, and Texas, however, extend immunity to all persons who so render aid. A recent poll of doctors and medical personnel in those states which have adopted Good Samaritan laws shows that the statutes have not achieved their desired effect, that is, to encourage doctors to come to the aid of those in peril. Over fifty percent of the doctors polled in Good Samaritan states said that they still would not stop and render aid to the injured.13 In fairness to the physicians, the statutory conditions placed upon the grant of immunity are, in many cases, vague and ill-defined; they leave a great many factual questions to be decided by a jury, arguably encouraging the emergency patients to bring action for malpractice.14

Finally, let us assume that our rescuer, with competent first aid and hypothermia training, acting as a reasonable, prudent person in the face of this emergency, injures himself in his effort to save the victim. Can he recover for his injuries? Under the principle of law known as the rescue doctrine, one who is injured in undertaking the rescue of a person who is in imminent and serious peril may, absent rash or reckless conduct on his part, recover for his personal injuries from the person whose negligence created the perilous situation. The majority view is that the doctrine is applicable even where the party being rescued was the one guilty of the negligence creating the danger. Essentially, the rescue rule expands the risks which a rescuer may properly take in order to save a third person in danger from harm. Thus, conduct which ordinarily might be held negligent may not necessarily be so considered when performed by a rescuer in an effort to save another from bodily injury. An example is the case of Doran v. Kansas City,[15] in which a child drowned attempting to rescue his brother from drowning in a water-filled hole in a public park. Recovery on the basis of the rescue doctrine was allowed, in light of the fact that the city knew for a long time of the conditions which attracted children to the dangerous hole.

An excellent summary to this section discussing the individual and rescue was written by the eloquent Judge Cardozo in the Wagner v. International R. R.[16] case in 1921:

> "Danger invites rescue. The cry of distress is the summons to relief. The law does not ignore these reactions of the mind in tracing conduct to its consequences. It recognizes them as normal. It places their effects within the range of the material and probable. The wrong that imperils life is a wrong to the imperiled victim; it is a wrong also to his rescuer.

PRODUCTS LIABILITY LAW AND MANUFACTURERS OF HYPOTHERMIA PREVENTION EQUIPMENT

Products liability law is a relatively new field of law which has developed rapidly as a result of the increasing complexity and hazardous nature of products introduced in the marketplace. Very simply, it means that a legal liability is created when a product which is defectively made or designed causes injury to another. A wide range of survival/hypothermia prevention products currently available could be affected by this quickly growing field of law.

Recovery under products liability law is generally sought using one or more of the following legal theories: negligence, breach of express or implied warranties, or strict liability. The trend is clearly from "buyer beware" to "seller beware." A brief discussion of these three theories follows.

A. Negligence - The subject of negligence has been generally discussed in the preceding sections. With regards to product liability, proof of negligence in manufacturing a product that proximately causes injuries that are reasonably foreseeable will impose liability upon the manufacturer. An example of this could be a negligently manufactured survival suit which falls apart upon usage.

B. Warranty - Causes of action arising from breach of warranty are based upon the provisions of the Uniform Commercial Code, which has been adopted in 49 states. The UCC lists three types of warranty: express warranty (Sec. 2-313), implied warranty of merchantability (Sec. 2-314), and implied warranty of fitness (Sec. 2-315).

Express warranty applies when the seller makes an oral or written statement of promise about the product to the buyer. An example would be a sleeping bag guaranteed to keep you warm at 20 degrees below zero.

The implied warranty of merchantability is involved when there has been no representation by the seller; the product is nevertheless warranted for its general purpose, that it will do what it is supposed to do. A life jacket, for example, (or personal floatation device, if you prefer), is designed to keep a person afloat. If it fails to do so, a breach of the implied warranty of merchantability could be found.

An implied warranty of fitness provides the final source of protection for the buyer. It becomes involved when the seller knows that the product will be used by the buyer in a particular way. For example, a small inflatable rubber boat would have an implied warranty of merchantability to not leak, have a certain loading capacity, etc. But, if the seller knows that the buyer intends to use that open boat for a survival life raft, then the product is further warranted under fitness to be suitable for survival conditions. The liability in this case would obviously fall upon the seller who made the promises and not the manufacturer.

C. Strict Liability - A theory which is rapidly gaining strength and which can be brought to bear relatively easily by the buyer is strict liability. The theory is adopted in most jurisdictions in the form expressed in the *Restatement of Torts 2nd* Sec. 402A:

> One who sells any product in a defective condition unreasonably dangerous to the user or consumer or to his property is subject to liability for physical harm thereby caused.

This liability is imposed if two additional requirements are met: (1) that the seller be engaged in the business of selling; and (2) that the product reach the consumer without substantial change. Liability is imposed even if the seller has "exercised all possible care in the preparation and sale of his product."17

From this brief summary, it is evident that manufacturers and sellers of products designed for special service must be extraordinarily careful in the production and advertisement of their goods.

CONCLUSION

The single most important point running through this paper is caution. Hypothermia training must be carried out in as safe an environment as possible; rescue operations should be conducted as carefully as emergency conditions allow; and manufacturers of equipment designed to prevent hypothermia must be very cautious about the way their products are manufactured and advertised.

The law does nothing to interfere with trained personnel undertaking a hypothermia rescue using recognized techniques. It provides protection for both the rescuer and the victim if negligence occurs. All in all, it provides a reasonable balance of the interests of society and the individual in this exciting new field of emergency medical care.

Notes

1. 65 Corpus Juris Secundum Negligence Sec. 1 (2)

2. NEA, "Who is Liable for Pupil Injuries?" National Commission on Safety Education (February 1963), p. 11

3. USYRU Meets in Seattle," Soundings, (January 1980), p. 14

4. Id.

5. for further information, see Clayton, Robert D. and Torney, John, Aquatic Instruction, Coaching and Management, Minneapolis: Burgers Publishing, (1970).

6. Note, "The Bad Samaritan: Rescue Reexamined," 54 Georgetown Law Review 629, (1966).

7. Osterlind v. Hill, 263 Mass. 73, 76, 160 N.E. 301, 302, (1928).

8. Restatement of Torts 2nd Sec. 314

9. Code Penal Art. 63

10. Lacey v. U. S., 98 F. Supp 219, (D.C.Ma. 1951).

11. The American National Red Cross Safety Programs, Section II, Instructor Information, p. 2 (June 1977). Confirmation by telephone communications to Red Cross National Headquarters, December 1979.

12. 219 F. 2d 559, (5th Circ. 1955).

13. Editorial, "The Good Samaritan and the Law," 273 New England Journal of Medicine 934 (1965).

14. Note, "Good Samaritans and Liability for Medical Malpractice," 64 Columbia Law Review 1301, (1964); see also Note, "California Good Samaritan Legislation: Exemptions from Civil Liability While Rendering Emergency Medical Aid," 51 California Law Review 816, (1963); and Note, "Good Samaritan Legislation: An Analysis and a Proposal," 38 Temple Law Quarterly 418, 1965).

15. 241 Mo App 156, 237 SW 2d 907, (1951).

16. 232 NY 176, 133 NE 437, (1921)

17. Restatement of Torts 2nd Sec. 402A (2) (a)

Edward M. O'Brien, Ph.D.
Assistant Professor
Electrical and Computer Engineering
Clemson University

Dr. O'Brien received his BS in Electrical Engineering in 1971 from Colorado State University, and his MS and Ph.D. in Biomedical Engineering in 1974 and 1977 from Iowa State University. He was appointed to the Electrical and Computer Engineering faculty at Clemson University. He currently holds the rank of Assistant Professor. His research interests include systems physiology and biomedical instrumentation.

ABSTRACT

EXPERIMENTAL EVALUATION OF THE EFFECTIVENESS OF HYPOTHERMIA PROTECTION EQUIPMENT

E. M. O'Brien, R. M. Harnett, F. R. Sias, J. R. Pruitt
College of Engineering
Clemson University
Clemson, South Carolina 29631

Experiments were conducted on a diverse group of immersion hypothermia protection articles to determine their effectiveness. The articles examined included a ski vest PFD, jacket-type devices, a short wet suit, deck suits, dry suit flight ensembles (ventile cotton and gortex), dry foam survival suits and dry suits with an inflatable air-bladder for insulation. One article of the last type was designed to provide respiratory heat reclamation. A total of 16 articles were tested. These experiments were conducted using human subjects in either 53° or 35°F water depending upon considerations of the suit type and the safety of the subjects. Experiments were terminated when the subject's rectal temperature reached 95°F or after 3 hours whichever came first. The cooling data so obtained was used to predict survival time in 35°F water for an average, thin and heavy individual. The survival time predictions for the person of average somatotype ranged from 2.8 hours while wearing the ski vest PFD to 27.1 hours wearing the air-bladder insulated dry suit employing respiratory heat reclamation. The corresponding survival time ranges for the thin and heavy individuals are from 1.3 to 30.2 hours and from 4.0 to 73.2 hours respectively. The same two articles again provided the least and most protection.

A STUDY OF IMMERSION HYPOTHERMIA

PART I:

Experimental Evaluation of the Effectiveness of Hypothermia Protection Equipment

by

E.M. O'Brien, Ph.D., R.M. Harnett, Ph.D.,
F.R. Sias, Ph.D. and J.R. Pruitt, M.D.

College of Engineering
Clemson University
Clemson, S. C. 29631

1.0 INTRODUCTION

The selection of equipment to provide protection from hypothermia during accidental immersion in cold water is difficult not only because the ability of the equipment to prolong life is difficult to assess, but also because there may be several additional attributes of the equipment which are variously important to different potential users. Merchant mariners or commercial fishermen require equipment which can be donned quickly in the event of an accident which necessitates prolonged survival in cold water. Aviation personnel who routinely fly over cold water may require equipment which can be worn for several hours at a time in warm air while they perform their various functions in the aircraft. Because they often are equipped with electronic devices which render them easy to locate by search and rescue teams, the aviators may not require protection during prolonged exposure (many hours). Some aviators, such as tactical aircraft crews or even search and rescue crews, may also place considerable demands

* Sponsored by U. S. Coast Guard Office of Research and Development
Contract Number DOT-CG-72074-A

on their protection equipment to be quickly donned. Deck crewmen on boats and workers on offshore oil platforms may require equipment that can be used in a constant-wear mode but which will not interfere with their ability to perform their duties either directly by reducing their mobility or indirectly by inducing exceptional fatigue. There are other equipment performance attributes which are important in making selection decisions for equipment to be used by different groups with different requirements. This study was formulated to provide an evaluation of selected attributes for state-of-the-art equipment relevant to such selection decisions for merchant mariners, Coast Guard operational personnel and recreational boaters. Cold protectiveness and wearability are specifically presented.

The range of equipment to be considered for inclusion in this study was restricted to devices which are commercially available and to existing prototype devices. No new prototypes were developed for inclusion in the study. In addition, the selection of test articles was restricted to include in the study only one article representing each general type of equipment. The study was not intended to compare the products of different manufacturers which employ the same general design features.

The conduct of the cold protection effectiveness investigation was restricted to be based on data which could be obtained from safe, in vivo, cold-immersion experiments using human subjects. Thus human responses to cold-immersion, while wearing the test articles, could be observed only over a narrow range of body core temperatures involving the mildest hypothermia. The estimation of survival times associated with the test articles was, of necessity, based on extrapolations of observations made in mild hypothermia.

2.0 DESCRIPTIONS OF THE TEST ARTICLES

The test articles considered in this study may be categorized by general design approach into the following five groups.

1. Wet suits covering entire body (WE)
2. Wet suits covering partial body (WP)
3. Dry suits with little intrinsic insulation (D)
4. Dry suits with foam-rubber insulation (DF)
5. Dry suits with air-space insulation (DA)

The following paragraphs present descriptions of the test articles grouped into these categories. The ancillary equipment with which they were tested is also described.

Two ensembles of ancillary equipment were standardized for use in testing certain of the test articles. One, which will be referred to as "standard work/recreation clothing", consists of denim jeans, a light-weight, long-sleeved cotton shirt, cotton undershorts and T-shirt, cotton athletic socks and low-top canvas sneakers. The other, referred to as "standard ancillary aviator's ensemble", consists of one suit of nomex underwear and undershirt (CWU-43/P and CWU-44/P), one pair of cotton athletic socks, low-top canvas sneakers, and an aviator's water wings flotation device (SRU-21 and LPU-10).

2.2.1 Wet Suits Covering Entire Body

Bayley WeatherMate Plus (WE1)

The Bayley WeatherMate Plus, is a two-piece suit constructed of neoprene foam rubber. The jacket features a deployable diaper-like closure at the groin, a hood formed from the collar by closing a zipper and an orally-inflated flotation bladder located mainly in the upper shoulders area. Cinching, belt-type closures are provided at the wrists and ankles. This suit was tested over the standard work/recreation clothing.

Henderson Zip-On Exposure Suit (WE2)

The Henderson Zip-On Exposure Suit, is essentially a 3/16 inch neoprene wet suit with zippered gussets provided on the arms, legs, hips and torso to facilitate donning and to permit tightening the fit of the suit in the event of inadvertent entry of cold water. Accessories include a hood, three-finger mitts and hard-sole booties. Velcro closures are provided at the wrists and ankles to retard the entrance of outside water into the puckers caused by closing the zippered gussets. This suit was worn over undershorts only.

Stearns Heavy-Duty Offshore Survival Suit (WE3)

The Stearns Heavy-Duty Offshore Survival Suit, is a one-piece jumpsuit,lined with PVC foam rubber of varying thickness (thicker on torso than arms). A hood attaches to the suit by two snaps. Zippered closures are provided at the wrists and ankles. Supplemental flotation is provided by an orally-inflated flotation bladder located in the upper chest area. This suit was tested over the standard work/recreation clothing.

White Stag Nylon-Two Wet Suit (WE4)

The White Stag Nylon-Two Wet Suit, is constructed from 3/16 inch neoprene rubber (Rubatex 1400). Accessories include a hood, 5-finger mitts and soft-sole booties. Zippered closures are provided at the wrists and ankles. This suit was tested over undershorts only.

2.2.2 Wet Suits Covering Partial Body

Henderson Prototype Jacket (WP1)

The Henderson Prototype Jacket,is constructed of neoprene foam rubber of varying thickness. An integral hood stows under the collar. Zippered gussets are provided on the arms and torso. Velcro closures are provided at the wrists. A beaver tail, slightly larger than on a standard wet suit closes the bottom of the jacket. It was tested over the standard work/recreation clothing and with a small kapok Type II Mae West flotation aid.

Medalist Ski Shorty (WP2)

The Medalist Ski Shorty, is a one-piece short wet suit constructed of nylon-faced neoprene rubber 1/8 inch thick. It was tested in conjunction with a wet suit hood (White Stag 3/16 inch), light weight flight coveralls (CWU-27/P), cotton athletic socks, canvas sneakers and the water wings flotation device (SRU-21 and LPU-10). The short wet suit was worn over undershorts only.

Mustang U-VIC Thermofloat (WP3)

The Mustang U-VIC Thermofloat, is lined with PVC foam rubber of varying thickness. Recessed knit cuffs provide some protection from outside water entry. A deployable diaper-like device provides groin protection and closes the bottom of the jacket. A thin hood stows inside the collar. This jacket was tested over the standard work/recreation clothing.

NADC Modified Wet Suit (WP4)

The NADC Modified Wet Suit, is a combination of flight suit and a short-sleeved, one-piece wet suit. The wet suit construction is of neoprene rubber and features zippered closures at the ankles. Fittings and tubing are provided in the suit to allow it to be attached to a forced-air cooling system to remove excess body heat while in a dry environment. This capability was not exercised during testing. This suit was tested with one suit of nomex underwear, athletic socks and sneakers.

Stearns Windjammer Jacket (WP5)

The Stearns Windjammer Jacket, is lined with PVC foam rubber of varying thickness. Recessed knit cuffs provide some protection from outside water entry. A thin hood stows inside the collar. This jacket was tested over the standard work/recreation clothing.

Stearns Offshore Survival Jacket (WP6)

The Stearns Offshore Survival Jacket, is lined with PVC foam rubber of varying thickness. An additional liner of 1/8 inch neoprene foam may be closed after entering the water providing additional protection to the torso. This liner is closed at the bottom by a narrow beaver tail. Recessed knit cuffs provide some protection from outside water entry. Additional elastic, wrap around closures are provided at the wrists. An insulated hood is an integral part of this jacket. This jacket was tested over the standard work/recreation clothing.

Texas Recreation Corporation Nylon-Covered PFD (WP7)

The Texas Recreation Corporation Nylon-Covered PFd, is lined with unicellular foam rubber. The design features no openings through which water could pass except the front, which is closed by three buckles. Selecting for snug fit reduces the ability of water to enter around the vest. This vest was tested over the standard work/recreation clothing.

2.3 Dry Suits with Little Intrinsic Insulation

This group of test articles share the property that they are generally constructed from thin material which seeks to provide a water barrier during immersion. This allows one to achieve cold protection by imposing beneath the suit a garment (e.g., nomex, waffle-weave underwear) which will immobilize an air layer.

Beaufort MK-10 British Immersion Coverall (D1)

The Mark 10 immersion coverall, is a one-piece suit with integral foot coverings which can be worn under flight boots. It is constructed of double-layered ventile fabric. Ventile fabric is designed to permit the elimination of waste heat by passing water vapor when in the dry, but to provide a water barrier during immersion because of changes that occur in the fabric. The coverall is closed by means of a single waterproof zipper which closes from the right shoulder to the left hip. Water is also excluded from the suit by elastic seals at the neck and wrists. The suit was tested with one suit of nomex underwear and canvas sneakers.

NADC Goretex Experimental Coverall (D2)

The NADC Goretex Experimental Coverall, was constructed of a light, canvas-type nomex to which "goretex" had been laminated on the inside. The theory of this construction is that it permits the elimination of waste heat in the dry since goretex is permeable to water vapor while providing a water barrier during immersion because of changes that occur in the goretex. The coverall has integral foot coverings which could be worn under flight boots. The coverall is closed by means of a single waterproof zipper which closes from the left shoulder to the groin. Water is also excluded from the suit by elastic seals at the neck and wrists. The suit was tested with the standard ancillary aviator ensemble.

U. S. Air Force Modified Anti-Exposure Assembly (D3)

The U.S. Air Force Modified Anti-Exposure Assembly is a modification of the CWU-21/P. It is constructed of single-layered ventile fabric which is designed to permit the elimination of waste heat, by passing water vapor when in the dry but to provide a water barrier during immersion because of changes that occur in the fabric. The assembly has integral foot coverings which can be worn under flight boots. The coverall is closed by means of a single waterproof zipper which closes from the groin to the throat. Water is aslo excluded from the suit by elastic seals at the neck and wrists. The suit was tested with the standard ancillary aviator ensemble.

2.4 Dry Suits With Foam Rubber Insulation

The test articles in this category share the features that they seek to keep the occupant dry and warm. Thermal insulation is provided in the form of a foam-rubber-stabilized layer of air.

Bayley Exposure Suit (DF1)

The Bayley Exposure Suit, was tested in two types of foam rubber (neoprene and PVC) each 3/16 inch thick. The suit includes integral head, hand and foot protection and will accommodate shoes inside. The suit is closed by a single waterproof zipper which closes from the groin to the chin. The intrinsic buoyancy of the suit is augmented by an orally-inflated "pillow" which attaches to the upper back area by two short zippers. Water is excluded from the suit by a soft rubber seal around the wearer's face. Flotation attitude may be controlled somewhat by expelling excess air from the legs of the suit through "valves" located on the toe area of each leg. This suit was tested over the standard work/recreation clothing.

Helly-Hansen Survival Suit (DF2)

The Helly-Hansen Survival Suit, utilizes foam rubber to impede conductive heat transfer and has a metalized foil layer between the outer material and the foam rubber to impede the loss of heat by radiation. The suit includes integral head and foot protection and will accommodate shoes inside. The suit is closed by a single waterproof zipper which closes from the groin to the chin. Water is excluded from the suit by neoprene rubber seals at the wrists and around the wearer's face. This suit was tested over the standard work/recreation clothing. The hands were protected by 3/16 inch neoprene three-finger wet-suit mitts.

S.I.D.E.P. Seastep Survival Suit (DF3)

The S.I.D.E.P. Seastep Survival Suit is constructed of 5 mm thick closed-cell, nylon-lined neoprene rubber. The suit includes integral head and foot protection. Integral five-finger hand coverings are also provided but are constructed of much thinner material. The entrance is a tubular attachment joining the suit at the shoulders. It is closed by a zipper but the waterproof seal of the entrance is provided by rolling it and hooking it to a metal ring on the chest. This ring also serves as the focus for a built-in harness facilitating retrieval by winch from the water. Intrinsic flotation is augmented by an inflatable, front-mounted bladder. The suit does not accommodate shoes inside. It was tested over the standard work/recreation clothing, less the sneakers.

2.5 Dry Suits With Air-Space Insulation

The suits in this group share the feature that they seek to provide cold protection through an air-space which is contained in and controlled (for thickness) by an inflatable, air-tight bladder. This contrasts with the dry, foam suits which immobilized an air-space in closed-cell foam rubber.

ILC Industries Prototype Survival Suit (DA1)

The ILC Industries Prototype Survival Suit consists of two main components. An outer shell to which goretex has been laminated permits the release of water vapor in the dry but provides a water barrier during immersion. Inside this shell is an inflatable bag which surrounds the entire body. The two layers of the bag are heat sealed together in round patches at regular intervals to control the thickness of the air layer when fully inflated. The centers of the heat sealed patches were removed to provide paths for water vapor to escape the body carrying excess body heat with it. Integral protection is afforded the feet. An inflatable hood was also attached to the back of the suit. The hands are protected by separate inflatable mitts. Inflating seals are provided at the neck and wrists. The suit has fittings and tubing to allow it to be connected to a forced-air cooling system to remove excess body heat while in a dry environment. This capability was not exercised during testing. The outer shell is closed by a single zipper (not waterproof) which closes from the groin to the neck. A separate watertight closure made of heavy plastic and similar to the closures of a zip-lock bag is provided inside this zipper. This suit was tested with the nomex underwear and cotton athletic socks. The air bag was orally inflated to the maximum extent possible.

Dr. Rentsch's Prototype Survival Suit (DA2)

Dr. Rentsch's Prototype Survival Suit is a modified Beaufort Mark VII Submarine Escape and Immersion Suit. The prototype completely encloses the body (except for the hands) with respiration being accomplished through gas exchange orifices in the bicurved face plate. A separate mouth port is provided for issuing distress calls (e.g., by blowing a whistle). The suit is an inflatable insulation bladder surrounding the body. A separate inflatable Mae West-like flotation bladder is provided. The two layers of the insulation bladder are sealed together at regular intervals (giving the dimpled appearance) to control the thickness of the air layer when the bladder is fully inflated. Integral air-space protection is provided the feet and head. The hands are protected by inflatable mitts. Elastic seals are provided at the wrists. The suit closes by a single waterproof zipper extending from the groin to the neck and then around the right side of the head to a terminal position at the top, left side of the head. Exhaled gasses are shunted down a plastic tube to the inside of the suit in an attempt to reclaim respiratory heat losses. Opening the mouth port effectively eliminates this heat reclamation aspect of the suit. This suit was tested over the standard work/recreation clothing with the air bladder orally inflated to the maximum extent possible. It was cold-immersion tested in two conditions: mouth port closed and mouth port open. This was done to obtain an indication of the potential usefulness of respiratory heat reclamation.

3.0 COLD-PROTECTION EFFECTIVENESS INVESTIGATION

3.1 Objectives

The objective of the cold-protection effectiveness investigation was to establish a quantitative measure of the effectiveness with which each test article selected for this investigation protects victims of accidental immersion from potentially-lethal losses of body heat. To facilitate the meaningful interpretation of these quantitative results they were expressed in terms of survival-time estimates. To facilitate comparisons among the test articles the survival times were estimated to correspond to immersion in 1.7°C (35°F) water. It was known that several of the test articles could not be tested in water that cold, due to test subject discomfort and the risk of damage to peripheral tissues. Therefore, it was anticipated that the survival-time estimates for these test articles would have to be established using an analytically-based adjustment to estimates associated with warmer water.

It was desired that the analysis of the experiment results should provide the capability to estimate survival time for individuals with selected physical structures (morphologies). This capability was needed to determine the survival times afforded individuals with morphologies different from the average. It was also needed to permit comparisons among the survival times of the test articles for selected morphologies when the articles were tested by different test subjects. Achieving this capability required that a quantitative measure of morphology be internalized into the analysis methodology. It was hoped that this analysis approach would also serve to reduce unexplained (random) variation in the results.

3.2 Methodology

The estimation of survival times was, of necessity, based on extrapolations of the core cooling observed in volunteer test subjects wearing the suits during cold-water immersions in which only mild hypothermia was induced. As indicated in Table 1-3, the determination of a lethal level of core cooling (measured rectally) is nontrivial. It was for this reason that Hayward, et al., (1978) parameterized on its value using 27, 30 and 33°C. For present purposes core cooling is assumed to be lethal at 30°C. It is at this level that cold-induced physical and mental debilitation remove the immersion victim's ability to participate meaningfully in the

TABLE I-3

LEVELS OF HYPOTHERMIA†

°F	°C	
99.6	37.6	"Normal" Rectal Temperature
96.8	36	Increased Metabolic Rate in attempt to balance heat loss
95.0	35	Shivering maximum at this temperature
93.2	34	Patients usually responsive and normal blood pressure
91.4	33	SEVERE HYPOTHERMIA BELOW THIS TEMPERATURE
89.6	32	Consciousness clouded } Pupils dilated most shivering ceases
87.8	31	Blood Pressure difficult to obtain } Pupils dilated most shivering ceases
86	30	Progressive loss of consciousness; Increased muscular rigidity; Slow pulse and respiration
85.2	29	Cardiac arrhythmia develops
82.4	28	Ventricular fibrillation may develop if heart irritated
80.6	27	Voluntary motion lost along with pupillary light reflex, deep tendon and skin reflexes - appear dead
78.8	26	Victims seldom conscious
77.0	25	Ventricular fibrillation may appear spontaneously
75.2	24	Pulmonary Edema develops
73.4	23	Maximum risk of fibrillation (24–21)
71.6	22	
69.8	21	
68.0	20	Heart Standstill
66.2	19	
64.4	18	Lowest Accidental Hypothermic patient with recovery
62.6	17	ISO-ELECTRIC EEG
48.2	9	Lowest Artificially Cooled Hypothermic patient with recovery

† From Harnett, et al., (1979)

preservation of his life. Table I-3 makes clear that the cold, in and of itself, is not necessarily lethal at 30°C. However, survival below this level depends upon exogenous support of flotation and freeboard for breathing passages. While many of the test articles considered in this study provide abundant buoyancy, none is intrinsically capable of guaranteeing breathing passage freeboard. Most could however be supplemented with flotation devices with sufficient righting moment to support respiratory ventilation. However, at present the use of flotation devices with this intrinsic capability is not required by all individuals at risk of cold-immersion and therefore may not be relied upon to extend survival beyond the point of physical and mental debilitation.

Design of the Experiment

The basic experiment plan called for obtaining 5 replications of cold immersions with each of the 17 test articles (Rentsch's prototype twice) indicated for the cold-protection effectiveness investigation in Table I-2. These were to be performed in such a way that each test article was worn by test subjects exhibiting a reasonable range of physical characteristics. Because a study of rewarming therapies (described in Part II of this report) was integrated with this suit investigation and additional rewarmings were desired, additional experiments were obtained with some of the suits extending their sample sizes to 6. Table I-4 shows the sample sizes which were obtained with each suit and the means and standard deviations of the temperatures of the water and air in which the experiments were done. Two target temperatures were used 1.7°C (35°F) and 11.8°C (53.2°F). The warmer water temperature was selected to match that used by Hayward, et al.(1978) and to preclude injury to unprotected or lightly protected peripheral tissues.

Table I-5 presents the physical characteristics of the 19 male test subjects who participated in this investigation. The subjects who tested each of the test articles and the sizes they wore are indicated in Table I-6. Because of the special nature of the comparison to be made between the two conditions with DA2 (mouth port open and closed), special emphasis was placed on arranging the test subject - test article assignments to involve the same subjects in both experiments with this suit.

This repeated use of test subjects was not possible to accomplish overall. The volunteers were free to withdraw from participation in the project at any time - a right some of them exercised; e.g., KC, JH, CM, MO, TP, PS and BS.

TABLE I-4
EXPERIMENT SAMPLE SIZES AND WATER TEMPERATURES

Suit Code	Suit Description	Number of Replications	Water Temperature (°C) Mean	S.D.	Air Temperature (°C) Mean	S.D.
WE1	Bayley WeatherMate Plus	5	11.8	0.1	21.3	0.5
WE2	Henderson Zip-On Exposure Suit	5	1.9	0.3	21.4	1.2
WE3	Stearns Heavy-Duty Offshore Survival Suit	5	12.1	0.4	21.4	0.7
WP1	Henderson Prototype Jacket	5	12.0	0.3	21.1	0.0
WP2	Medalist Ski Shorty	5	11.8	0.1	21.8	0.9
WP3	Mustang U-VIC Thermofloat	5	11.8	0.0	20.6	1.0
WP5	Stearns Windjammer Jacket	6	12.0	0.3	21.4	0.8
WP6	Stearns Offshore Survival Jacket	5	11.8	0.1	21.0	0.2
WP7	Texas Recreation Corp. Nylon-Covered PFD	6	11.8	0.1	21.6	1.1
D2	NADC Goretex Experimental Coverall	6	11.9	0.1	22.0	1.6
D3	U. S. Air Force Modified Anti-Exposure Assembly	5	11.8	0.0	22.2	1.2
DF1	Bayley Exposure Suit (PVC foam)	5	2.0	0.3	20.8	0.6
DF2	Helly-Hansen Survival Suit	6	1.9	0.5	21.6	1.2
DF3	S.I.D.E.P. Seastep Survival Suit	5	1.9	0.4	21.3	1.8
DA1	ILC Industries Prototype	5	1.7	0.2	22.9	3.2
DA2	Rentsch's Prototype (mouth port closed)	5	1.9	0.3	22.7	1.3
DA2	Rentsch's Prototype (mouth port open)	5	1.7	0.2	22.6	3.3

TABLE I-5
DESCRIPTIONS OF COLD-IMMERSION SUBJECTS

Subject	Age	Height (cm)	Weight (kg)	Heath-Carter Somatotype Components * I	II	III	Surface Area † (m^2)	Total Skinfold Thickness ‡ (mm)	Mean Reciprocal Skinfold Thickness @ (mm^{-1})
JC	21	182.0	88.2	4.0	6.0	1.5	2.11	37	.083
KC	21	185.0	85.4	3.5	4.0	2.0	2.13	31.7	.095
CE	23	182.9	65.5	2.0	4.0	4.5	1.86	21	.143
GF	23	178.2	67.3	2.5	4.0	3.5	1.85	26.5	.115
BH	23	178.9	82.7	4.5	4.0	1.5	2.03	43	.071
MH	25	182.7	64.1	1.5	2.5	5.0	1.83	18	.170
JH	21	170.3	70.4	4.0	5.5	1.5	1.82	36.7	.083
MK	22	183.0	75.9	2.5	5.0	3.0	1.98	26	.123
PK	21	183.9	91.4	4.5	6.0	1.5	2.16	41	.078
CM	21	186.6	70.2	2.5	3.0	4.5	1.95	25	.122
RM	24	168.3	63.6	4.0	5.0	2.5	1.73	37	.084
MO	21	180.0	76.4	3.5	6.5	2.5	1.96	33	.091
TP	25	185.2	76.4	3.0	3.5	3.5	2.02	29	.108
CR	19	180.4	69.3	2.0	4.0	3.5	1.90	22	.148
JR	21	178.5	60.9	3.0	3.0	4.5	1.78	30	.103
PS	19	179.2	75.4	3.0	4.5	2.5	1.95	31	.097
BS	21	187.1	71.4	2.5	4.0	4.5	1.96	27	.118
SW	22	177.5	66.3	3.0	4.0	3.5	1.82	28	.115
TW	23	177.0	74.5	4.0	4.0	2.0	1.92	38.2	.083
Averages	21.9	180.4	73.4	3.1	4.3	3.0	1.93	30.6	.107

* See Carter (1975)
† From Dubois Body Surface Chart prepared by Boothby and Sandiford (Mayo Clinic)
‡ Skinfold thicknesses measured at tricep, subscapular and suprailiac with Lange Caliper.

TABLE 1-6
ASSIGNMENT OF COLD-IMMERSION SUBJECTS TO TEST ARTICLES

TEST ARTICLES	TEST SUBJECTS																			Range of Total Skinfold Thickness (mm)
	JC	KC	GE	GF	BH	MH	JH	MK	PK	CM	RM	MO	TP	CR	JR	PS	BS	SW	TW	
WE1			M	M			M	M										M		21 - 36.7
WE2				M					L						M			M	L	26.5 - 41
WE3		M		M	M			M										M		26.5 - 43
WP1			M		L			M			M						M			21 - 43
WP2		L	M					M	L			M								21 - 41
WP3			S		M			M	L				M							21 - 43
WP5		M	S		M				M							M		S		21 - 43
WP6				S/M	L/E				L/E			S/M						L/M		26.5 - 43
WP7	L	L	M					M	L								M			21 - 41
D2	40		38	40						40		40					40			21 - 37
D3			M							M	M			M			M			21 - 37
DF1(PVC)				X					X					X			X	X		22 - 41
DF2				M		M		M					M				M		M	18 - 38.2
DF3				M				M				M		M				M		22 - 33
DA1						X					X			X	X				X	18 - 38.2
DA2(closed)						X					X			X	X				X	18 - 38.2
DA2(open)						X					X			X	X				X	18 - 38.2

S = Small
M = Medium
L = Large
S/M = Small/Medium
L/E = Large/Extra Large
38 = Chest size (inches), length-regular
40 = Chest size (inches), length - long
X = Unsized prototype or one-size fits all

Furthermore, these subjects were simultaneously participating in the study of rewarming therapies in which their useful participation was limited to eight experiments. Therefore, they could not participate in more than eight cold-immersion suit experiments.

The plan for analyzing the experimental results was formulated to relieve the necessity for complete replication in testing each article with each subject. Survival-time predictions would be developed from regression-based relations which quantitatively predict cooling behavior in each particular suit as a function of the physical characteristics of a selected individual. A separate regression relation would be established for each suit from the cooling behavior observed during its tests. The primary requirements of this approach to developing survival-time estimates are that a reasonable number of replications be performed with each test article and that each be tested by subjects representing the range of physical structures for which survival-time estimates are desired. Table I-6 indicates the range of total skinfold thickness (three sites: tricep, subscapular and suprailiac) exhibited by the subjects testing each article. The significance of this total skinfold thickness (which provides the basis for Heath-Carter Somatotype Component I) as a quantifier of physical structure is established in Section 3.4. The ranges in skinfold thickness shown in Table I-6 all contain the 30.6 mm value used as a quantitative descriptor for the "average" man. The use of a 30.6 mm total for an average man is based on the average of the 19 test subjects described in Table I-5 and its significance is also discussed in Section 3.4.

Experiment Protocol

The cold-immersion experiments were conducted, generally two at a time, in a tank of refrigerated water between June 30, 1978 and June 15, 1979. All were conducted beginning in the early afternoon (between 1-2 p.m.). Subjects were requested to report to the laboratory having had no alcohol or medication for 24 hours or food or tobacco for 2 hours. If there was doubt as to the proper size of a test article for a subject to wear, he was asked to try on the most likely sizes and the one affording the best fit was selected. After voiding his bladder and/or bowels, instrumentation was applied to the subject, including a rectal temperature probe; skin probes for great toe, thigh, groin, subscapular, bicep and forearm temperatures; ECG and sphygmomanometer. Next the subjects donned clothing appropriate for the article they were to test that afternoon (either standard work/recreation clothing, nomex underwear and socks, or for WE2 and WP2 just undershorts). The subjects then began a 30-minute rest period which they spent reclined on a 4" foam rubber mattress and, depending upon their clothing, covered for thermal comfort. Following the 30-minutes of rest, measurements of their rate of oxygen uptake and the other parameters were recorded while the subjects were still reclined and resting. The subjects then donned the test article and entered the cold-immersion tank via a hydraulic chair lift. When testing wet-mode suits, a gradual entry into the water was permitted taking up to 4 or 5 minutes. This reduced the trauma of the entry and presumably the stressfulness of the exposure (although blood pressures of 160/100 mm Hg were not uncommon during the initial phase of the immersion). The immersion was regarded as initiated when the subject was immersed to waist level.

During the course of the immersion, temperatures were monitored continuously and recorded periodically with the sampling frequency being determined on the basis of the rates of changes of the parameters. Measurements of the rate of oxygen uptake were generally made at 1-hour intervals through the immersion plus an additional measurement was made just before removing the subjects from the cold water. Oxygen uptake measurements were not made in test article DA2 (open or closed).

The cold-immersion experiments could have been terminated on the basis of any one of the following criteria.

1. rectal temperature reduced by 2°C or to 35°C
2. any skin temperature reduced to 5°C
3. discretion of the test subject
4. discretion of the attending physician
5. discretion of the research team leader

In practice, the attending physician never found it necessary to terminate an immersion experiment, nor was one ever terminated because of excessively-cold skin.

The immersions were conducted in a steel tank containing water about 1.67 meters deep with surface of 1.83 by 3.05 meters. The water was agitated by a small air-powered turbulator (primarily intended to deice refrigeration coils and prevent thermal stratification of the water) and a 12-volt, DC-powered trolling motor (to prevent formation of thermal boundary layers around the immersed subjects). An effective water velocity of 3 to 5 meters per minute was produced. This velocity is more than the 1.5 meters per minute shown by Baker (1979) to be required to effectively maximize convective heat losses due to relative motion of the water. No other provision was made to attempt to simulate effects of open water.

Throughout the immersion, the subject's position in the water was essentially that which resulted from the inherent flotation of the test articles. With some test articles this inherent flotation was augmented by inflating flotation bladders. This was the case for WE1, WE3, WP2, D2, D3, DF1, DA1 and DA2. Inflating the bladder accompanying DF3 had no effect on flotation attitude in the calm water in the immersion tank. Therefore, it was not inflated during the cold immersions. One test article (WP1) required supplemental flotation to provide reasonable breathing-passage freeboard during the immersion. This was provided by a kapok, Mae West Style Type II PFD which was selected because of its minimal interference with the thermal performance of the test articles.

Instrumentation

The instrumentation used to monitor temperature data in this study was all manufactured by Yellow Springs Instruments. Skin temperatures were measured with a Model 44TD, 12-channel monitor (50°C face sweep) using Model 409 probes (1.1 second time constant) taped to the skin. Rectal and esophageal temperatures were measured with a Model 46TUC, 6-channel monitor (11°C face sweep) using Model 401 probes (7.0 second time constant). The accuracy of temperature probes was verified, over the range of 12.6 to 37.8°C.

3.3 Results

The first step in analyzing the results is to adopt a general model of the cooling process.

Selecting a Model of the Cooling Process

Three considerations predominate the selection of a model of the cooling process.

1. The parameters of the model must be estimatable from the data obtained during the cold-immersion experiments.

2. The model should "fit" the observed data reasonably well.

3. The model should have some basis suggesting that extrapolations of the temperature response below levels seen experimentally are reasonable.

Of these three considerations, numbers 1 and 3 are very much more important than number 2. Consideration 3 will be addressed first.

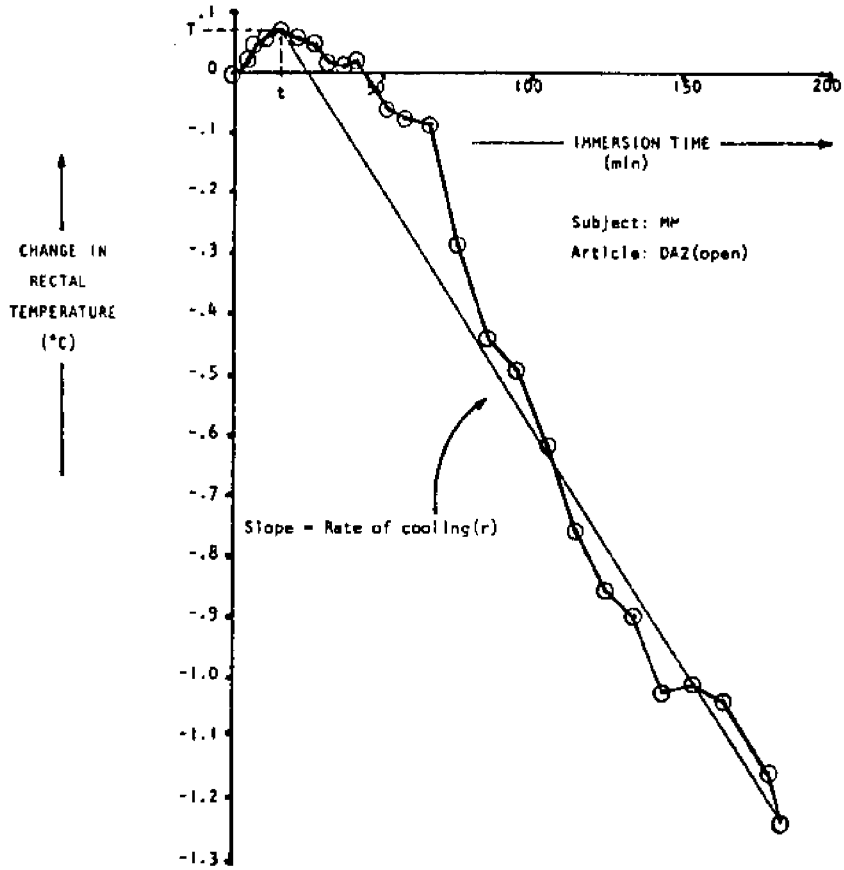
There is little real evidence on which to base extrapolations of core temperatures for individuals protected by equipment of varying efficiencies. Alexander (1945) presents the time-rectal temperature profile of a prisoner murdered by cold-water immersion at Dachau concentration camp. The temperature reduction, once it began, occurred at an essentially constant rate (about 11°C/hr). One might expect that a well-protected immersion victim would cool, perhaps linearly, until at some point the gradient between the victim and the water is reduced sufficiently and the metabolic rate is increased sufficiently to collectively reduce the rate of cooling. This would produce a convexity (deceleration) in the cooling profile. One might also expect, based on the information in Table 1-3, that as the core temperature approaches 32°C, reduced capacity for shivering thermogenesis would increase the rate of cooling. This would produce a concavity (acceleration) in the cooling profile.

The determination of survival time requires an estimation methodology, but there is no truly adequate basis for the estimation. Therefore, in the absence of indications to the contrary, a linear model is the most desirable.

A Linear Cooling Model

Figure 1-1 exemplifies the linear model adopted for developing survival-time estimates. The model entails three parameters: the maximum elevation in core temperature (T), the time at which this maximum elevation occurred (t), and the rate of cooling (r) that occurred after time t. The rate-of-cooling parameter is simply based on the slope between the observation at time t and the last observation recorded. The adoption of this particular linear model involved consideration 1 from the earlier list. A simpler, two-parameter model was considered first. The only parameters required to describe this simpler model are the time at which the change in rectal temperature returns to zero and the rate of cooling following this time. For these parameters to be estimable from the experimental observations (consideration 1), it is necessary that the change in rectal temperature must have returned to zero in each experiment.

FIGURE I-1
EXEMPLARY RECTAL TEMPERATURE RESPONSE



This was not the case in a few experiments. Therefore the three-parameter linear model was adopted to describe the cooling process. It was dictated by considerations 1 and 3. Consideration 2, which may superficially seem important, did not enter into the selection of the model.

Experimental Observations

The results of the cold-immersion experiments are summarized, in terms of the linear-model parameters, in Table I-7. The means and standard errors of the means are shown for each of the three parameters for each of the test articles. The t parameters have been presented in units of hours to facilitate later estimation of survival times in hours. It should be noted that the t's range over such small values (less than 0.59 hours) that they would not

TABLE I-7
RESULTS OF COLD-IMMERSION EXPERIMENTS

Test Article	Parameters: t (hrs) Mean	t (hrs) S.E.M.	T (°C) Mean	T (°C) S.E.M.	r (°C/hr) Mean	r (°C/hr) S.E.M.	r (°C/hr) S. D.
WE1*	.37	.16	.11	.02	0.64	.16	.36
WE2	.34	.09	.25	.09	0.62	.13	.29
WE3*	.33	.11	.15	.04	0.46	.10	.23
WP1*	.25	.07	.18	.09	1.06	.34	.76
WP2*	.36	.04	.15	.05	0.51	.05	.11
WP3*	.32	.07	.20	.08	1.09	.46	1.03
WP5*	.31	.06	.29	.05	1.19	.46	1.13
WP6*	.33	.05	.14	.03	0.48	.12	.27
WP7*	.19	.08	.20	.08	1.68	.49	1.20
D2 *	.59	.15	.30	.13	0.55	.10	.25
D3 *	.40	.02	.26	.09	1.30	.40	.89
DF1 (PVC)	.22	.09	.04	.02	0.37	.03	.07
DF2	.36	.07	.12	.03	0.48	.10	.25
DF3	.45	.10	.15	.03	0.47	.07	.16
DA1	.54	.11	.13	.03	0.33	.03	.07
DA2 (closed)	.16	.08	.04	.02	0.27	.03	.07
DA2 (open)	.42	.12	.06	.03	0.44	.01	.02

* Results obtained in approximately 11.8°C water, other results obtained in approximately 1.7°C water.

contribute more than a small proportion of reasonable survival times (a few hours or more depending upon the suit).

3.4 Analysis and Discussion

In analyzing the results of the cold-immersion experiments, the first step was to develop the capability to predict, for each test article, the parameters of the cooling model for the body structures of interest (thin, average and heavy). Because the parameters t and T were expected to have relatively little impact upon survival-times estimates, it was decided that this effort would be concentrated upon predicting the rate of cooling r and that the survival-time estimates for each suit would be based upon the average values $\bar{t}$ and $\bar{T}$ shown in Table I-7.

Development of Cooling Rate Regression Predictors

A set of six quantitative measures of physical/metabolic attributes were composed and investigated to determine if one would explain the variation in cooling rates observed with each of the test articles. The indices, denoted X1 through X6 are defined as follows.

1. $$X1 = \left[\frac{\text{Heath-Carter III}}{(\text{Heath-Carter I})\cdot(\text{Heath-Carter II})}\right]$$

2. $$X2 = \left[\frac{X1}{\text{Metabolic Rate After 1-Hour Immersion}}\right]$$

3. $$X3 = \left[\frac{\text{Weight}}{\text{Surface Area}}\right]$$

4. $$X4 = \left[\frac{\text{Mean Reciprocal Skinfold Thickness}}{X3}\right]$$

5. $$X5 = \left[\frac{(\text{Surface Area})\cdot(\text{Mean Reciprocal Skinfold Thickness})}{\text{Metabolic Rate After 1-Hour Immersion}}\right]$$

6. $$X6 = \left[\text{Total Skinfold Thickness}\right]^{-1}$$

The first index, X1, is based entirely on the three components of the Heath-Carter somatotype method. This index was found by Hayward, et al., (1978) to explain cooling-rate variation moderately well. The second index, X2, was formulated to determine what improvement in the performance of X1 would result from including the consideration of the individual's capabilities to generate heat. Metabolic rate measured after 1 hour in the cold was chosen since it was available most consistently. The third index, X3, is formulated to consider the individual's propensities to exhibit thermal inertia as measured by body weight and the area that he possesses through which heat may be lost. The fourth index, X4, was recommended by Keatinge (1979) as having worked well in his experience. The "mean reciprocal skinfold thickness" was computed as $(\sum_{i=1}^{3} S_i^{-1})/3$ where S_1, S_2 and S_3 are the tricep, subscapular and suprailiac skinfold thicknesses. The fifth index, X5, was formulated to consider the primary thermodynamic factors which should affect changes in core temperature -- surface area, thermal conductivity of surface material and the rate of internal heat production. The last index, X6, was formulated to be a simple measure of fatness. Of the 6 indices, X1, X2, X4, X5 and X6 were arranged to be direct indicators of expected cooling rate. That is, cooling rate would be expected to increase as each of them increase. Index X3 is arranged in reverse fashion -- cooling rate should decrease as X3 increases.

Each of these indices were computed for each test subject from the data presented in Table 1-5. First-order, least-squares regression relations were established relating cooling rate to each of the 6 indices for each test article. They are of form $r' = ax + b$ where the x is one of the 6 indices and r' is the predicted cooling rate. The accuracy with which regression relations conform to data is often expressed by "F test statistics". The significance of these statistics may be interpreted by the "level of significance" at which the hypothesis, that the observations follow the linear model ($r' = ax + b$), may be rejected. Small levels of significance indicate that the regressions conform well to the observations. Table 1-8 presents the significance levels for the $r' = ax + b$ regressions for each index and each test article. No regressions were possible with indices X2 and X5 for test article DA2 since metabolic rate data during immersion was unavailable. Table 1-8 also shows the average and maximum of the significance levels for each index. The best indices are X4 and X6 which exhibit an average significance level of about 2 percent and a maximum significance level less than 7 percent. This indicates that either of these indices could be used to predict cooling rates for this collection of test articles. Because of its simplicity index X6 was chosen for use in this study.

Index X6 has a value of 1/30.6 = 0.0327 for the average of the test subjects participating in this study. This corresponds to a value of 3 in component 1 of the Heath-Carter somatotype method. The "middle range" for this component is from 3 to 5 (Carter, 1975). This indicates that the group of test subjects described in Table 1-5 (all college students) are thinner than a comparable group selected at random from the population at large.

TABLE I-8

SIGNIFICANCE OF INDICES FOR PREDICTING COOLING RATES

($r' = ax + b$ Model)

Test Article	X1	X2	X3	X4	X5	X6
	Physical/Metabolic Attribute Indices					
WE1	.080	.084	.087	.060	.078	.065
WE2	.050	.048	.031	.031	.034	.032
WE3	.066	.064	.064	.064	.054	.066
WP1	.044	.019	.082	.012	.131	.006
WP2	.003	.004	.001	.002	.004	.002
WP3	.158	.213	.119	.068	.165	.067
WP5	.001	.001	.026	.007	.005	.006
WP6	.006	.002	.022	.024	.064	.026
WP7	.009	.005	.005	.003	.090	.002
D2	.013	.008	.004	.006	.002	.006
D3	.133	.132	.130	.046	.101	.053
DF1(PVC)	.004	.002	.003	.002	.001	.002
DF2	.006	.002	.016	.011	.007	.011
DF3	.008	.009	.010	.006	.011	.008
DA1	.006	.006	.007	.005	.003	.004
DA2(closed)	.003	-	.001	.007	-	.007
DA2(open)	.000	-	.000	.000	-	.000
Average	.035	.040	.036	.021	.050	.021
Maximum	.158	.213	.130	.068	.165	.067

Elements in table are levels of significance at which the regressions may be accepted as accurate predictors of cooling rate.

However, these test subjects may be more representative of military personnel, merchant seamen and recreational boaters who may be more fit than the population at large. To establish a quantitative description of the "thin" and "heavy" individuals for survival-time estimation, Heath-Carter component I values of 2 and 6 will be used. These values correspond to 21 and 62 mm total skinfold thicknesses, respectively. Reviewing the data describing the range of total skinfold thickness with which each suit was tested (Table I-6), it may be seen that all test articles were tested at or near a 21 mm total skinfold thickness but none were tested near 62 mm. This means that the regression relations for predicting cooling rates are valid for thin (21 mm) and average (30.6 mm) individuals but are not necessarily valid for heavy (62 mm) individuals. Therefore another model must be developed in which more confidence can be placed for predicting cooling rates of heavy individuals.

As skinfold thickness increases its reciprocal (index X6) decreases approaching zero and presumably the corresponding cooling rate decreases toward zero. A zero value of the reciprocal of total skinfold thickness, which means infinite total skinfold thickness, is of no practical importance. However, by forcing a linear cooling-rate predictor to indicate a cooling rate of zero when the reciprocal of total skinfold thickness reaches zero and by simultaneously forcing it to give the best (least-squares) fit to the experimental data, one may achieve reasonable extrapolations of the cooling-rate observations for large skinfold thicknesses (small reciprocals).

The linear model which passes through the origin is of form $r' = c \cdot x$. The least squares estimator for the coefficient c for a particular test article is:

$$c = \left[\frac{\sum_{i=1}^{n} X_i \, r_i}{\sum_{i=1}^{n} X_i^2} \right]$$

where n = the number of cold-immersion experiments with the test article

X_i = index value for subject in experiment i with the article.

r_i = cooling rate observed in experiment i with the article.

These linear models were developed for each of the test articles and evaluated (as the $r' = a \cdot x + b$ models were) with the F test statistics. The levels of significance of the models using index X6 were calculated for each test article. The average of them is about 0.6 percent and the maximum is about 2.4 percent. This indicates that these models using index X6 are quite accurate. Hence, they will be used to estimate the cooling rates for heavy individuals. The cooling-rate, regression predictors for thin, average and heavy individuals are shown for each test article in Table I-9. Both regression models are based on analysis of the exact values of index X6 and the cooling rates observed with each subject testing each article. The numbers of data points analyzed for the test articles are indicated in Table I-4 by "Number of Replications".

It is interesting to note that the only two appearances of negative values of "a" (the coefficient of the first order term in the basic cooling-rate, regression predictor) occurred for the two sets of experiments conducted with test article DA2. It was previously indicated that the X6 index varies directly with anticipated cooling rate. The negative coefficients of the index in the DA2 models reverses this behavior. This indicates that thin individuals cool slower than heavier ones in that suit (a reversal of the normal relationship). It should be recalled that DA2 is a one-size-fits-all inflatable suit. The reversal might result from thin individuals allowing the suit to inflate to a greater thickness than is possible with a larger person wearing the suit. This would provide greater buoyancy and thermal protection for a thinner individual. The increased buoyancy and lighter weight of the thinner individual would reduce the surface area immersed in the cold water. While this result was not found with the other inflatable test article (DA1), a relatively small value of "a" was found. The failure of the sign to reverse could indicate that, while generally the same factors described for DA2 were acting, the separate outer shell of DA1, which preserves more uniform effective air spacing between wearer and water, renders it less sensitive to those factors.

Establishing Cooling-Rate and Survival-Time Estimates

To determine the cooling rate estimates for individuals with the three selected total skinfold thicknesses one simply has to evaluate the appropriate predictor model, given in Table I-9, at the appropriate value of the X6 index (thin 0.0476; average 0.0327; and heavy 0.0161). The resulting cooling rate predictions are given in Table I-10. These rates are those expected when individuals with the various somatotypes are immersed in water of the temperatures in which the various suits were tested. The negative first-order coefficients discussed earlier for test article DA2 have resulted in larger cooling rates for average individuals

TABLE I-9

COOLING-RATE † PREDICTOR MODELS

Test Article	"Thin And Average" Individuals ($r^2 = ax + b$ Models) a	b	"Heavy" Individuals ($r^2 = cx$ Models) c
WE1*	20.514	-0.125	17.262
WE2	29.838	-0.319	19.990
WE3*	0.987	0.427	13.435
WP1*	74.746	-1.535	33.097
WP2*	11.147	0.124	14.558
WP3*	77.702	-1.527	35.391
WP5*	116.224	-2.580	41.372
WP6*	31.062	-0.456	16.546
WP7*	132.123	-2.858	52.963
D2*	20.570	-0.203	15.201
D3*	76.328	-1.705	34.505
DF1(PVC)	7.038	0.119	10.219
DF2	16.076	-0.138	12.649
DF3	22.673	-0.378	12.775
DA1	3.570	0.202	8.496
DA2(closed)	-1.956	0.346	6.484
DA2(open)	-0.271	0.451	10.738

† Cooling rates given in °C/hr

* Cooling rates predicted for immersion in 11.8°C water, other cooling rates predicted for immersion in 1.7°C water.

TABLE I-10

COOLING RATE † ESTIMATES
(Experiment Water Temperatures)

Test Article	Morphology: Thin Estimate	Thin S.D.	Average Estimate	Average S.D.	Heavy Estimate	Heavy S.D.
WE1*	0.852	.484	0.546	.424	.278	.588
WE2	1.101	.486	0.657	.305	.322	.420
WE3*	0.474	.588	0.459	.407	.216	.424
WP1*	2.023	.388	0.909	.333	.533	.715
WP2*	0.655	.099	0.489	.083	.234	.109
WP3*	2.172	.963	1.014	.816	.570	1.092
WP5*	2.952	.851	1.221	.579	.666	1.285
WP6*	1.023	.355	0.560	.229	.266	.313
WP7*	3.431	.641	1.462	.540	.853	1.186
D2*	0.776	.261	0.470	.229	.245	.311
D3*	1.928	.892	0.791	.867	.556	.416
DF1(PVC)	0.454	.085	0.349	.071	.165	.103
DF2	0.627	.280	0.388	.247	.204	.406
DF3	0.701	.181	0.363	.149	.206	.274
DA1	0.372	.084	0.319	.079	.137	.124
DA2(closed)	0.253	.079	0.282	.075	.104	.175
DA2(open)	0.438	.044	0.442	.042	.173	.207

† Cooling rates given in °C/hr

* Cooling rates predicted for immersion is 11.8°C water, other cooling rates predicted for immersion in 1.7°C water.

than for smaller individuals. This, of course, assumes that these individuals (thin and average) are immersed in the same type of one-size-fits-all suit. Custom fitting or even simple sizing could change this. It should be noted that the use of the $r' = cx$ model to predict cooling rates for heavy individuals wearing DA2 implicitly assumes that sizing to fit will be done.

Table I-10 also shows the standard deviations (S.D.) of each of the cooling rate predictions obtained from the regression relations. These standard deviations were computed for each test article and body morphology as follows.

$$S.D. = \left\{ MSE \cdot \left[1 + \frac{1}{n} + \frac{(X^P - \bar{X})^2}{\sum_{j=1}^{n} (X_j - \bar{X})^2} \right] \right\}^{1/2}$$

where MSE = mean square error from analysis of variance performed on the respective regression relationship

n = number of subjects testing the article

X^P = value of (total skinfold thickness)$^{-1}$ for which cooling rate is to be predicted

X_j = value of (total skinfold thickness)$^{-1}$ for subject j testing the article ($j = 1, 2, \ldots, n$)

$\bar{X} = (\sum_{j=1}^{n} X_j)/n$

These standard deviations recognize the intrinsic error in the regression relation, the size of the sample upon which it is based as well as the proximity of the value of the independent variable, at which the prediction is developed, to the values upon which the regression is based. These standard deviations indicate clearly that the cooling rate predictions involve less error for the average body morphology than for the thin or heavy ones.

Comparing the standard deviations for the average man to those for the cooling rates in Table I-7, it may be seen that the regression-based approach to estimating cooling rates which are sensitive to somatotype variation has produced only small reductions in random variation. Thus the main contribution of the regression-based analysis has been that it allowed survival-time estimates to be developed for selected somatotypes for all test articles.

This gives comparability in the results even though different groups of subjects tested each article. It is important to notice that though random variation was not reduced as much as had been hoped, it was certainly not increased to any significant extent by the analysis approach. It was increased for only three test articles: WE1, WE3 and DA2 (open); and these increases are unimportant in the comparison of the test articles because of the close agreement between the sample means ($\bar{r}$) and the regression estimates (r') for these three articles. The survival time estimates for thin and heavy individuals (though their random variation may be seen to be often large) could not have been developed without the regression-based analysis.

Each survival time is formulated as the time required for the individual to cool to 30°C core temperature. This time is the sum of that required for temperature to reach its peak value plus the time required for subsequent cooling to 30°C. It will be assumed that the time required to reach the peak temperature is the mean of these times ($\bar{t}$) observed with the respective test articles. It will also be assumed that the individual enters the water with a "normal" core temperature of 37.56°C and that his initial increase in core temperature will be the same as the mean of these values ($\bar{T}$) observed with the respective test articles. Thus cooling begins from a peak temperature of $(37.56 + \bar{T})$°C. The survival-time estimate (S) is as follows

$$S = \bar{t} + \frac{(37.56 + \bar{T}) - 30}{r'}$$

where $\bar{t}$ and $\bar{T}$ are selected for the appropriate test article from Table I-7 and r' is selected for the appropriate test article and morphology from Table I-10. The survival-time estimates resulting from this calculation are shown in Table I-11 ranked in order of decreasing values for the average individual. The test articles have been divided into two groups in this table. Those listed above the horizontal line were tested in 1.7°C(35°F) water. Those listed below the line were tested in 11.8°C(53.2°F) water. To achieve comparability among these two groups of test articles, the survival-time estimates for those tested in 11.8°C water will be adjusted (shortened) to approximate those which would result when immersed in 1.7°C water. It should

TABLE I-11

SURVIVAL-TIME † ESTIMATES
(Experiment Water Temperatures)

Test Article	Morphology: Thin	Average	Heavy
DA2 (closed)	30.2	27.1	73.2
DA1	21.2	24.6	56.7
DF1 (PVC)	17.0	22.0	46.3
DF3	11.4	21.7	37.9
DF2	12.6	20.2	38.0
DA2 (open)	17.8	17.7	44.5
WE2	7.4	12.2	24.6
D2*	10.7	17.3	32.7
WE3*	16.6	17.1	36.0
WP2*	12.1	16.1	33.3
WE1*	9.4	14.4	28.0
WP6*	7.9	14.1	29.3
D3*	4.5	10.3	14.5
WP1*	4.1	8.8	14.8
WP3*	3.9	8.0	13.9
WP5*	3.0	6.7	12.1
WP7*	2.5	5.5	9.3

† Survival time estimates given in hours.

* The estimates for these test articles apply for immersion in 11.8°C water.

be noted that in Table I-II only the lowest-ranked test article of the top group would rank below any of those in the bottom group if the groups were merged.

The problem of adjusting the survival-time estimates for changes in immersion-water temperature is a complex but unavoidable one. It is unavoidable if one wants to identify the least-inhibiting suit that will give at least 4 hours of survival time in 1.7°C water. The problem is complicated because much more than mere thermodynamics is involved. When immersion-water temperature is lowered by 10.1°C one can expect a more pronounced elevation in rates of thermogenesis and possibly more pronounced peripheral vasoconstriction as well. These differences in physiologic responses may, to some degree, offset the increased rate of heat loss to be expected because of the increase temperature gradient existing between the immersion victim and the water. However, these response differences may be expected to vary among the test articles due to variation in the rates of cooling of different body surface areas.

The best available approach for quantitatively predicting the impacts, upon the cooling process, of immersion in colder water while wearing the suits which were tested in 11.8°C water, is to perform a detailed numerical simulation of the immersion, including consideration of characteristics of the test articles. Part III of this paper addresses an investigation of the accuracy of a variety of mathematical models for performing simulation of cold immersion. It is concluded in Part III that even with the best model considered (Montgomery's model) and with an improved metabolic rate control submodel substituted, the accuracy with which the model represents actual observations varies among the test articles. Therefore, one may not assume that the model produces results which are comparable among the test articles in colder water.

However, it is possible to use model simulation results to modify observations obtained in 11.8°C water to produce estimates for 1.7°C water without assuming that the model is accurate in an absolute sense. Instead one must assume only that the model's results, obtained for a given test article in different water temperatures, are relatively accurate (changes are proportionally accurate). This weaker assumption enables the estimation of proportional changes in the parameters of the cooling models ($\bar{t}$, $\bar{T}$, r') due to changes in immersion-water temperature, which may then be used to adjust the corresponding parameters developed from the data obtained from experiments in 11.8°C water. From these adjusted parameters, corresponding survival-time estimates can be developed. This process is symbolically described in the following algorithm.

1. Define parameters based on results in 11.8°C water.

   $\bar{t}_i$ = mean time for temperature to peak in test article i (i = 1, 2, ..., 10, since 10 suits were tested in 11.8°C water)

   $\bar{T}_i$ = mean elevation in rectal temperature at peak value in test article i

   r'_{ij} = regression-predicted cooling rate for morphology j in test article i (j = 1 represents thin, 2 represents average, 3 represents heavy

2. Define morphologies in terms of model inputs.

Morphology	Ht (cm)	Wt (kg)	Body Fat (%)*
thin	182.9	65.5	3.2
average	180.4	73.4	9.6
heavy	182.9	86.4	15.3

*Based on estimation in Montgomery's model drawn from Siri (1956)

3. Perform mathematical simulation for each morphology in each test article in 11.8°C and 1.7°C water. Determine

   f_i = ratio of time for temperature to peak for average morphology and test article i in 1.7°C water to the corresponding elevation in 11.8°C water

   g_i = ratio of elevation in rectal temperature at peak value for average morphology and test article i in 1.7°C water to the corresponding elevation in 11.8°C water

   h_{ij} = ratio of rate of cooling (peak to end) for test article i and morphology j in 1.7°C water to the corresponding rate of cooling in 11.8°C water

4. Estimate time for temperature to peak in test article i in 1.7°C water (K_i).

$$K_i = f_i \cdot \bar{t}_i \text{ for } i = 1, 2, \ldots\ldots, 10$$

5. Estimate elevation in rectal temperature at peak value in test article i in 1.7°C water (L_i)

$$L_i = g_i \cdot \bar{T}_i \text{ for } i = 1, 2, \ldots\ldots, 10$$

6. Estimate cooling rate for morphology j in test article i in 1.7°C water (M_{ij})

$$M_{ij} = h_{ij} \cdot r'_{ij} \text{ for } i = 1, 2, \ldots\ldots, 10 \text{ and } j = 1, 2, 3.$$

7. Construct survival-time estimates for test article i and morphology j in 1.7°C water (S'_{ij}).

$$S'_{ij} = K_i + \frac{(37.56 + L_i) - 30}{M_{ij}}$$

This approach to adjusting the cooling model parameters is consistent with the earlier development of parameters based on experimental observations in that distinctions in values of the minor parameters (t and T or K and L), due to variation in body structures, are not made.

The parameter ratios (f_i, g_i and h_{ij}) obtained by exercising Montgomery's model including the improved metabolic-rate-control submodel, 1.7°C-water results in the numerator and 11.8°C-water results in the denominator, are shown in Table I-12. The mathematical model could not simulate the effects of a device covering only part of the torso. Therefore, no results and hence no ratios could reasonably be obtained for WP7. For purposes of adjusting cooling parameters to allow estimation of survival time in 1.7°C water, it was assumed that the parameter ratios for WP7 are the same as those for WP5. It should be noted that the ratios of times to reach peak temperatures range from 1/3 to 3/4. The ratios of elevations in temperatures are based on small numbers, hence their range is relatively large (0 to 5). The ratios of cooling rates are generally well behaved among the test articles and among the body structures.

The cooling parameters resulting with the use of these adjustment factors are shown in Table I-13. These adjusted parameters are identified by the symbols used to represent them in the algorithm stated earlier. The survival-time estimates in 1.7°C water will be shown in a later table summarizing the results of this investigation.

TABLE I-12

RATIOS † OF COOLING PARAMETERS FROM MATHEMATICAL MODEL

Test Article (I)	Ratios of Times to Peak Temperatures (f_I)	Ratios of Elevations in Temperatures (g_I)	Ratios of Cooling Rates (h_{IJ})		
			Thin	Average	Heavy
WE1	.500	5.000	1.884	1.969	2.250
WE3	.667	4.000	1.864	2.007	2.118
WP1	.667	1.000	1.863	1.987	2.092
WP2	.500	0	1.700	1.769	1.841
WP3	.500	1.500	1.923	1.958	2.240
WP5	.750	1.500	1.987	2.040	2.366
WP6	.600	1.250	2.009	2.050	2.446
WP7*	.750	1.500	1.987	2.040	2.366
D2	.333	2.000	1.793	1.816	2.023
D3	.500	1.500	1.683	1.750	1.912

† Ratios constructed with 1.7°C-water parameters divided by 11.8°C-water parameters.

* Ratios for WP7 assumed same as for WP5

TABLE I-13
COOLING PARAMETERS ESTIMATED FOR 1.7°C WATER

Test Article (I)	Times to Peak Temperatures (K_I)	Elevations in Temperatures (L_I)	Cooling Rates (M_{IJ})		
			Thin	Average	Heavy
WE1	.19	.55	1.605	1.075	0.623
WE3	.22	.60	0.884	0.921	0.457
WP1	.17	.18	3.769	1.806	1.115
WP2	.18	0	1.114	0.865	0.431
WP3	.16	.30	4.177	2.013	1.277
WP5	.23	.44	5.866	2.491	1.576
WP6	.20	.18	2.055	1.148	0.651
WP7	.14	.30	6.817	3.000	2.018
D2	.20	.60	1.391	0.854	0.500
D3	.20	.39	3.245	1.384	1.063

4.0 WEARABILITY INVESTIGATION

Many of the cold-protection articles tested in this study are designed to be worn by individuals while pursuing their normal duties or activities. Therefore the choice of an article must be based on wearability as well as cold protectiveness. This aspect of the articles was investigated through mobility-reduction and fatigue-induction investigations.

4.1 Mobility-Reduction Investigation

The objective of the mobility-reduction investigation was to quantitatively assess the interference with mobility associated with wearing each test article selected for this investigation. The elementary movements which were selected for inclusion in this study were: shoulder flexion, extension, abduction, internal rotation and external rotation; elbow flexion; hip flexion (knee straight), extension (knee straight), flexion (knee bent), abduction, adduction, internal rotation, and external rotation; knee flexion; hand flexion; and spine flexion and extension. Selections were based upon importance of the movements in most physical activity.

The general approach to quantifying the mobility reduction associated with wearing a particular test article was to measure the ranges of motion of 5 test subjects for each selected movement while wearing nominal clothing (the standard work/rection clothing described in section 2). These measurements were repeated while wearing each of the test articles. The range of motion for each subject and each selected movement in a particular test article was compared to the corresponding range measured in the nominal clothing and the reductions were determined. This approach uses each subject as his own experimental "control". This measurement of ranges of motion was actually the second step of a two-step evaluation procedure.

The first step of the procedure was the subjective evaluation of motion inhibition performed by the test subjects. In this subjective evaluation they assigned an ordinal score depending upon their assessment of each elementary movement as follows.

Score	Definition
0	No interference at all
1	Can achieve full motion with extra effort
2	Slight reduction of motion
3	Moderate reduction of motion
4	Great reduction of motion

Following the subjective scoring, the reduction in motion was determined only for the elementary movements for which subjective scores of 2 or greater were obtained. The reduction of movement was determined by measurement of the ranges of each movement in and out of the test article, as described earlier. A reduction in motion of 0 was assigned to each elementary movement for which a subjective score of 0 or I was obtained.

A number of the test articles feature either deployable attachments or zippered gussets to increase comfort in the normal mode of wear while retaining cold-protection effectiveness. In general these articles were tested with these devices positioned so as to maximize comform and mobility in the dry. No flotation bladders were inflated and no supplemental flotation devices were worn during this investigation. All main entry closures were closed.

4.2 Fatigue-Induction Investigation

An objective of this investigation was to quantify and compare the propensities of several constant-wear, cold-protection articles to induce fatigue in the wearer. A second objective was to determine the increase in mean skin surface temperature resulting from wearing each article. The standard work/recreation clothing is used as the basis of comparison.

It would be impossible to predict the exact working activities of all individuals who might wear the cold-protection articles. Therefore, it was decided to test the articles with 5 subjects engaged in three exercises from which various working activities could be implied. The exercises were (A) sitting at rest for 30 minutes, (B) touching the toes for 5 minutes at a rate of 30 toe touches per minute, and (c) climbing two nine-inch stairs at a rate of 100 paces per minute for 5 minutes.

The articles were worn in the same manner as in the mobility-reduction investigation. Percent increases in heart rate and increases in average skin temperature were determined for each exercise and test article. The average skin temperatures were determined by weighting the three measurements according to the distribution of body surface between legs (39%), arms (19%) and torso (42%), (Hardy and DuBois, 1938). The results for the three exercises were averaged to produce fatigue and thermal stress descriptors for each test article. This averaging was done according to five different activity models. Each model was defined in terms of the relative importance of each exercise to the activity being modeled. They are indicated by the weighting factors in the following table.

Model Number	Type of Activity	Exercises A	B	C
1	Uncertain	.33	.33	.33
2	Generally Active	.10	.45	.45
3	Generally Sedentary	.80	.10	.10
4	Mostly Upper Body	.10	.80	.10
5	Mostly Lower Body	.10	.10	.80

The results of this analysis were compared across the five activity models leading to the conclusion that they were very similar for all the models and thus insensitive to variation in the particular activity being pursued. Thus the final results for both the fatigue and the thermal stress investigations are based upon Activity Model 1.

5.0 SUMMARY OF RESULTS AND DISCUSSION

The results of this study are shown in Table I-14. The suits have been ranked according to the estimated survival time in 1.7°C water for an individual with average morphology. The dashes indicate that a suit was either not tested in the cold water or not considered a constant-wear article.

A number of interesting observations may be drawn from the results in Table I-14. The respiratory heat reclamation feature of DA2 seems to significantly extend survival time. That for the average individual is extended from 17.7 to 27.1 hours. It should be noted that "dry foam" and "dry air" suits were categorically superior to dry suits and wet suits. This is consistent with the results of Hayward, et al. (1978). Suit D3 was regularly observed to contain significant amounts of water following cold-immersion experiments. It, therefore, should not be regarded as a proper dry suit. The other dry suit (D2) did not suffer this difficulty and performed better than all but one of the wet suits for an average individual. The best wet suit was WE2, probably due to its snug fit and resistance to flushing. The best wet-mode, partial-body suit, WP2, was the only one indicated to provide a thin individual more than four hours of survival time. This is due in part to it being tested in conjunction with the water wings flotation device. The next-best suit, WP6, is indicated to provide a thin individual about four hours of survival time. The longer survival times for the thin individual than for the average one in suit DA2 (open and closed) are due to the regression predictors obtained for that suit and probably result from the factors discussed earlier. The snug fitting ski vest, WP7, yields a 60% increase in estimated survival time over the kapok type of PFD investigated elsewhere (Hayward, et al. 1978).

The wearability indicators of mobility-reduction and fatigue inducement are also summarized in Table I-14 for those articles thought to be candidates for use in a constant wear mode. The mobility reductions are expressed in terms of the reductions in range of motion (averaged per subject for all 17 elementary movements) and the average number (per subject) of the 17 elementary movements for which full range of motion was achievable but only

TABLE I-14

EFFECTIVENESS AND WEARABILITY RESULTS

Test Articles	Survival Times (hrs)			Reductions in Range of Motion (°)*	No. of Movements Requiring Extra Effort*	Mean Percent Increase in Heart Rate†	Mean Increase in Surface Temperature† (°C)
	Average	Thin	Heavy				
DA2(closed)	27.1	30.2	73.2	-	-	-	-
DA1	24.6	21.2	56.7	18	3.8	11.5	1.8
DF1	22.0	17.0	46.3	-	-	-	-
DF3	21.7	11.4	37.9	-	-	-	-
DF2	20.2	12.6	38.0	3	3.0	19.1	2.7
DA2(open)	17.7	17.8	44.5	-	-	-	-
WE2	12.2	7.4	24.6	11	4.4	12.2	2.1
D2	9.8	6.1	16.5	57	4.5	6.8	0.8
WE3	9.1	9.5	18.1	6	3.0	4.2	2.1
WP2	8.9	7.0	17.7	28	3.0	4.0	1.4
WE1	7.7	5.2	13.2	20	3.4	9.8	2.4
WP6	6.9	4.0	12.1	0	1.0	1.7	1.5
D3	5.9	2.6	7.7	0	0.0	3.2	0.8
WP1	4.5	2.2	7.1	0	3.2	12.8	1.4
WP3	4.1	2.0	6.3	0	0.6	3.6	1.2
WP5	3.4	1.6	5.3	0	0.8	0.9	1.0
WP7	2.8	1.3	4.0	-	-	-	-
D1	-	-	-	0	2.0	8.5	1.2
WP4	-	-	-	41	5.6	5.3	2.0
WE4	-	-	-	10	5.8	8.9	2.6

* Averaged per subject

† Based on Activity Model I

at the expense of extra effort. The fatigue-induction and overheating results for Activity Mode I are also summarized in Table I-14. These are the mean percent increase in heart rate and the mean increase in surface temperature.

Concerning wearability, the WP type articles are better than the WE articles. The exception was the CWU-33/P(WP4) which was classified as a WP article only because it is short-sleeved. The addition of gussets to a wet suit such as WE2 offers little improvement in wearability compared to the standard wet suit WE4. The dry foam article, DF2 offers distinct cold-protection advantages however the wearability may be a problem as indicated by the large increase in heart rate and skin temperature associated with it. The wet partial body suit WP2 offers the best cold-protection of the WP-type suits however its wearability is less than the others of that type. This is due, in part, to characteristics of the flight coverall worn over the short wet suit during testing. The D-type suits appear to be very wearable with the exception of suit D2. However this suit was rather snugly fitting and therefore wearability improvements could possibly be obtained by more generous use of fabric such as in D3.

A dry-type suit such as D2 appears quite attractive from a cold-protectiveness standpoint and potentially so, regarding wearability. However, a question as to the heat resistance of the goretex material, from which D2 is constructed, has been raised (Harnett, et al., 1979).

In summary, this study was conceived to develop a basis for informed selections from the state-of-the-art in personal, immersion-hypothermia protection equipment. It is not possible to prescribe an optimal choice for all users based on this research. That must be left for the user who is aware of his priorities. This paper could only summarize some of the essential information needed to evaluate the trade-offs which are imbedded in the equipment selection problem.

6.0 REFERENCES

Carter, J. E. Lindsay (1975), "The Heath-Carter Somatotype Method", San Diego State University Syllabus 266165-513, Revised Edition, October, 1975.

Hardy, J. D. and E. F. DuBois (1938), "The Technique of Measuring Radiation and Convection", J. Nutrition, 15:461.

Harnett, R. Michael, Fred R. Sias, and James R. Pruitt (1979), "Resuscitation from Hypothermia: A Literature Review", Final Report U. S. Coast Guard Contract Number DOT-CG-72074-A, Task Number V, Clemson University, February 14, 1979.

Harnett, R. M., E. M. O'Brien, F. R. Sias, and J. R. Pruitt (1979a),"Experimental Evaluations of Selected Immersion Hypothermia Protection Equipment", Final Report U. S. Coast Guard Contract Number DOT-CG-72074-A, Task Number III Part 2, Clemson University, October 12, 1979.

Hayward, J. S., Lisson, P. A., Collis, M. L. and J. D. Eckerson (1978), "Survival Suits for Accidental Immersion in Cold Water: Design-Concepts and Their Thermal Protection Performance", University of Victoria, January, 1978.

Panel: Preventing Hypothermia
(protective clothing and survival equipment)

Position Statement

Edward M. O'Brien, Ph.D.
Clemson University

There are many different types of articles designed to protect persons against hypothermia due to cold water immersion. These articles can be classified either as dry mode suits or wet mode suits. The dry mode suits are whole body suits and can be further classified according to the type of insulation used. There are those using air insulation, those using foam insulation and those which provide very little insulation of their own (these are the dry shell type of suit). Of the wet suits there are those which cover the entire body and those which partially cover the body.

No sweeping statement can be made as to the best suit since the choice of suit depends often on other factors beside maximum survival time. Some of these factors are wearability, buoyancy, and fire resistance. However, the different types of suits available can roughly be ranked as follows concerning estimated survival time in 35°F water. Dry suits with air as the insulating medium provide the longest estimated survival time, dry suits with foam insulation are ranked next. Following these suits there is a large difference in the estimated survival time with the wet suits covering the entire body and the dry shell suits ranked next. The last suits in the ranking are those wet mode articles which only partially cover the whole body. Such a ranking is not as obvious concerning other factors governing suit choice.

Concerning increasing survival times, experiments have shown that a snug fitting ski vest PFD increases the estimated survival time by about 60% over a kapok Type II Mae West PFD and that reclaiming heat lost in respiration can increase survival time. An individual in a cold environment loses a significant amount of heat in warming and humidifying inspired air. Most of this heat is then subsequently lost with the expired air. An increase of 10 hours (a 53% increase) in the estimated survival time of an average individual wearing a dry suit with air insulation and respiratory heat reclamation as compared to the same suit without the respiratory heat reclamation has been shown. Therefore it seems desirable to incorporate this concept into the more protective dry suits.

The following characteristics would be desirable in the implementation. 1) The reclaimed heat should be used to pre-warm the inspired air. 2) The moisture in the expired air should be trapped (possibly to be reclaimed by the victim). 3) There should be no direct mixing of inspired and expired air because it might allow a carbon dioxide build up.

Another item of some importance and concern deals with the use of a goretex composite in the construction of light weight dry shell suits. Goretex is a synthetic microporous material which in its dry state allows air and water vapor to pass through it. When exposed to water it expands closing off the micropores thus becoming impermeable to water. The composite material generally consists of an outer layer of nomex (a fire resistant material), a layer of goretex, and an inner layer of either nomex or nylon. Fire exposure tests have shown that the goretex material tends to shrink and pucker when exposed to heat and to resist expansion back to its original shape. This would indicate that normal movement within a suit made from the goretex composite which was exposed to heat may in fact tear the goretex causing the suit to leak water.

The concept of a "dry" suit made from goretex is attractive for aircraft personnel who must constantly wear a cold protective device. However further research into its characteristics when exposed to heat is recommended.

Dr. Erling J. Oksenholt, D.O.
2930 W. Devils Lake Road
Lincoln City, Oregon 97367

Dr. Oksenholt practices medicine in a hospital near the Oregon coast and is thus the nearest hypothermia treatment facility for most coastal near-drownings. He has developed an effective hypothermia protocol for both the rescue teams and emergency room staff.

DR. ERLING OKSENHOLT

HYPOTHERMIA PROTOCOL

1.- Notify Hospital Immediately of possible Hypothermia victim

2.- Hospital to notify -- Hypothermia team
   - a.- 2 Physicians
   - b.- Inhalation therapist
   - c.- Lab. technologist
   - d.- X-ray technologist
   - e.- Physical therapy
   - f.- 2 Nurses

3.- If time available - hospital to send part of hypothermia team to beach

4.- Rescue Personnel
   - a.- Resuscitate all hypothermia victims (Not dead until warm and dead)
   - b.- Immediately place victim on stretcher - Do not allow victim to walk
   - c.- Handle patient gently
   - d.- Immediately remove wet clothes and pat dry
   - e.- Place cardiac monitor on patient
   - f.- Begin hot humitified 0_2 (105°- 110°)
   - g.- Place rectal temperature probe
   - h.- Place IV at K/O
   - i.- Allow no oral fluids

5.- Hospital procedures
   - a.- Temp. above 92° - Place in whirlpool 98° - 102° and hot humified 0_2 and warm IV fluid
   - b.- Temp. below 90° - Hot humified 0_2 plus warm IV fluid if not comatose
   - c.- Comatose or Arrested - May consider using peritoneal rewarming run 2/L as quickly as possible and remove (Warm fluids in surgery warmer at 130°)
   - d.- Monitor core temp. q 5 minutes.

e.- 1-2gm Cephalosporin IV for those with temp. below 92°

f.- Steroid 1-2gm Solumedral IV

6.- Lab.

a.- Chest x-ray - portable

b.- Electrolytes

c.- Blood gases

Motify PO_2 and PCO_2 to temp.

d.- Clotting studies and platelet count

7.- Admit all hypothermia victims with temp. below 95°

8.- Possiblilities to consider for future studies

a.- Value of Mast pants to prevent DIC

b.- Use of Barbiturates

Levels of 40-50ug/ml

Phenobarbital or Pentobarbital

9.- Patient needing C.P.R. - may be intubated - No patients with spontaneous heart beats.

10.- Defibillation - not to be done until core temp reaches 90° - 92° or greater.

HYPOTHERMIA CART

Purpose: The following guidelines should establish what equipment is located on the hypothermia cart; and, what equipment or solutions are located in other areas of the hospital.

General Directions/Guidelines:

A. A cart, completely equipped, will be kept in the respirator therapy room for the sole purpose of treating patients with acute hypothermia. The cart will be prepared at all times and the following equipment will be readily available:

1. 2 heated oxygen units with tubing and masks.
2. 1 extension cord.
3. 1 thermocouple (electric) thermometer with rectal prob
4. 4 Eveready batteries.
5. 2 Centigrade thermometers.
6. 1 screw driver.
7. 2 Centigrade conversion table sheets, one on each heat oxygen unit.
8. 2 Flowmeters with nipples.
9. 4 Oxygen masks (adult).
10. 4 Oxygen connecting tubing.
11. 1 OEM hand nebulizer.
12. 4 2000 ml bottles of Impersol.
13. 2 emesis basins.
14. 4 Scalpels with #11 blade.
15. 4 Betadine Solution Swabsticks.
16. 10 packs 4 by 4's
17. 10 packs K-Y jelly.
18. 2 airways (2 of each size ie: adult and child).
19. 10 copies of peritoneal dialysis record.
20. 3 Trocath peritoneal dialysis catheters #V4900 McGaw.
21. 2 Imperson sets with drainage bag. #1612 Abbott.
22. 1 small bottle of either vodka or 50% grain ETOH for inhalation.
23. 4 rolls tape 1".
24. 10 20 ga 1½ Angiocath.
25. 5 Medicuts.
26. 5 Butterflies 23 x 3/4.
27. 10 alcohol swabs.
28. 2 K-75 3-way stopcocks.
29. 2 I.V. loops (Connector loops).
30. 2 anesthesia Venosel (I.V. tubing) # 1884.
31. 1 500 ml Dextrose 5% in water.
32. 1 500 ml Lactated Ringer's Injection U.S.P.
33. 1 ambu-bag resuscitator.
34. 1 Puritan Heated Nubulizer with cora tubing and aeroso mask.
35. 1 Throat suction set (complete).
36. 1 Dririete set with black corrigated tubing.
37. 1 Heated water bath.

R. S. Pozos
Department of Physiology
School of Medicine
University of Minnesota-Duluth

ABSTRACT

EFFECT OF THE TEMPERATURE OF INSPIRED AIR
ON THE AMPLITUDE OF SHIVER

R. S. Pozos
Department of Physiology
School of Medicine
University of Minnesota-Duluth

Current thinking concerning thermoregulation states that the hypothalamus is the key site of thermoregulation. Recent results in our labatory indicate that the oral cavity might be sensitive to the temperature of inspired air. Surface electromyograms of the forearm, motion and air temperature were measured and recorded on a tape recorder. The temperature of cold inspired air caused an instantaneous increase in the amplitude of shiver in humans. These results are of significance since they indicate that there are some reflex loops which monitor inspired air, possibly in addition to the hypothalamus. In addition, this data would be important relative to different ways of elevating core temperature. Using warm humidified air to increase core temperature might inhibit some mechanisms that monitor temperature and control shiver.

Influence of Breathing Hot humidified Air on the Amplitude of Shiver

R. S. Pozos, L. E. Wittmers, Jr., P. Iaizzo, and S. Burgstahler
Department of Physiology, School of Medicine
University of Minnesota-Duluth, Duluth, Minnesota 55812

Shivering is a thermoregulatory neuromuscular response to cold and serves as one mechanism for increasing metabolic rate thereby increasing heat production. Although it is commonly observed, an exhaustive study of the electromyography of this important physiologic response has not been undertaken. This study deals with some initial observations concerning shiver and its modification by breathing humidified air of various temperatures.

Subjects were placed either in cold water (12°C) or in cold air (32°C). Temperatures were recorded from the rectum, tympanic cavity, from the skin surface over the pectoralis major, trapezius, and masseter. Surface electromyograms were recorded from the extensor digitorum, soleus, masseter, pectoralis major, and trapezius muscles. Motion was detected using an AVR-250 accelerometer attached to the knee. The signals were recorded on a tape recorder and later analyzed on a PDP-12 computer.

All subjects were stress tested and signed human consent forms before the experiment. As the person became cold, peripheral temperature dropped and there was an initial tensing of the musculature. This tensing is best seen in Figure 1 in which there is an increase in motor unit firing in the latissimus dorsi and in the masseter. This firing increased in intensity until there was synchronous bursts. In some individuals in cold air environment, the legs would demonstrate a clonus like activity which was synchronized with the EMG of the soleus. Eventually the subject, whether in water or in air, demonstrated an overt shiver (Figure 2) which was characterized by a waxing and waning of the amplitude of the shiver. This amplitude modulation is a well documented observation especially of muscle groups of the trunk. It is interesting to note that the leg shiver was not as evident in water as in air. This might be due to the fact that the legs were moving slowly in the water and also that stretch reflexes might not be as activated in water as when the subject is standing in air. In our laboratory, overt shiver of the legs was evident when the subject stood on the deck--whereas in the water, EMG activity associated with shiver was very low.

In the seven subjects tested (6 males, 1 female), there was a variability in the pattern of shiver in that not all individuals shivered in the jaw first.

In our studies, it has been observed that inspiration has been associated with the intensity of the shiver. We were interested in the increasing emphasis on rewarming hypothermic patients using hot humidified air. In our initial studies, subjects were made hypothermic by placing them in a cold environmental chamber and waiting until overt shiver was continuous. The subjects were then instructed to breathe hot humidified air (40^{o}C). As Figure 3 shows, when the subject breathed in hot humidified air, there was a reduction in the electrical activity of the soleus, pectoralis major, trapezius, and a decrease in the amplitude of the tremor. In some subjects associated with the inspiration of hot humidified air was an overt decrease in goose bumps and a blushing, especially on the backs of certain subjects. The response was instantaneous and persisted as long as the subject inspired the hot humidified air. After cessation of breathing the hot inspired air, there was a rebound effect, i.e. a pronounced increase in amplitude of the shiver.

Control experiments in which the subject just bent forward and touched the mouthpiece or breathed in cold air did not elicit the above responses. In fact, breathing in cold air increased the amplitude of the shiver.

During these experiments the core temperature was always higher than that of the periphery. Thus the shiver in all these studies was due to a decrease in peripheral relative to core temperature. The immediate decrease in amplitude of shiver with hot inspired air might be attributed to activation of thermal receptors in the mouth and/or respiratory tract. Since the response was so immediate, it does not seem that enough time had elapsed for warming of certain nuclei in the hypothalamus. Rather, this data substantiates other work which indicates that shiver may be produced by reflex loops independent of higher centers.

This preliminary data indicates that rewarming subjects using hot humidified air may influence those mechanisms that control certain aspects of the generation of shiver.

This work was supported in part by a grant from Sea Grant (DOC/NA79AA-D-00025).

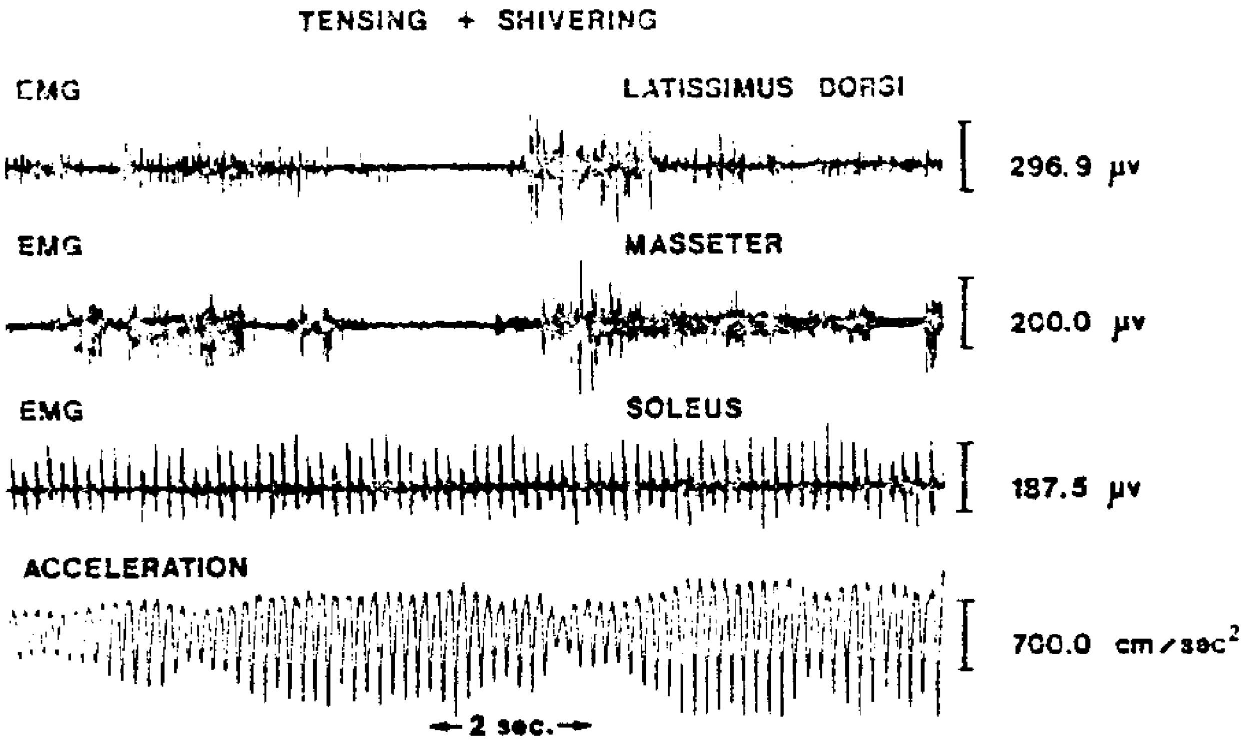


Figure 1. An example of tensing and shivering in a subject as the peripheral temperature dropped. Note the increased motor unit firing in the latissimus dorsi and masseter muscles.

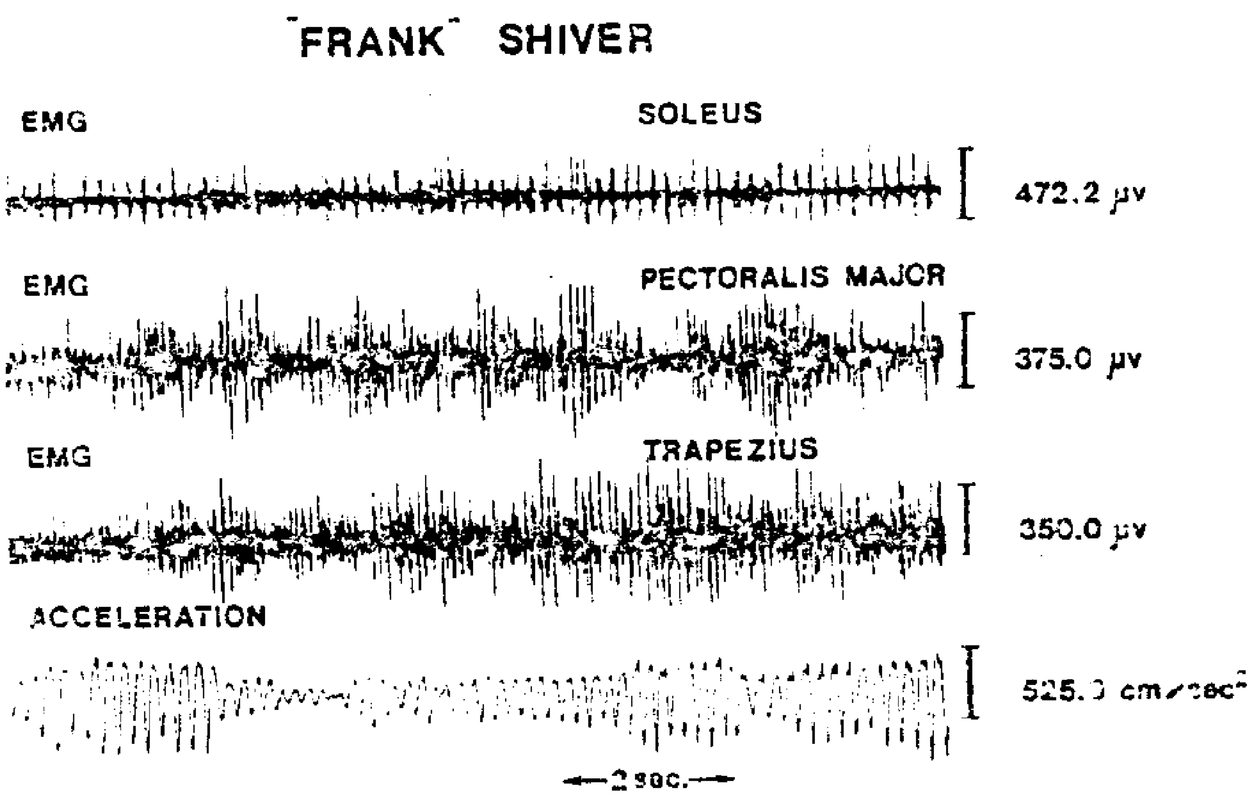


Figure 2. EMG and acceleration patterns associated with overt or frank shiver. Note the periodic changes in

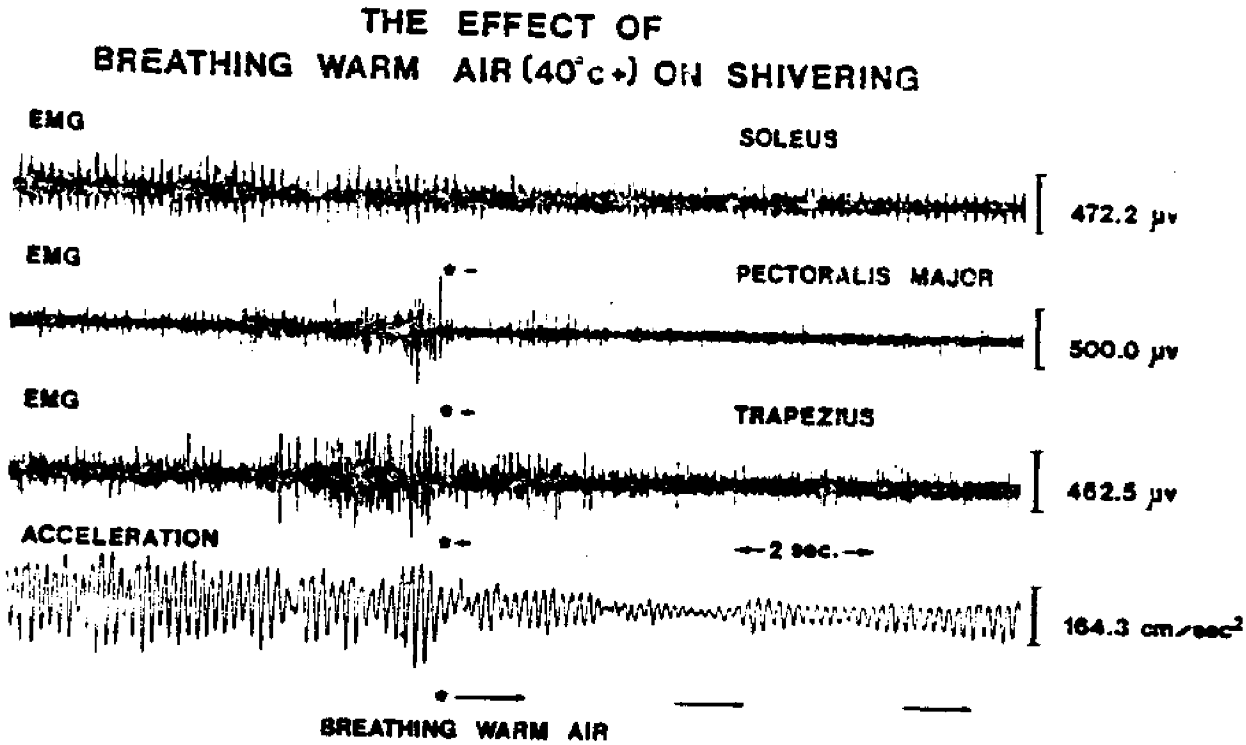


Figure 3. Effects of breathing warm humidified air on the electrical activity of three muscles as well as the acceleration pattern associated with shiver. Note the immediate* (first inspiration) decrease in both electrical activity and acceleration when the subject breathes the warm humidified air.

Workshop on Urban Hypothermia, Alcohol and Hypothermia, and Physically Handicapped and Hypothermia

R. S. Pozos, L. E. Wittmers, Jr., and N. Bradley
Department of Physiology, School of Medicine
University of Minnesota-Duluth, Duluth, Minnesota 55812

Although this topic is wide ranging, I believe there is a certain underlying theme from which the topic might make sense--and that is the various physiologic mechanisms that come into play when a person is hypothermic.

As a person is becoming hypothermic, many reflexes come into play. The initial tension of the skeletal muscle, the shiver, the peripheral vasoconstriction, the bradycardia, and increase in arterial pressure all depend on an intact neural system. In addition, there are those physical factors such as amount of fat, amount of skeletal muscle, etc. which will help determine the rate of heat loss. Finally, there are the metabolic responses which are associated with hypothermia, e.g. an increase in circulating catecholamines, lipids, and sugars.

In the case of physically handicapped persons, the insult to their CNS will obviously alter their reflex responses to cold. Although the term physically handicapped is encompassing, I use it to refer to groups that have suffered some form of altered motor function. Patients who are classified as suffering from cerebral palsy, stroke, multiple sclerosis, amputees, muscular dystrophy, are included in this group. In our laboratories, we have noticed an increase in the spasticity and rigidity of hypothermia patients who suffer from strokes or have cerebral palsy. Since thermal receptors of the skin influence the excitability of skeletal muscle reflex arcs, it is quite conceivable that severe impairment of function may be seen in physically handicapped people who are exposed to cold water. The degree of sensitivity to the cold water may differ among the physically handicapped. In fact, they may not be able to stand cold water stress to the same degree as normal individuals. Some physically handicapped individuals have low amounts of fat which also may influence their ability to survive in hypothermic environments. Since many physically handicapped individuals have lesions in the cerebral hemispheres or cerebellum, many complex reflexes that are involved in thermoregulation may be impaired. For example, lesions in the cerebellum alter the form of shiver so that it assumes a more choreiform kind of movement.

In the case of gerontologic patients who have not suffered any overt pathology, there is nevertheless a decrease in the ability to withstand hypothermia, the so-called urban hypothermia. A good definition of gerontologic patients relative to hypothermia is difficult. In this discussion, any individual past the age of 60 might be considered as being in this category. Overall there is a decrease in responsiveness of receptors so that the gerontologic person does not sense cold as early as does a younger person. Since many gerontologic persons are receiving medication for controlling cardiovascular or other pathologies, the influence of these drugs on altering the sensitivity of the autonomic nervous system relative to hypothermia needs to be thoroughly investigated. Many drugs which influence vasodilation tone of the cardiovascular system will compromise a gerontologic person's ability to withstand cold environments. To complicate the matter further, multiple drugs are prescribed to old individuals and their combined effects on the body's ability to regulate temperature are relatively unknown.

In terms of metabolic responses, let us assume an elderly person suffers from diabetes. What kind of problems will a diabetic encounter when exposed to a hypothermic environment? Again the research has not been done.

Finally, to round out this complex story, the effect of alcohol on the thermoregulatory mechanisms is in dispute. Although alcohol is considered a potent vasodilator, recent studies indicate that alcohol up to levels considered intoxicating (0.1 g%) does not seem to significantly influence the rate of fall of core temperature in a hypothermic environment. There might be some question about the levels of intoxication used in the above experiments, since in many accidents the levels of intoxication are much higher than .08 to .1 g%. In addition, although the decrease in core temperature is considered one of the primary parameters to consider, other ones may have just as great an importance. Shiver is supposedly decreased with high alcoholic levels and also alcohol might interfere with the ability to perform fine motor movements. In reviewing the literature, there is scant attention paid to the chronic alcoholic. Although there are cases of alcoholics who are found frozen every winter, I wonder how many survive. Many alcoholics do an impressive job remaining alive in subzero temperatures. Does alcohol really act like an antifreeze?

In both of the situations listed above--the physically handicapped and the elderly--alcohol ingestion may play a predominant role. Studies should be encouraged that address the specific problem areas above. It is very interesting that until recently no research into temperature regulation of the physically handicapped or of gerontological people was actively underway.

On a very practical aspect, personal flotation devices are usually not constructed with the physically handicapped in mind. In some initial studies undertaken in our laboratory, most personal flotation devices do not work in keeping the physically handicapped subject afloat so they can swim properly. Since approximately 20 million people are considered physically handicapped and there are active programs underway to promote the physically handicapped to use swimming pools, this is an urgent area of concern.

The following are considered as areas where research should be actively pursued:

1) The role of various CNS structures in terms of shiver generation and thermoregulation.

2) The role of stretch reflexes in thermoregulation.

3) The alteration of the autonomic nervous system with age and the consequent effect on temperature regulation.

4) The alteration of thermoreceptor sensitivity with age and the consequent effect on temperature regulation.

5) The alteration in "physical fitness" of older people and how this affects temperature regulation.

6) The effects of drugs commonly used with older patients and their effects on temperature regulation.

7) An exhaustive study of the acute and chronic effects of alcohol and its metabolites on temperature regulating systems in the body.

8) An in depth study of the hypothermia effectiveness of existing personal flotation devices.

9) Designing life jackets with the physically handicapped in mind.

10) Researching the effects of various drugs used to control cardiovascular function and quantitating their effects on the thermoregulatory centers of the body.

This work was supported in part by a grant from Sea Grant (DOC/NA79AA-D-00025).

Nancy Richardson
Marine Education Specialist
Girl Scouts of the U.S.A.
830 Third Avenue
New York, NY 10022

HYPOTHERMIA

ypothermia? "Low body temperature" probably makes more sense but still may seem as emote as Antarctic ice. Not so! Even on a "nice" day, a day hiker or eager swimer may shiver, fumble, or forget, showing symptoms of mild hypothermia. At the exreme, hypothermia is behind many stories of "death from exposure" or "drowning."

lthough sometimes called "the killer of the unwary," fear of hypothermia, low body emperature, need not keep Girl Scouts from venturing out any more than fear of fever, igh body temperature, might. Preventive measures are logical, symptoms are easily ecognizable, and early treatment is simple and effective.

he following pages define the terms, describe the conditions, preventive measures, ymptoms, and treatment. The reasons behind the suggestions and cautions are added o that they may be wisely applied to differing circumstances. Although cold, wet, r windy conditions occur without purposeful malice, nature's neutral challenges are st met with an alert mind and a prepared body. The will to live does make a difence.

CHILLING FACTS

- Hypothermia weather is not "freezing."
  10°C (50°F) air and moderate wind can catch the unwary.

- Moving air or water is more chilling than still air or water.
  40°F air + 20 mph wind = 20°F equivalent chill temperature!
  4°C air + 32 kph wind = -7°C equivalent chill temperature!

- Hypothermia water is not "icy."
  Some people can't keep body temperature up even in 22°C (75°F) water!

- Water conducts heat at least 25 times faster than air.
  20°C (70°F) air feels warm, 20°C (70°F) water feels cold!

- Evaporative cooling is faster in a wind.
  Wet, cold clothing can refrigerate 240 times faster than dry, warm clothing!

- Most cases of mountain hypothermia occur between 1°C and 10°C (35°F - 50°F) Mist, sweat, and rain are important contributing factors!

Metric abbreviations: C = Celsius; kph = kilometers per hour

TERMS TO KNOW...

- Hypothermia = "Low/temperature." Hypothermia, or lowered internal body temperature, occurs when the body loses heat faster than it can produce it.

- Long-term hypothermia refers to gradual cooling of the body, with a prolonged progression of symptoms. Changes in body chemistry and fluid imbalances complicate treatment.

- After-drop refers to further lowering of body temperature after warming treatment has begun. Any exercise may result in cooled blood circulation problems leading to heart and breathing stoppage.

- Survival time refers to the time between exposure to hypothermic conditions and death. Preparation and preventive measures being equal, the speed of the progression of symptoms varies with the amount of energy reserve and body type of each individual. Women and children are more likely to succumb first because of their smaller bodies, even though women have more body fat for insulation.

- Immediate disappearance syndrome refers to death by cold shock and drowning from sudden immersion in cold water.

- PFD = Personal Flotation Device. A PFD is a buoyant jacket, vest, bib, cushion, or ring designed to be worn or thrown to keep a person afloat.

- HELP = Heat Escape Lessening Position. HELP, like a fetal position, is assumed to slow cooling from major loss areas (groin and sides of chest.) Keeping knees up with arms at sides is recommended on land, or in water when a PFD is worn.

- Huddle refers to 2 or 3 people forming a close group to preserve body heat. It too is recommended on land as well as in water, when PFD's are being worn.

- Drownproofing refers to relaxed, face-down floating recommended only in "warm" water.

- Foul-weather gear refers to a windproof and waterproof outfit of jacket and pants.

FREEBIES!

Hypothermia and Cold Water Survival
U.S. Coast Guard, Aux - 202 (10-76)

Cold Water Survival
The Canadian Red Cross Society
with the assistance of Mustang Sportswear, LTD,
Vancouver, B.C. V6B 2L3

For the Unprepared - Hypothermia, A Killer Companion
The Adirondack Mountain Club, Inc.
172 Ridge Street, Glens Falls, New York 12801

Fatigue - Exhaustion (.02 ea.)
Survival Education Association
9035 Golden Given Road, Tacoma, WA 98401

With the film By Nature's Rules
Four Lines of Defense Against Hypothermia
Mountain Rescue and SAFECO Insurance
Association Sterling Film Libraries
866 Third Ave., New York, N.Y. 10022

BE PREPARED !

AN ALERT MIND IS THE BEST SURVIVAL TOOL!	A PREPARED BODY IS THE BEST SURVIVAL KIT!

Plan ahead for emergencies:
- File trip or float plan
- Plan checkpoints and signals
- Monitor the weather
- Enforce the buddy system
- Select a sensible leader
- Keep a positive outlook!

Be in good condition and carry gear to:
- Stay dry (rain gear, spare large plastic bag)
- Stay warm (spare wool layers, a hat)
- Fuel up (energy foods, hot drinks)
- Produce heat (dry tinder, waterproof matches)
- Stay afloat (PFD)
- Signal distress (whistle, light, flares)

+ STAY WARM !

PROTECT CRITICAL HEAT-LOSS AREAS:
- "When your feet are cold, put on a hat." From 25% to 50% of total body heat lost radiates from the <u>head</u>.
- Assume HELP to protect <u>sides</u> of chest and <u>groin</u>, other major areas where blood vessels are close to the surface.
- If in water without flotation, <u>don't</u> drownproof - with the head under water the combined effect of major head heat-loss and faster water conductivity cuts survival time drastically (75%!). Slowly treading water is twice as effective as drownproofing.

MAXIMIZE INSULATION:
- Wear layers of wool clothing rather than one heavy garment. Layers insulate as body heat warms the trapped air. Top layer should be windproof and waterproof. Apply this to feet too ... leather or rubber shoes are warmer than canvas.
- On water, wear PFD on top of other layers. Insulating properties of a float coat quadruple survival time. Fitted foam vest triples time, with kapok vest, then bib-type PFD's least warm.
- Keep collar, hood, and cuffs snug to prevent moving air or water from exchanging cold for warmed layers.
- Insulate against cold surfaces. Avoid sitting, kneeling, or lying down without padding (grass, leaves, newspapers.) Remember the "sit-upon"?
- Wear gloves when handling cold objects.
- Keep metal tools, knives, axes, sheathed away from the body.

BEFORE VENTURING OUT IN THE COLD:
Compare cotton and wool when wet. Dip a cotton sweatshirt cuff and a wool sweater cuff into about an inch of water. Watch one "wick". Which would stay drier and warmer? Put on one wet wool sock and one wet cotton sock (glove, sleeve). Which feels warmer? In a "wind"?

+ STAY DRY !

- Cover up <u>before</u> getting wet or change to dry clothes and keep them dry! Wet clothes lose up to 90% of their insulating value.
- Wear wool. It is still 40-60% effective even when wet.
- Avoid cotton. It "wicks," spreading moisture from fiber-to-fiber making a larger area to cool by evaporation.
- Avoid plastic alone. It has poor insulating qualities and body moisture builds up inside unless well ventilated.
- Avoid wearing a poncho in wet or windy weather. It "leaks" - moisture drips in and heat flows out. Keep one handy to rig a shelter or windbreak.
- Keep up "loft" of down. If down gets wet or matted, insulating air spaces between feathers are lost.

BEFORE VENTURING OUT IN THE WET:
Test foul-weather gear when under a shower or sprayed by a hose. Exercise and perspire in foul-weather gear. Does it leak? Does it "breathe"?

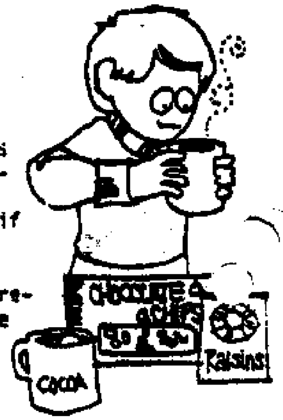
*SLOW DOWN !

- "Quit while you're ahead!" means to quit while your head can still think safely. Cool blood slows, delivers less oxygen: the brain suffers. Use energy only to make things snug and sheltered before reserves and reason are lost.
- Reduce perspiration by reducing exertion. Perspiration means the body is dumping heat and moisture. Energy can go into producing heat rather than motion if the body is at rest.
- Make short rest stops. Five to seven minutes is long enough for muscles to dump built-up lactic acid and relieve the "tired feeling."
- Rig a distress signal to show without constantly expending more energy. Wave, splash, shout, or whistle only when rescuers are likely to see or hear.
- Swim only if it counts. Be certain of reaching a worthy goal (flotation, other people, shore.) Swimming sends warm blood to shoulders and limbs, greatly increasing heat-loss. In 10°C (50°F) water, hypothermia hits a "good" swimmer wearing a PFD after swimming only 1300 meters (1400 yards). In 0°C (32°F) water, 185 meters (200 yards) is the limit!

BEFORE VENTURING OUT TOO FAR:

Practice distress signals. Use the best attention-getter: CONTRAST.
Know why emergency gear is "international orange".
Learn to set off a flare.

*FUEL UP !



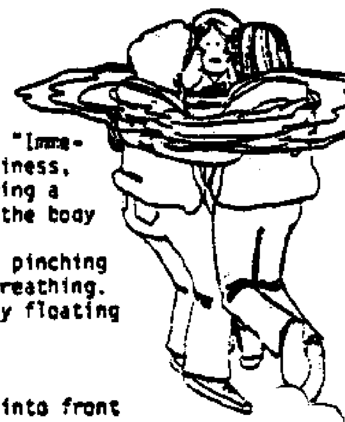
- Eat well regularly. Maintain an energy reserve with a balanced diet.
- For quick, ready energy, have frequent sugary snacks. Avoid "junk" foods, as usual. Gorp, raisins, chocolate, and candy will keep up the body's heat-production without burning the reserve supply.
- Provide hot drinks to warm the inner core. Energy levels will benefit too, if drinks are healthful (soup, bouillion, broth, cocoa, tea with sugar, or hot fruit drinks.) Avoid too much coffee.
- Don't have alcoholic drinks. Alcohol gives a false impression of warmth by reducing shivering. Actually, surface blood vessels are relaxing, allowing more blood to circulate and cool more.

BEFORE VENTURING OUT IN WET WEATHER:

Test water-proof matches and match holders by dunking them in water.
Then, in the rain or under a sprinkler, light a fire.
Boil water for energy drinks.

*STAY AFLOAT !

*HELP (Heat Escape Lessening Position)



- Put on a PFD.
- If forced to enter the water, go in slowly. Sudden immersion may cause "Immediate Disappearance Syndrome" with uncontrollable rapid breathing, dizziness, and acute pain. Surviving such cold shock may be possible only if wearing a PFD. Relieved of the struggle to keep from gulping water and sinking, the body has a chance to adjust to the cold.
- If forced to jump in, be prepared for cold shock. Increase buoyancy by pinching nose and holding breath, hopefully long enough to surface and control breathing.
- Once in, try to get out of the water and stick with the boat or a nearby floating object. Rig protection from any wind.
- If nothing floating is around, stick with other people. Form a HUDDLE.
- If alone, assume HELP.
- If not wearing a PFD, layers of clothing increase buoyancy. Blow down into front of jacket to improvise flotation. If possible, trap air in boots for buoyancy. Inflated pants make a float too.

BEFORE VENTURING OUT ON THE WATER:

Test different types of PFD's for buoyancy and warmth.
Practice HELP and HUDDLE positions.

SYMPTOMS

If the inner core temperature deviates only 1°C (2°F), distress signals from the brain warn of the onset of trouble. Recognize the symptoms!

SHIVERING, COLD HANDS & FEET

Shivering is usually the first sign of possible hypothermia. The body is using bursts of energy in an effort to produce heat, but the heat loss goes on. "Cold hands mean a warm heart." The body constricts surface blood vessels to reserve warm blood for the inner core. Since the temperature of the extremities may drop to 4°C (40°F), without damage, frostbite is not necessarily associated with hypothermia. Symptoms of hypothermia demand treatment before frostbite.

STOP: Recognizing and attending to these first symptoms may only require helping the victim put on dry clothes. Don't ignore the symptoms.

BODY TEMP:
33°-36°C
(92°-96°F)

CLUMSINESS, LOSS OF DEXTERITY

As the limbs receive less and less warm blood, responsive movement becomes more and more difficult. Muscle control centers are affected too, since less oxygen is transferred by cold blood in constricted blood vessels. The victim stumbles and fumbles. Along with growing numbness, the victim is unable to get going after a rest stop.

STOP: Don't believe a victim's claim of "I'll catch up," she really CAN'T. Find or rig shelter and start rewarming!

LOSS OF REASON AND RECALL

The brain's thought control centers, starved for warm, oxygen-rich blood, start closing down. The victim acts careless and dazed. Responses may be inappropriate or show loss of memory. Speech is slow and slurred. Without reason, the victim may over-exercise, using up energy reserve to the point of collapse. Beyond caring, the victim may give in to conditions, dozing off without protection from the elements.

STOP: Don't believe victim's claims of "I'm Okay." The victim really doesn't know better! Before it's too late, keep the victim awake and provide protection and heat.

SHAKING, MUSCULAR RIGIDITY

The exhausted body gathers futile and wasteful bursts of energy, at times shaking the victim violently. Since cold, slowly moving blood stagnates, body chemistry is altered and muscles become rigid. With a slow and irregular pulse, breathing is also erratic. Skin may appear discolored and feels very cold and puffy to touch.

BEWARE: Cold shock to vital organs, abnormally low blood pressure, and chemical imbalances may be fatal, even hours after warming treatment has apparently "cured" the victim. MEDICAL ASSISTANCE IS CRITICAL!!!

Body Temp.
30°-33°C
(86°-92°F)

COLLAPSE ... DEATH

...n the brain control centers fail, vital organs struggle on with increasing difficulty and irregularity. Breathing and heart beat finally stop. Lungs may hemorrhage, causing frothing at the mouth.

DON'T GIVE UP! Although fatal after-drop is likely, don't assume death until the victim is warm and dead. MEDICAL ASSISTANCE IS IMPERATIVE.

BODY TEMP. 25°-30°C (78°-86°F)

TREATMENT

To provide selective and gradual warming is the simple treatment for raising lowered body temperature. Take care! Beware of after-drop.

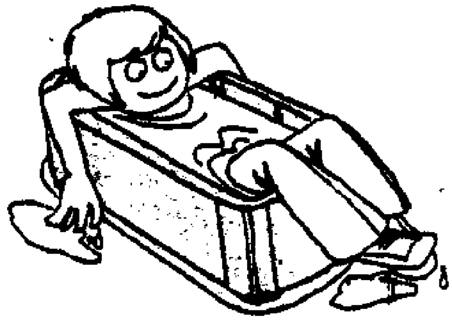
ALWAYS:

- Insulate victim against cold
- Protect victim from wind and wet
- Minimize movement of victim's body (even walking takes energy)
- Try to keep victim awake
- Keep victim's head low, feet up (get warm blood to head first)
- Beware of after-drop
- Protect victim from helicopter wind-chill
- SEEK MEDICAL ASSISTANCE

NEVER:

- Never leave victim without a heat-source (it won't help to just cover the victim)
- Never massage or rub the victim (expecially NOT with snow!)
- Never jostle the victim (such movement could cause heart stoppage)
- Never give alcohol
- Never give a sedative, tranquilizer, or pain reliever
- Never give up without medical advice

▵ WARM BATH



VICTIM: Must be conscious

RESCUER:
- Concentrate heat on trunk to prevent "after-drop"
- Start water at 20°C (70°F) raise to 42°C (110°F) (comfortable to elbow test) over 10 minute time span

▵ HOT TOWELS

VICTIM: May be unconscious

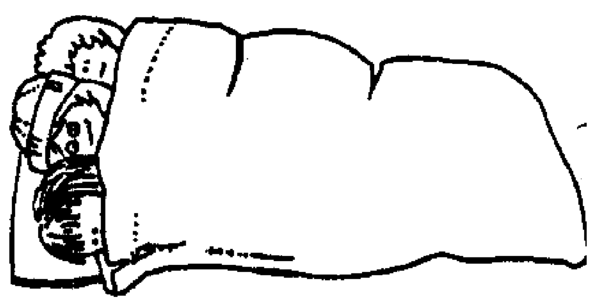
RESCUER:
- Wrap trunk (not limbs) in hot towels or blankets
- Keep warming with warmer water (like bath)
- Hot water bottle or wrapped, hot rocks OK too
- Beware of causing superficial burns

▵ WARM AIR

VICTIM: Must be handled GENTLY.

RESCUER:
- Do not try to get the victim to swallow warm drinks.
- Scarf over mouth and nose will trap warmth from exhaled air and pre-warm next breath
- Mouth-to-mouth resuscitation transfers warm air to victim (conscious or not)
- Special respirators provide warmed, moisture-laden air

▵ BUDDY-WARMING



VICTIM: Must be handled gently (conscious or not)

RESCUER:
- Remove all wet clothing (cut away to avoid jostling)
- Place victim on side in sleeping bag or blankets
- Warmth donor(s) should strip too
- Position donor(s) for direct skin-to-skin, heat transfer to front and back of victim.

by Nancy H. Richardson

ABSTRACT:

Drowning Facts + Myths, Part II

By: LCDR D.S. SMITH, USCG
Chief, Boating Affairs Branch
Second Coast Guard District, St. Louis, MO

New, provocative developments in water and boating safety understandings augur for reductions in aquatic fatalities. Unfortunately, those most responsible for disseminating such information are frequently conditioned not to productively recognize and/or respond to it. Methods are introduced and discussed for productively modifying behavior in such instances.

These methods are derived from understanding and applying:

Education, Eden and Enthusiasm; Philosophy, Psychology, and Technology: Illogical, Irrational, and Irreverent Behavior.

These concepts are examined, illustrated, and integrated in the paper. Direct relationships between them and the present hypothermia seminar are drawn. A "game plan" for producing change in individuals or organizations is outlined.

Lt. Commander David Smith
Boating Safety Branch
Second Coast Guard District
St. Louis, Missouri

Lt. Cmmdr. Smith is heavily involved in training instructors in hypothermia treatment and cold water survival techniques. He is the author of the Coast Guard's "Handbook for Coldwater Survival" and has appeared on numerous TV and radio shows to discuss this topic. In the Second Coast Guard District where he heads the Boating Affairs Branch, the methods he has been teaching were put into practice and resulted in a 17 percent reduction in one year of drowning deaths in his district. He is a graduate of the Coast Guard Academy and has worked with Coast Guard personnel in the area of leadership and motivation throughout his career.

DROWNING FACTS AND MYTHS - PART II
LIEUTENANT COMMANDER DAVID S. SMITH, USCG

INTRODUCTION

Review of reports of drowning, or occupational/recreational, water related deaths, indicate that almost all of these fatalities are easily avoidable. Yet, because of human proclivity toward occasional or chronic aquatic ignorance or stupidity, far too many people manage to drown themselves each year. The purpose of this paper, therefore, is to illuminate approaches proven affective in reducing the numbers of these deaths. This pursuit will proceed from the prospective of three E's, three O's, and three I's. These relate to: Education, Eden and Enthusiasm; Philosophy, Psychology and Technology; and Illogical, Irrational and Irreverant behavior.

The First E-Education

We are all products, victims,[1] or actually involved in the formal process of education. What is education? There are probably as many answers to this question as there are persons asking it. Education is one of the most general, non-specific and malleable of terms. It has myriad meanings. Its interpretation varies among individuals as well as institutions. To by-pass this quandry, might we, at least within the context of this paper, consider the roots of the word and a literalization of them as binding?. Education is taken from the latin: e ducere, to lead out. That is fine, but what does "to lead" mean? Again, could we, for the purpose of our discussion compromise upon: to guide and to influence?

In education, therefore, we are attempting to guide and to influence others as they move (or are caused to move) from one point to another. May we consider these points to lie along a spectrum labeled understanding, with our actual activities defining levels of understanding? Moreover, might we also state that we desire:

a. That these understandings and their resultant activities be purposeful:

b. Be productive (useful to the whole rather than destructive);

c. Remain firmly in our behavioral repertoire, over time?

If so - we may have arrived at a workable concept of education, i.e. a purposeful, lasting, productive modification of behavior.

Fine. Now we have a concept to work with. However, before attempting to bend behavior, we should agree on other, basic considerations.

THE THREE Os.

As man-and womankind take their first, faint, faltering steps into the cornucopial abyss of space, we are begining to comprehend the biblical adage concerning all things' working together.[2] The earthly ecologist has reminded us of the precise balances and interactions of nature on our planet. Correspondingly, the cosmologist and his physicist contemporaries are also beginning to discover the amazing interrelationships of all bodies, both great and small, in the cosmos.[3] This leads to two gentlemen of special note in our considerations. These gentlemen are Doctor Eric Berne and Mr. Julian Jaynes.

Doctor Berne's simplification-interpretation of psychoanalytic thought has given us a method for analysing and comprehending human behavior, both ours and other persons', known as Transactional Analysis or T/A. Doctor Berne has postulated that we are several, if not many interacting persons in one.[4] He tells us that our behavior depends on the persons within us as developed through our upbringing, innate personal attributes, and the situation at hand. Moreover, most of our behavior, most of the time can be described as repitious replaying of certain "taped" instructions or postions, unconsciously perpetuated, reinforced, and maintained by us.[5] Doctor Berne's work gives us a least two insights useful in our discussions.

Firstly, to adequately view people, ourselves included, we have to objectively consider them from several viewpoints. Secondly, most of what we do, we do unconsciously.

Ergo, to change or to modify our behavior we have to be aware of what we are doing, compared to what we might rather do, then concentrate on methods for changing our inner tapes, or reprograming our cerebral computers.

Mr. Jaynes' impact on our considerations also has to do with how we think. Running through most modern, as well as many not so modern attempts to explain human behavior in the singular or plural, is the dichotomous theme of mechanistic versus holistic thought.[6] Jaynes postulates that our left and right cerebral hemispheres respectively control the analytical and synthetical aspects of our thinking.[7] For several soundly stated reasons, Jaynes sees humanity progressing from a mechanistic, analytical way of viewing the universe, to more of a holistic, synthetical posture. As one hemisphere has to do with rationality, and reasoning, and the other with emotion and intuition, the most workable approach seems to involve accomodation of both.[8]

Therefore, in dealing with the problem of preventing / reducing death in the water, we should analyize the related facts and then synthesize them into an employable, comprehensive solution - approach.

What does this have to do with the three Os? And more basically, what are the three Os?

The First O - Philosophy.

To track with Dr. Berne we should view ourselves from several aspects. In this paper these viewpoints fall under philosophy, psychology, and technology. What is philosophy, and who or what is a philosopher? For our purposes, a philosopher is one who searches for deeper, yet common meanings. Philosophy also can be thought of as a way of viewing, or playing, the game of life.

It can be successfully argued that philosophy, at least in rational, proportedly thinking beings,[9] preceedes and shapes behavior. In other words, what we do is activated, allbeit too often from tapes, by what we think we should do. As an agreeable, useable example, what really underlay the lunar landing of July 20th, 1969? Along with important technological understandings and undertakings, there was a philosophical compulsion being actualized, which is best described by James F. Bell. Mr. Bell said, "To face tomorrow's problems with yesterday's solutions, is to view life at a standstill. If we are to progress there is not one of us doing something well today, who can't do it better tomorrow. New initiatives, new understandings, new competancies lie all about us, if we only have the vision to see them and the courage to grasp and to use them".

Who was James F. Bell? He was the administrator of NASA, the person most directly accountable for the activities of 7/20/69. Didn't Bell's philosophies as well as rocket fuel have much to do with this particular ascension? Courage and vision are as equally important to our basic water safety theme as they are to grasping and altering any human problem. Later, we will discuss them in relationship to the three I's.

The Second O - Psychology

As philosophy gives indications of why we do what we do, psychology, the study of behavior, tells us how we do what we do. We have stressed several basic psychological concepts in our comprehensive approach to reducing water fatalities. For instance, we indicate that many persons employed in life guarding at pools or beaches, really do not know what a drowning person looks like.[10] This is due to our reactions' being dependent on and conditioned by what we think we see, rather than what is actually transpiring. We have stressed the belief that an appreciable portion of drowning or hypothermic accident victims may be declared dead when alive, because they either appear dead, or because the erstwhile rescuer has been situationaly conditioned to believe them dead.[11] We also have investigated and interpreted common, psychological relationships in different types of recreationists which result in their becoming victims of aquatic accidents. An example of this is the fisherman who, especially in the spring or fall, repeatedly ventures alone or unheralded upon cold, lethal waters, devoid of other humans. When this fisherman typically refuses to wear or to use a personal flotation device, while all too typically imbibing alcoholic spirits, he sets himself for tragedy either in the immediate or discernable future.[12]

We have also discussed how knowledge of behavior is essential to our encouraging and producing change in others. We stress the simple tasks of ingratiating ourselves with an audience or class by giving them both our gifts and ideas. Also stressed is our communicating on several levels through touch as well as visual and auditory example and experience.[13] These are all valuable, yet too frequently overlooked tools in a well rounded attempt to approach others, and to share new, exciting, worthwhile ideas.

At this point, holistic/mechanistic inneractions also come into play both in an individual or organizational sense. Thor Hyerdahl, a philosopher as much as an explorer - scientist, has given us a perceptive model/parable of the primary failings of modern, analytically oriented science.[14]

Hyerdahl likens many, if not most of those who labor so dilligently in ever narrowing disciplinary nitches, to miners, extracting precious jewels. Yet, when these jems of understanding travel from the digging pits, no one is available on the surface to mold or to meld them into a workable, understandable whole. The metaphor in our deliberations is easily grasped. As an example, the United States Coast Guard has, for years, faithfully kept records of how, where and when boaters meet untimely ends.[15] These data have been used for numerous studies, both within or without the government, to understand and to develop responses to boating accidents. However, as the well meaning statisticians labored diligently to accrete bits of information, few individuals outside the pale of statistics attemped to: (a) comprehensivelly interpret the data; or (b) to broadcast what the data or its trends meant. Mechanistic, traditionally, "tribally" dominated, conservative organizations are innately, (inertly) inclined to dote upon their own understandings and not to generally share (dilute) them with, or by outside influences.[16] For instance, when Mr. Frank Pia originally submitted his excellent "Drowning Facts and Myths" film to the Coast Guard, very few who saw it appreciated what they were seeing. Their primary response was, "we deal with boating deaths, this film mainly treats drownings." The fact that most boating deaths are drownings, didn't seem important!

Similarly, in another related example of normal interorganizational, territorial myopia, the statsticians haven't communicated with the propagandists. The standard protective prescriptions given and perpetuated by the propagandists exhort boaters not to: speed; overload their boats; and to become experienced, disciplined operators. Unfortunately, the quiesent statisticians have known for some time that speeding, overloading, and operator inexperience, although important, were not the primary causes of fatal boating accidents. Rather, the leading, overwhelmingly typical fatality involves falls from, or capsizing of, non-moving, less than overburden boats, by persons well aquainted with what they were doing! Disquieting revelations of a like nature from the total spectrum of water fatalities led to deeper, philosophic attempts to gain a truer perspective of what interrelately occurs to cause in-water deaths. And, more importantly, which synthetically generated, global approaches are of value.

in treating these causes. Of similar importance and impact have been comprehensive attempts to share information developed through the above perspectives. We are now participating in one of these informational endeavors.

The Third O - Technology

The third O is directly related to the second E in our discussion. This E denotes Eden. Eden may not only have been a real place, but in many ways it may still exist. Technology is that part of modern life which allows us to do much of what we do. It allows us to enrich our life styles and to expand our ability to grasp and to use all the many resources that we find surrounding us.

There are few people attending this conference who live in caves. We are all the products of, and influenced by, a modern technological society. Through modern technology we are able to visualize solutions to many problems, and, through computer enhanced designing, we are able to produce the solutions in fantastically short time periods. As awesome as the potentials of modern science are, we still have constraints on our abilities. These constraints involve two words that have been previously mentioned. The words are vision and courage. It takes vision to see where solutions must be derived; or, how some solutions produce more problems and to anticipate these. It takes vision to understand problems. It takes courage both to generate thoughts concerning these difficulties and to change methods and approaches we have been using for years, methods involuntarily taped into our behavior. How many of us are ritualized into seeking old solutions to new problems?

As an example, manufacturers of life saving devices and safety equipment have worked hard to meet the problems of survival, especially in cold water. Unfortunately, many people needing these devices are completely unaware of their existence. One group may lack the aggressiveness (courage) to plumb new markets, while the other is slow to explore (envision) new, existing solutions. These two groups have not secured a bridge of understanding between them. Building this bridge is also one of the purposes of our conference.

The Three Is.

The three I's of Irrational, Illogical, and Irreverent behavior are especially germain to our discussion. It can been said that realty is in actuality a temporal, relativistic, consensus. It can also be said that to advance we need new and different thoughts which continually border on the edge of irrationality or consensus. Many of the ideas being discussed, demonstrated, and employed at this conference are, to many people, totally irrational. To tell the average, experienced outdoorsman that the more clothing he wears the better he will float, is to him a statement that simply does not make sense. We are thinking differently here. But, too frequently in our culture, being different is equated with being less. This conference is demonstrating that being different is not less, rather being different may represent a great resource in dealing with any problem.

In a similar vein, much of what we are discussing appears illogical. The path from Ptolemaic thought to Copernicus to Newton to Einstein is laced with illogic. Each one of these thinkers changed, indeed shattered, the concepts which moved before them. Their ideas did not fit the standard, existing frame of thought. But, because of them, we have advanced. Is it therefore logical to assume that we know all and that there is no need to change? This is especially true as we meet in the ninth decade of the 20th century, surrounded by all the wonders and mysteries that modern science is continually exploring. As we need irrational thought we also need illogical thinkers who are willing to break with the past, to pursue new, different and frequently fruitful ideas.

The third and last I, irreverence, has to do with doubt. This particular doubting relates to personally proving what is true. This is one basis of discovery learning. We use discovery learning in our pool demonstrations, allowing each person to see and to experience the points we are stressing. Also, we insure that our instuctors undergo that which they teach, before they give it to others. This is the challange of irreverence. Many of you, upon leaving this convocation, will come into direct conflict with widely and long held theories of survival, both in and out of the water. Basic to this outlook is the need for testing before we accept, in dogmatic and yielding fashion, previously generated ideation and concepts. As our world more rapidly changes and technology brings us revelations heretofore undreamed, an uncompromisingly irreverant outlook may be necessary for more than aquatic survival.

The Third E - Enthusiasm

Enthusiasm probably is the single greatest element in provident and productive change in individuals and organizations. Before we can productively involve someone else, we must be involved ourselves. To motivate, you must be motivated yourself. Enthusiasm is the key to motivation. The word enthusiasm comes from two greek words: en, a prefix meaning to be full of; and the overall root, theos. These two words are related directly to the latin basis of the word inspiration. They both literally mean to be full of the spirit of God.

It can be appreciated therefore, that what we are attempting to do is in some ways a religious activity. Although it may seem strange to interject this thought into the ending of our discussion, we are not departing from the precepts of the well known educational philosopher, Alfred North Whitehead. In Whitehead's final, philosophical analysis of the purpose and calling of education, he stated that education was a religious duty.[17] As can be discerned from what has gone before, the concept and the thrust of a calling and a higher direction, threads itself through our present, convocative deliberations.

In all of the foregoing we have considered both survival in the water, and survival in a much larger sphere. Outlined within this paper, and demonstrated through the growth and acceptance of this conference, are the key methodologies for insuring survival, through change, in any organization, corporate, or social.[18]

Footnotes/Bibliography

1. An introductory apology is required. Prior to demeaning other disciplines, the nascent educator must admit, in too many cases, Johnny can't read. Hopefully, the following will suggest approaches useful in my house as well as yours.

2. "And we know that all things work together for good to them that love God...according to His purpose," Romans 8:28. How frequently we embrace the initial part of this statement, but overlook the proviso on the end.

3. "There is... considerable current scientific interest in the implications for our world view, brought on by the recent experimental observation of "quantum interconnectedness", an apparent connection between distant events. This Quantum Connection is codified in a theorum of great elegance known as Bell's Theorum. This theorum emphasizes that no theory of reality compatible with quantum theory can require spatially separated events to be independent. Rather it must permit physically separated events to interact with each other in a matter that is contrary to ordinary experience. This aspect of modern theory, which has been experimentally tested and confirmed, reveals that parts of the universe apparently separated from each other can nonetheless act together as parts of a larger whole, a statement more expected to be found in mystical (or religious, see 2. above) writing than in a theory of physics." Targ R., and Puthoff, H., Mind Reach, New York, Delacorte Press, 1976, page 170. Also see, J. S. Bell, "On the problem of hidden variables in quantum theory, in Rev. Modern Physics, XXXVIII (July, 1966), No. 3, 447.

4. See Eric Berne, Beyond Games and Scrips, New York, Grove Press, 1976; and, Thomas Harris, I'm OK, Your OK, Boston, G. K. Hall, 1974.

5. The Swiss educational psychologist Jean Piaget also talks of this, from a different view point, in Genetic Epistomology, New York, Norton, 1971. Piaget postulates that perhaps only one out of ten persons is practiced in following the "What if, then" proposition in daily life. In other words, when psychologists refer to approximately 60% of humanity as depressed, they are saying that most of the time, most of us do not closely pay attention to, or contemplate outcomes of our activity.

6. Jaynes, J., The Origin of Consciousness in the Breakdown of the Bicameral Mind, Boston, Houghton Mifflin Company, 1977.

7. For an interesting, highly readable treatment of this see, Sagan, C., The Dragons of Eden, New York, Ballentine Books, 1978.

8. Doctor Jonas Salk, a philosopher as well as a scientist, has written: "Success in dealing with any problem is based upon... recognition and appreciation of the two complementary components of each dualism in a balanced coalescence. See Survival of the Wisest, New York, Harper and Row, 1973, page 54.

9. Carl Sagan (op. cit. 7.) is the model of renaissance man. His profession is basically astronomy/exobiology. From this pursuit he has distilled: "The primiary question now facing the human race, is not whether there is intelligence in outer space, but rather, whether there is intelligence on Earth."

10. Actual drownings are shown in Frank Pia's film "Drowning facts and Myths" (Water Safety Films, 3 Boulder Brae Lane, Larchmont, New York, 10538.). Of striking importance is the normal non-reaction of people surrounding the victim. Of the hundreds of water safety professionals and volunteers I have lectured, fewer then one in ten initially knew the three universal drowning behaviors demonstrated in Mr. Pia's film. Do you know them? I.e.: arms outstretched, simultaniously pressing downward on the water; head back; mouth open, but no sound.

11. Smith, D. "The EMT and the Cold Water Connection", The EMT Journal, Volume 3, No. 4 (December 1979), pages 55-58.

12. Harnett, R. and Bijiani, M., The Involvement of Cold Water in Recreational Boating Accidents - Final Report, Washington D. C., U. S. Coast Guard Office of Research and Development, Report No. CG-D-31-79, April 19[illegible], page 56.

13. Approximately 50% of all communication is non verbal, while [illegible] of all external stimulation in sighted persons is visual. See Koneva, M. and Barbour, A., Louder Than Words, Columbus Ohio, Charles E. Merrill Publishing Company, 1976.

14. See Hyerdahl, T., Early Man and the Sea, New York, Double Day, 19[illegible], for insightful comments on the "objectivity" of modern science.

15. Boating Satistics 19 -, Commandant Instruction M16754.1 (old CG-357), Washington D. C., U. S. Coast Guard.

16. For an interesting view of why this happens see Robert G. Snyder, "Knowledge, power, and the university: Notes on the impotence of the intellectual", in Gunter Remunling Ed., Towards the Sociology of Knowledge, New York, Humanities Press, 1971.

17. See Alfred North Whitehead, The Aims of Education and Other Essays, New York, MacMillan, 1929. "The essence of education is that it be religious..." A religious education ... inculcates duty and (true) reverence. Duty arises from our potential control over the course of events. Where attainable knowledge could have changed the issue, ignorance has the guilt of vice," and, "Education is the art of the utilization of knowledge."

18. "The mentally active scholar will acknowledge... that his mind roams far and wide. All is grist to his mill and he does not limit his supply to any one fenced-off field. Yet the mind does not really roam abroad. It returns with what is found, and there is constant exercise of judgement to detect relations, relevencies, bearing upon the central theme. The outcome is a continously growing intellectual intergration... "Within the limits set by capacity and experience, this kind of seeking and using (see op.cit. 17 above), of amassing and organizing, is the process of learning everywhere and at any age." John Dewey, The Way out of Educational and Confusion, pages 34-35.

The Cold Water Connection

by

LCDR D. S. SMITH, USCG

(NOTE: Although the statistical basis for this paper was obtained from Governmental or Public Service Agencies in the United States, the author believes the concepts developed herein are clearly applicable and transferable to any nation located in, or at a higher latitude than the Temperate Zone.)

Water-related recreation is one of the safest pastimes in the United States. Over 100 million swimmers and 53 million boaters annually enjoy themselves on and in our waters.[1] Comparatively speaking, the approximately 6,500 swimmers and 1,300 boaters who died in the water last year were an extremely small portion of this user population. When viewed against the total number of hours spent on or in the water, these fatality figures are insignificant, or are they? In the United States, water-related deaths usually classified as drowning, are the second greatest cause of accidental deaths among children. They are also the third leading cause of accidental deaths from ages 1 to 44.[2] If you happen to be a friend of, or related to, one of the unfortunate 7,800 people who drowned last year, you certainly wouldn't believe water deaths are insignificant. Moreover, if you were one of the far large number of people touched in some way by these needless and tragic deaths, you would want to do something about preventing them. Can something be done?

The overall accident rate for water fatalities has slightly diminished during the last several years. The accident rate is the total of incidents compared to the number of people exposed to the hazard. The number of people involved in swimming has slowly increased, in line with population growth. Boaters, on the other hand, have multiplied at a dramatic annual rate. The United States Coast Guard, individual state boating safety agencies, the American Red Cross, and other volunteer organizations involved in recreational safety, have been working hard to minimize boating accidents and general water safety hazards. As a result of their endeavors, the boating fatality rate was reduced 50% from 1972 to 1977.[3] However, despite this impressive decrease in boating deaths, most experienced water safety officials believe that very little can be done to further significantly reduce the overall water-related death toll.

1. Freeman, K., (Estimated from Records of) National Swimming Pool Institute, Washington, DC; and,
Stone, R., 1977 Boating Statistics Boating Industry Association, Chicago, Illinois, 1978.

2. Recht, J. L., Accident Facts, 1977 Edition, National Safety Council, Chicago, Illinois, 1977, page 8.

3. Boating Statistics 1977, U. S. Coast Guard Publication CG-357, U. S. Coast Guard, Washington, DC, 1978, page 7.

Their shared belief is largely based on the fact that almost all water accidents are caused by gross carelessness or ignorance, either on the part of the victim or others such as parents or responsible persons immediately involved in the accident. Although this is the general attitude that describes the water safety business, approximately the same number of people died every year from polio in the United States in the 1930's and 1940's as now die from drowning.[4] Last year no one in the United States died from polio. We were able to wipe out polio. Why can't we do the same with drowning? One of the prime problems is that identifying and treating the causes of infantile paralysis are in some ways far simpler than dealing with the traditional disregard of consequences and judgmental errors that result in water-related deaths. On the other hand, new and interesting discoveries in human psychology and physiology are being made every day; which, if properly understood, packaged, and disseminated, could result in startling reductions in water deaths. Here are a few of these ideas. Being at best a poorly aquaticly-adapted mammal, as a fisherman, water fowl hunter, or person who spends time near or on water, you are a prime potential victim. Leafing through the following, then, might prove to be some of the most important reading of your life.

Many who drown, don't. Some declared dead from drowning, aren't. Doctor John Hayward and his associates at the University of Vancouver, British Columbia, and Doctor Martin Nemiroff, University of Michigan Medical School, are two key researchers in the fight to reduce water-related deaths. Doctor Hayward is one of the world's leading authorities on hypothermia, or reduction of inner body (core) temperature due to exposure to a chilled or chilling environment.[5] Doctor Nemiroff specializes in pulmonary medicine or treatment of damage to the lungs and respiratory system.[6] These two authorities' research, coupled with current findings from boating and swimming accident statistics, are giving us different ideas about the causes of water accidents and the means to prevent them.

Although water-related deaths are usually called drownings, at least five different processes are involved. There are "wet" drownings where the victim dies from water inhaled into the lungs. There are "dry" drownings where the victim has little or no water in the lungs but suffocates due to blockage of the breathing passage. Some victims expire from shock-induced heart attacks. Many "drowning" victims die from hypothermia, or what is commonly called exposure. Finally, an appreciable percentage of deaths in boating accidents result from the victim's being thrown from, and then struck by, his own craft.

---

4. Historical Statistics of the United States - Part I, Department of Commerce, Bureau of Census, Washington, D. C. 1975, pages 9, 77.

5. Hypothermia and Cold Water Survival, U. S. Coast Guard Pamphlet, Aux-202 (Rev. 10-77), U. S. Coast Guard, Washington, D. C. 1977; and Cold Water Survival, Crowley Environmental Services Corporation, Seattle, Washington, 1976.

6. "Reprieve from Drowning", Scientific American Magazine, August 1977, page 57.

Analysis of statistics proves more significant information. Believably enough, 2/3 of all drowning victims cannot swim.[7] The American Red Cross states that victims usually die 10 feet or less from safety. Coast Guard boating accident studies indicate that only 7% of available PFDs(Personal Floatation Devices, life jackets or life preservers), are worn by people unintentionally thrown into the water. About one half of all boating fatalities occur during the cold water months of the year (September through May).[8] The air may be warm in May, but in many parts of the nation, the water certainly is not. Fisherman, both in boats and wading or on the beach, are frequent drowning victims. Over one half of all fatal boating accidents occur to unpowered or low powered craft under 16' in length. Most boating victims are over 26 years of age and have more than 100 hours of boating experience.[9] Many, if not most boaters or others required to use PFDs have little or no knowledge of how to properly wear them.

Factors which create stress or impair reaction time, such as the improper use of alcohol and addictive or harmful drugs, are increasingly recognized as an important aspect of water fatalities. Other stress factors are the frequently unnoticed, yet decidedly detrimental effects of continued exposure to sun, wind, vibration, noise, and other environmental factors present in the average boating day.[10] These most frequently effect people either unaccustomed to them, or in poor physical condition.

The Cold Water Connection, or the both harmful and helpful effects of cold water, is an important part of this total picture.

The average fatal boating accident may occur as follows: one or two older experienced, weekend fisherman will put their small, low or unpowered and relatively unstable rowboat or canoe into a somewhat isolated or unpopulated lake or pond in late September of early May. They may or may not tell anyone where they are going. They probably cannot swim. They may be in less than average physical condition. They will not wear PFDs, although they may carry Coast Guard-approved floatable cushions in their boat. They will be wearing heavy clothing. They will probably have some alcoholic beverages with them. At approximately 4:00 in the afternoon they will stand or suddenly shift their balance. The boat will capsize or tip enough to throw one or both into the cold water. Their reactions in the next seconds will determine life

7. Swimming and Water Safety - Course Manual, American Red Cross, Washington, D. C., 1977.

8. Op. Cit., reference 3. above, page 23.

9. Ibid, page 21.

10. Mac Neill, R., and Cohen, S. Recreation Boat Safety Collision Research - Phase II, Volume I Report # CG-D-129-76, National Technical Information Service, Springfield, VA., 1976, page 19; and Miller, J. M. Gatchell, S. M. Dykstra, D. R., The Visual Behavior of Recreational Boat Operators, Report # CG-D-31-77, National Technical Information Service, Springfield, VA, 1977, page 5.

or death. Unless they have been specially prepared or trained, they will probably panic. If they have been drinking alcoholic beverages, they may be confused and disoriented. They may struggle or attempt to remove their heavy clothing or try to swim to the nearest safety. They will quickly lose heat and ability to function in cold water, especially if their capalaries have been dialated by consumption of alcohol. They may have massive cardiac arrest induced by the shock of cold water, lose consciousness and rapidly sink to the bottom. It may be hours before anyone realizes they are in difficulty. It may be days before their bodies are found, if ever.

What can be done to prevent this particular type of accident? Understand and appreciate the inherent problems of small boat instability, plus accept the idea that the older we get, the more unstable we become. Tell someone where you are going and exactly what time you will be back. Appreciate the fact that increased amounts of alcohol speed instability and disorientation, especially in colder water. In cold weather boating always wear a PFD. And learn to swim. Note that insulated clothing, minimized movement, clear thinking, and a PFD provide the best possible defenses against cold water.[11]

Shopping for one of the warm, serviceable, and stylish "float coats", which are also Coast Guard approved PFDs, is one good way of protecting yourself from cold water. Floatable snowmobile suits are also on the market. One of the Canadian makers of these coats claims they will protect and extend your survival in 50° F water up to 9 hours, which is two to four times longer than if unprotected.[12] These float coat PFDs are truly thoughtful Christmas and birthday gifts, as well as being worthwhile insurance policies in themselves. Spending a lot of money for a boat and associated gear, but not buying or actually practicing proper use of personal floatation devices, can be fatally foolish.

Swimming fatalities tend to fall into two general categories. Victims may either be improperly supervised, non-swimming children, or adolescents and adults (frequently intoxicated) who take unnecessary risks in unfamiliar situations.[13] The marked drowning frequency of 18 year old males often in cold water, shortly after high school graduation, underscores this point. Another extremely important aspect of drownings is that most potential observers or rescuers are unaware of the typical behavior of a drowning victim or distressed non-swimmer.[14] Drowning victims cannot call out for help; do not wave for help; do not move laterally in the water; are partially blinded

11. Smith, D. S., Handbook of Cold Water Survival, Second Coast Guard District, St. Louis, MO ,1977, page 7.

12. Cold Water Survival, Crowley Environmental Services Corporation, Seattle, Washington, 1976, and Hayward J., "Man in Cold Water", (16 mm sound/color film) University of Vancouver, Vancouver, British Columbia, 1976.

13. Steihl, C., Alcohol and Pleasure Boat Operators; Report #CG-D-134-75, U. S. Coast Guard, Washington, DC, 1975, page 6.

14. Pia, F., Drowning Facts and Myths, (16mm Sound/color film) Water Safety Films, Incorporated. Larchmont, NY 1976.

by immersion; and have poor control over leg and arm movements. Moreover, the average drowning occurs in 20-60 seconds. Unless those in position to offer assistance are trained in recognizing the typical movement of a drowning person, they may well witness the drowning but not realize what they are seeing.[15] This is especially true in drownings involving inebriated or drug affected victims, who frequently slip under the water while making no effort whatsoever to save themselves. Normally these victims are found only after detailed searches or when some one accidently steps on, or stumbles over them.[16]

Cold water is the villain in many water fatalities, but it also might be an unappreciated life preserver. Just as Doctor Hayward has demonstrated the harmful effects of cold water and what you can do to protect yourself in it (try H.E.L.P.)*, Dr. Niemeroff has discovered that a substantial percentage of presumably dead "drowning victims" are still alive.[17] In fact, Dr. Niemeroff has successfully revived, with no permanent after-effects, a young man who was trapped under water and ice for over 38 minutes.[18] Furthermore, in treating 50 drowning cases over the last 2 and 1/2 years, Dr. Niemeroff has successfully revived 33 persons, again without permanent brain damage. The average time underwater for these cases is 10 minutes. Most of these people are young and involved in cold water. **Dr. Niemeroff has no idea how many drowning victims are recoverable. He also has no idea of the time limits for survival under water. There is, however, some indication that about 15% of all drownings are "dry" with no water in the victim's lungs. These victims, frequently found floating on the surface, are the most easily revived. Additionally, the type of water, fresh, brackish, salt, etc, has an effect on revival attempts.

Going four minutes without oxygen may result in brain damage. However, we are now finding that some people, presumably dead from drowning who have been under water far longer than four minutes, still have breathable air in their lungs or usuable oxygen in their blood stream. These persons may appear dead.[19] Their skin and lips can be blue. They may have no observable pulse or detectable breathing. The pupils of their eyes may be fixed and dialated. Their bodies may appear ridged and cold to the touch. <u>Yet they are still alive</u>!

15. Ibid.

16. Ibid.

17. <u>Cold Water Drowning</u> - <u>A New Lease on Life</u>, U. S. Coast Guard Pamphlet. CG-513(MICHU-SG-77-104),U. S. Coast Guard, Washington, D. C. 1977.

18. <u>U. S. Coast Guard Hypothermia and Cold Water Survival Slide Show</u> Available from: National Audio-Visual Center, General Services Administration, Washington, D. C. 20409, 1977. (Price for slide presentation and script: $12.50)

19. Ibid.

Survival in these cases where the body tissues (especially the brain) are coolad, requiring less oxygen, is apparently aided by an involuntary reflex triggered by immersing the face in cold water. This reflex is known as "diving response". In diving response, a small, yet sufficient oxygen supply is very slowly and imperceptably circulated between the lungs, heart, and brain, but not to the extremities or skin. This diving response has been observed in air-breathing,aquatic mammals such as the whale, porpoise, or seal. When threatened, these animals have the ability to remain submerged for extended periods of time, up to a half hour for some species. Man, as a mammal, unknowingly has a capability for similar behavior. However, we are less apt to use this life saving response.[20] Diving response is related to hypothermia, since both involve the retreat of warm, oxygen-carrying blood into the body's core.

The treatment for hypothermia and cold water near-drowning is also similar. In both cases, the patient is warmed from the inside out. The best method for this in the unconscious patients is inhalation of moist, heated oxygen.[21] ***Agressive, sustained resuscitation, initialy attempted using rescue breathing and cardiac massage (cardiopulmonary resuscitation, or CPR) is recommended by Dr. Niemeroff in all drowning cases. He further recommends that even though the victim shows no apparent vital signs, they should be taken immediately to an adequate medical facility, treated with continuing CPR, or moist warm oxygen inhalation, and rewarmed to normal body temperature. As internal body temperature approaches its normal level, vital signs will become more apparent. Additionally, Dr. Niemeroff warns that many revived near drowning victims die within 24 hours of the accident. This is caused by residual, untreated water in their lungs. Therefore, in all drowning or near drownings, the victim should be taken to a hospital <u>immediately</u>.[22]

Cold water can kill, or in an unknown number of instances, cold water can prolong life. Much has to be learned about this interaction. The water temperature that marks the lethal/beneficial threshold has yet to be clearly identified. However, if you and your family go near the water, <u>learn to swim</u>. After that, find out how you can protect yourself or defensely use the <u>Cold Water Connection</u>. Lastly, attempt to teach your children the cardinal rule of safety: appreciation of the eventual outcomes of their actions. If you do this, you will not only teach safety, but you'll be teaching something much more valuable. Some call it common sense, some call it responsibility. All thinking adults respect it as <u>maturity</u>.

20. Op. Cit., referance 17. above, and, "Natural Life Preservers", <u>Time Magazine</u>, August 22, 1977, page 73.

21. Op. Cit., referance 11. above, p. 13; reference 18 above.

22. Ibid.

Additional Notes:

*H.E.L.P. Heat Escape Lessening Posture. In this position in the water, whether wearing a PFD or not, vital body heat can be conserved through insulating those areas where heat is most readily lost. The three prime heat loss areas are: the head, the armpits and down the sides, and the groin.[23] In H.E.L.P. the arms are securely held to the sides with wrists placed over the chest. The ankles are crossed, with legs drawn up as close as possible to the chest. The head should be maintained as much out of the water as possible. This posture, or huddling side to side with two or more people, may extend survival time two times longer than swimming or other activity. If thrown into cold water, the best survival technique is to initially move slowly and deliberately, using as little physical activity as possible. Rapid motion or other vigorous activity wastes body heat; forces out insulating and supporting air trapped in clothing; and disturbs warmed, insulating layers of water next to the body.[24] Therefore, in most cold water cases, it is advisable to assume the H.E.L.P. position or to raise the body as high as possible from the water (as on the bottom of an overturned boat) unless assistance is within very short swimming range.[25]

**Defining "cold water" is tough business even for the experts. It is probably somewhere around a water temperature of 70° F (21°C), but it may vary in each case due to the circumstances and physical makeup of the persons involved.[26]

***Rewarming hypothermia victims is best accomplished through placing heat producing sources such as heating pads or wet, warm towels or blankets over the areas of greatest heat loss.[27] In cases of conscious victims, drinking sweet, warm liquids increases bodily heat. However, in no case should alcoholic beverages be provided to a hypothermia victim. Less desirable methods for rewarming conscious victims are immersion of the trunk only in a tub of hot water; hot showers; or bundling with other naked persons in a sleeping bag. These rewarming techniques, symptoms, and cautions to be used with them are discussed in detail in the sources referenced in this paper.[28]

23. Cold Can Kill, (16mm Sound/Color film) (British) Royal Navy Training Films, 1972.

24. Op. Cit reference 11, above, page 7, pages 16-17.

25. Op. Cit., reference 18, above.

26. Ibid.

27. Ibid.

28. Ibid.

Boating Safety Division
Second Coast Guard District

- ON INSTRUCTING INSTRUCTORS -

Part I - The Eyes Have It

Part II - Leadership Communication

Part III - Requirements For Communications To A Naive Recipient

Part IV - A Philosophical Approach To Personal Interaction

April 15, 1978

ON INSTRUCTING INSTRUCTORS
—Part I—

1. General Outline.

a. How good an instructor are you? Do you get your points across? Good Communication is basic to our many educational endeavors. Too frequently we think we are communicating, and transmitting valuable information to people attending our courses and seminars, etc. But are we really? What follows are some suggested methods for presentating information to the boating public. We hope that you might consider, and possibly use them, and that they will encourage your sending some ideas back to us for discussion and possible further dissemination.

2. The eyes have it.

All of us have been exposed at one time or another to the basic rules for giving a speech. We are told to: organize our material; make sure that we have a good grasp of the points which must be made; do not appear to be frightened, excited or nervous; to maintain good eye contact with the audience, to speak audibly, clearly, and distinctly; and to summarize our comments at the end.

Although these are certainly some good examples of the qualities needed for effective public speaking, they are only the tip of the expert speaker's iceberg, because there are a lot of other things that you can easily learn to enhance interest and motivation in the groups you are addressing.

One of the prime considerations in communicating is the importance of non-verbal behavior as opposed to traditional concepts of verbal communications. There is in the Smithsonian Institute in Washington, DC a somewhat surrealistic presentation of the human form. At first glance it appears to be entirely out of proportion, the product of a mad painter's spaced-out dreams. Actually, what this drawing represents is the percentage of information received by our various sense organs. The eyes are huge, with the ears being next in size, followed by the hands,then the nose, and then the mouth. Psychologists tell us that we receive approximately 90% of all our communications through our visual sense. Complimenting this are other psychological estimations that between 60 to 80 percent of all human behavior and communication occurs in a non-verbal mode.

What this means to the presenter, is that if he wants to make, and to reinforce his points, he must not only be be effective verbally, but he must also use active and attractive visual presentations to more comprehensively communicate with his audience.

3. Follow the bouncing ball.

Although good speakers can capture and contain an audience simply through their vocal delivery, most of us have to use other stage props to get our points across. Hence, we depend on supplementary visual means to gain and to keep an audience's attention. One of the most familiar ploys seen recently is Chevy Chase's entrance into "Saturday Night Live". He always manages to immediately engage the audience by falling down as he starts the evening's program. (Also, since he has successfully used this highly visual move so much, the audience automatically expects and is looking for him to do it.) Although we don't recommend that presenters repeatedly hit the deck to gain group participation, we do strongly suggest that as much show and tell material be used as possible. We also recommend that speakers not limit themselves to a position behind a lectern or other immobile, stationary position.

This last idea has two aspects. If we make an audience use more of their energy, especially their eyes, in paying attention to us, then they are likely to become more interested in, and retentive of the information we present. Secondly, psychologists in the school setting have determined that there is a well defined space in front of a teacher's desk (or stationary position customarily occupied by an instructor) known as the "triangle of learning." This triangle normally includes most of the students on the front row and then tapers back three or four rows in a triangular configuration. Studies indicate that students on the sides and in the rear of the classroom are less apt to retain and to use information presented by a non-moving teacher. Therefore, to overcome this type of learning impediment, we recommend that the teacher move around the room to keep his or her triangle of learning spread out as much as possible as well as to keep people's eyes focused on her or him.

There is also strong evidence indicating that many people, because of unpleasant happenings or simple boredom during their early learning years and school experiences, are automatically turned off by situations and settings which represent a formal classroom atmosphere.

To counter this automatic, and frequently unknown obstacle, we again suggest that speakers do not remain stationary, but move around the room, using as many audiovisual aids, handout sheets, and other show and tell materials as possible. This approach has a few drawbacks. A moving instructor must have a strong voice and clear pronunciation, because he or she may frequently be too far away from a microphone to use it effectively. However, most of us, if we are really interested in making an adequate presentation, can, with serious practice, quickly develop acceptable vocal projection. Besides, occasionally speaking with force is good for you physically, because it exercises your heart, lungs, and abdomen and helps to get more oxygen to your brain.

4. Know your audience.

Communication is frequently defined as having five basic elements. These elements are: the sender; the screen of personal perceptions that the sender works from or through; the medium of communications: the screen of perceptions of the receiver; and the receiver him or herself. What this means, for effective communication, is that the person generating the message must be aware of: (a) own feelings and outlook toward the people being addressed; (b) own feelings about the subject being presented; and (c) the feelings and perceptions of the group being addressed, both toward the subject matter, and toward the speaker. Added to this, of course, must be an understanding of the media used to present the message or the communication.

As an example think of the problems created by a speaker who uses involved language and multi-syllable words when addressing people of lower educational backgrounds. On the other hand, the speaker can often get into difficulty by being too elementary in his approach to people who have a great deal of experience and competency in the area that he is discussing. Similarly, we frequently find presenters who cannot properly show slides or run a motion picture projector. A basic question we should ask ourselves is: "Do I want to impress (or talk down to) this group, or do I really want to help them learn as quickly and easily as possible?" Also, since the medium (as well as the presenter himself), can be considered part of the message - or to some folks- the entire message, we should also ask ourselves," What am I saying non-verbally about myself and my sponsoring organization?" Hence, our perceptions must be carefully examined to make sure that we are not unknowingly turning off a large percentage of our audience by alienating them simply through our appearance. In studying this last matter look back at the paragraph on non-verbal behavior. The old adage about actions speaking louder than words, is certainly true here.

Another consideration similar to perceptions is that of reality. What is real to our audience may not seem real to us, and vice-versa. We should therefore have an understanding of whom we are talking to and what, at the present time, is most important to them, and through which routes they can be most easily approached to insert our ideas into their stream of consciousness. We live in a rapidly changing world. Are you up to date with what's new? Or, do your talks reflect an ancient world that disappeared with the dinosaurs, five or six years ago?

5. Motivation.

Educational theorists say that education does not really take place until a person actually modifies or changes his behavior. Although we may congratulate ourselves on delivering a comprehensive presentation, we really haven't done much until the recipients modify or change their actions to reflect or act upon the ideas given them. This changing of behavior can be described as involving motivation, in that the recipient has to choose to do something differently because of information that we have presented.

How do we produce this change in behavior? One basic idea is that it is extremely difficult to motivate someone else, if you are not visibly motivated yourself. On the other hand, someone who is enthusiastic and full of drive about a project can normally turn on other people, simply through the radiation of his or her own interest and inspiration. Even though you may be entirely sold on material you are presenting, if you do not show the audience what you really believe, then you may find that they do not easily respond to you. A basic idea along this line is consideration of the spectrum of motivation. We may motivate at the highest level which is inspiration, or we can motivate at the lowest level which is intimidation. If we force someone to do what we would have them do, then once the intimidation is removed, the motivation may also be ended. However if we attempt to inspire others through our own example and through the interest that we have in our project, then there is a far greater chance of their also gaining inspiration and becoming self-starters in the same project.

The easiest way of motivating people through a presentation or a speech, is for you to entirely and thoroughly believe in what you are presenting. We are all frequently confronted by stage fright and apprehension before giving presentations. One of the best ways of overcoming this is to simply review the importance of what we have to say, both to ourselves and to the listener. This frequently will give us enough drive, enthusiasm, and confidence to push home the points we wish to make.

PLEASE REMEMBER: The Eyes Have It!

- Part II -

LEADERSHIP COMMUNICATION

1. Introduction

Part I of this series emphasized that most interpersonal communication is visual or non-verbal. Much of the way we influence others has to do with how we appear, rather than what we say. In this part of our discussion we would like to review different concepts of leadership as related to communication.

2. What Is Leadership?

There are over three thousand textbooks dealing with leadership either presently or recently in print. We hear a lot about leadership. Frequently people who suceed are pointed out as having good leadership. Conversely, those who fail are evidently poor leaders. In many commentaries urging people, in all levels of administration or politics, to do better jobs, writers stress the importance of leadership. Much is said about this term, but what does it really mean?

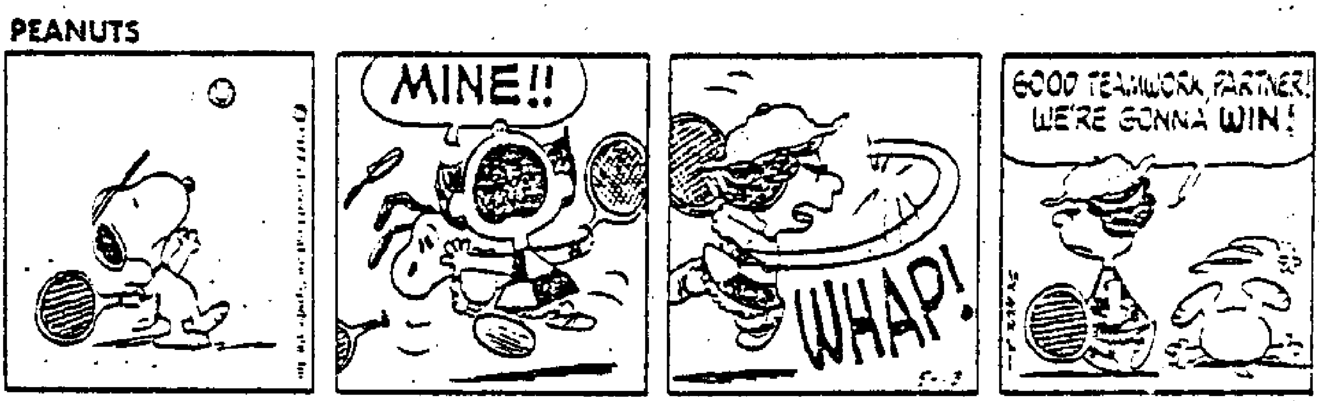
Taking the simpliest things first, leadership evidently has to do with people. Secondly, it involves accomplishing a task. Since leadership involves people, and principally a leader, then leadership is subject to all the fragile and failable whims of human nature. It should therefore be safe to define leadership as being an especially individualized aspect of our personalities. Although there are many writings available leadership, most of them are anecdotal or descriptive, in that they describe the behavior or traits of a person believed to exibit good leadership. However, a singular failing in most of these texts is that they do not clearly specify or prescribe universal requirements or criteria for outstanding leadership. In this light, about the best definition of leadership that we have come across is attributed to General Robert E. Lee. After he had left the military, Robert E. Lee became president of Washington and Lee University. Notwithstanding this position, General Lee was not known as a man of many words, or as a prolific writar. However, he is supposed to have expressed this about leadership: "A good leader is someone who: (a) takes care of his troops, (b) acts like a man *and, (c) knows his stuff.

*Not really limited to men. Women can have backbone too!

There are profound truths in the foregoing quotation. It is not our purpose or intention to take these words apart and to try to tell you what leadership should be. We would rather use them as a starting place to show how leadership does effect communications, especially if you are leading a classroom presentation, discussion group, or other gathering attempting to obtain knowledge or learn more about a subject.

Perhaps a workable definition of leadership can best be approximated by saying that a leader in our particular situation is someone who appreciates, develops and then focuses human potential. In this context let's talk about a few of the important aspects of classroom leadership.

3. Reality/Perception



The peanuts cartoon reproduced above is a very good presentation of the way each of us differently perceives reality. Snoopy's ideas about the responsibility of a tennis partner, are somewhat different from Lucy's. However, in the last panel we see that Lucy, in making the play, believes that her concept is the correct one. She evidently doesn't consider Snoopy's view. Lucy automatically thinks he agrees with her. The point here is that a good leader attempts to appreciate everyone's point of view, including his or her own, to find where the group is coming from or where the group may be going. By appreciating the other person's outlook, you may be able to sidestep, or to bend the other person to your point of view, or at least to lead them from less productive or distracting discussions. Also, the reality of the situation for Lucy is not the same reality as seen by Snoopy. There is a very basic need in all human interactions to make sure that we know where we are coming from in relation to other's efforts. In the classroom setting we must insure that we are expressing ourselves in terms which are familiar to the other fellow and that we are providing information that she or he seeks and needs, and for which they originally came to class.

4. Goings On In Down Home County.

The effect of a leader is reduced if his concept of reality is not in tune with those of the people he is attempting to lead. We all go through life with our own idea of what is happening around us and what is important. Quite frequently my concept will not at all be the same as yours. Usually through compromise we can work out these differences. But, we should realize that differences exist, are important, and must be treated. For instance, in Down Home County, where we reside, a few recent happenings truly illustrate this point. Down Home county issues licenses to cafe owners to dispense non-intoxicating beer. This title is clearly explained on the license. The reader thereof, in consuming 3.5% beer, is made to believe that no matter how much of this beer he or she consumes, they will not become intoxicated. This is a common belief in Down Home County. In many boating families the idea is to drink beer rather than hard liquor to not become intoxicated. Similarly, a member of a boating safety organization was advertised as being on hand for the grand opening of a brand new marina. On the day of the opening said member of the volunter boating safety organization was indeed on hand, with a can of beer in his hand. It wasn't continually the same can because the contents were rapidly emptied and replaced with another container. What we are saying is that the boating public in Down Home County in the grand opening of this marina, was seen to overwhelmingly and immediately associate suds with the official and the volunteer organization. Is this the image which we wish to create?

5. On Telling Stories

Leadership in smaller groups is often exchanged. For instance, when two people are talking, one will generally pause and indicate that he or she is through making their statement, to allow the other person to state their side of the story. This, in some ways, can be seen as a leadership situation, because there is most definitely a person in charge, but this responsibility shoots back and forth in a generally agreed manner. However, sometimes communications suffer breakdowns when this exchange of leadership, or an understanding of who should be in charge, is not followed. At a recent meeting of Coast Guard Auxiliary liaison officers, a very vital and productive discussion was being held dealing with communicating with state officials. Just as the discussion reached a high point, another person entered the room who had not been originally involved. Upon hearing the word communication this individual immediately jumped into the discussion and dominated the proceedings. Strangly enough the person's topic was, how we need to have better communications. Needless to say this unwanted interruption completely ruined the discussion and caused all the participants to go back to ground zero, and to start all over again. The person who made the interruption wasn't aware of the havoc he caused. How frequently do things like this happen? To you? By you?

6. The Slovic Solution.

Leadership in practical situations can also direct the social attitudes and understanding of the group towards new and higher planes which the group may not have encountered or considered before. To ease and lubricate the evergrinding wheels of social interaction amoung ourselves and others, I'd like to suggest that you consider the Slovic Solution the next time you encounter social binding or friction. The Slovic Solution is especially appropriate as a leadership ploy by those required to make delicate decisions between groups of different opinions, or factions which regularly assail each other in voluntary organizations, such as our Coast Guard Auxiliary. The Slovic Solution is nothing more than this: in most human interactions, the truth will almost always be found lying somewhere between the poles. Also, as you think about this point, please go over what we have mentioned about effective leadership as appreciating, and developing human potential. Within the group now reading these papers, there maybe a whole host of people who have potential for contributing a great deal to our organization. However, no one ever asked them to do their thing, or maybe many of us are unaware of just what things they, or even we, can do. It would therefore appear that in the classroom setting, if there is someone present who has a special expertise in the subject being discussed, it would be well to ask them to share with the class. By this method, we get to identify and to know the people who are in our class better, thereby building a sturdy air of understanding and rapport around our proceedings and making us more knowledgeable as a group and as individuals.

Personal development, of course, is the basic reasons for any educational endeavor. But what we should especially note is our allowing and encouraging each person to develop his or her specific ability in their own particular way. Too often, those of us who have experience in classroom presentations and instruction, begin to think that there is only one way to approach a certain topic, and that we have heard, discussed and rejected all possible variations of this one true method. This is manifestly false. There is always somebody, somewhere who can devise a better way of doing the most complex, or simplest of tasks. If we do not attempt to develop our own and other's abilities to bring different solutions to problems, then we will find that most problems remain unsolved.

Lastly, as a good ending, it is well to outline where further research or emphasis is needed in a particular field. By doing this we may be able to turn people on, or to focus what they have learned toward areas that need to be better defined or problems which need to be overcome. This challenges people and allows them to grow, to reinforce, and to use information that we have provided them.

Point to remember: The Slovic Solution.

To be continued.

-Part III-

REQUIREMENTS FOR COMMUNICATIONS TO A NAIVE RECIPIENT

1. Review

Our previous articles on improving presentations and communications with the public have emphasized two points. They are:

a. The eyes have it, or the importance of understanding and effectively using nonverbal means of communications to make your point or to reinforce previous information; and,

b. The importance of understanding basic leadership ploys in the teaching/classroom situation.

In this section we are going to introduce you to some new and possibly different ideas for improving your communications with those who may not be interested in what you have to say, or not familiar with the material you wish to cover.

2. Communications Requirements.

These are rules that a sender might follow to maximize the opportunity for a naive recipient to understand attempts at transmitting information. After you read these points, and think them over, try to visualize from whence they came, or from which discipline of science or education they were developed.

(1) Transmit on channels on which the recipient is likely to possess a sensitive receiver.

(2) Avoid the use of reference to sensations not likely to be shared by the receiver.

(3) Use references that are likely to be known by the receiver, using props to establish familiar language references whenever possible.

(4) Transmit in a way that provides reinforcement, reward, and encouragement for the discovery of the basic and most important facts. Do this in order to enhance the receiver's continuing intent to learn.

(5) Keep the duration of transmission within a time period reasonable for likely receivers.

(6) Use a language that is unambiguous (especially) with respect to order or sequence of the information provided.

(7) Use as primitive (or understandable) a technology as possible.

(8) Keep up efforts to communicate over as long a period as possible.

Although the foregoing principles have been slightly altered from the original text, do you as a reader have any idea where they came from? If you say from the formal fields of education, you are entirely wrong. If you said that they were generated as part of a public speaking or human relations course, you are again entirely wrong. Believe it or not, these eight primary methods for establishing communication with a naive recipient, (a person unfamiliar with your subject matter) was developed as part of the international effort to contact extra-terrestrial civilizations. They are taken from an article developed by Dr. A. J. Wilson and an engineer, T. J. Gordon. Their article dealt with the possibility of communicating with other forms of intelligent life.*

It is interesting to examine some of the points made in the original article, as these points may have a surprising importance for us in boating safety. The article's introduction reads as follows: "Many scientists believe that communicative societies exist elsewhere in the universe; in fact, Dr. Frank Drake has estimated that between a thousand and a million such societies exist within a thousand light years of earth. Yet, why haven't we heard them? Wilson and Gordon suggest we may not have detected intelligent signals, (or we may not be sending intelligent signals) because adequate decoding or encoding methods do not yet exist."

"Previous authors have invented various kinds of languages which they believe other races might use in trying to contact us. For the most part these have assumed that evolution brought the distant being along biological paths at least grossly similar to our own. But perhaps it is only our supreme egotism which leads us to believe that intelligent beings on other planets in distant galaxies, think, sense, and reason as we do. Differences in thought and sensory processes will lead to great difficulties in establishing communications between interstellar races or between any races for that matter. The coding (makeup) of a message sent by an intelligent race to attract the attention of another race will therefore have to be very carefully designed. Wilson and Gordon suggest some new criteria for this language."

*<u>Ahead of Time</u>, a book edited by Harry Harrison and T. J. Gordon, Doubleday, Garden City, NY, 1972, also see last page of this section for thoughts on the measuring of "intellegence"!

3. What is really going on here.

By this time you may have wondered what are we trying to prove by getting so far afield with all this mish mash about extra-terrestrial life and attempting to signal them. In reality, what the foregoing adequately illustrates, are some very, very basic rules for communication between presumably intelligent beings anywhere, anytime. For instance, in the paragraph immediately proceeding this, if you were to substitute words more familiar or closer to home, for the esteric terms used, you might begin to see an amazing pattern emerge, which can greatly and immediately improve your productivity as a speaker. For instance, in the last sentence of the above paragraph substitute the word speaker for "race", when race is first used, and an audience for "another race". Get the picture?

4. Further thoughts.

Perhaps you have been turned on by the philosophical and somewhat mind boggling thoughts in this section on instructing instructors. And then again, perhaps you have not. In summation it might be well to review a few of the philosophical insights which have allowed puny man to take his first hesitant, and somewhat clumsy steps toward the stars. You might not immediately think that this involves you, but then think again. The room you are sitting in, and the building which houses that room, and all the many services which maintain that building and adequately insure you of the continuance of the standard of life which you now enjoy, are intimately related to, and are direct products of increasingly complex technological innovations which have been recently brought about through discoveries in mechanics, engineering, and electronics generated by the space program. In the mid 1600's the English poet John Donne said something about not "asking for whom the bell tolls", with his idea being that we are all involved in humanity, together. A little more recently Benjamin Franklin said, in the desperate hours prior to our emergence as a nation, "we must either all hang together, or we will hang separately". If you agree with these ideas then possibly you will see how that which has gone before, and the ideas immediately following this paragraph, can serve to not only bring us closer together but to enable us to reach higher goals which we had heretofore possibly not conceived of, nor thought possible to grasp.

From Dr. Author C. Clark (2001, a Space Odyssey), "Whenever a respected and experienced authority in any field says that something is impossible, he is almost always wrong. However, when an authority says that something is possible, he is almost always correct."

From James F. Bell (Administrator of NASA, When Men First Walked on the Moon), "Facing Tomorrow's problems, with yesterday's solutions, is to view life at a standstill. If we are to improve, there is not one of us who cannot do better tomorrow, what he or she does well today. To advance we must search for, and use, new understandings, new initiatives and new competencies, which lay before us if we only have the vision to acquire, and to grasp them".

And finally from Dr. Carl Sagan (Cornell University Astronomer, and Exobiologist), "The primary question confronting the human race at this time, is not whether there is intelligent life in outer space, but rather, whether there is intelligent life on earth".

Point to remember: Like it or not, you are part of the future. What are you going to do with it, and how are you going to meet it?

-Part IV-

A PHILOSOPHICAL APPROACH TO PERSONAL INTERACTION

phil.o.soph.i.cal. archaic: characterized by learning or the spirit of inquiry......
(Webster's Third International Dictionary)

1. Introduction

In the first two sections we discussed tactics which can be used to improve classroom interaction and instructor's skills in presenting his or her material. In part 3 we talked about communication and philosophical ideas involved with communications. In this part we again deal from a philosophical outloook, but the intent here is to help you, as a member of a human organization, to get an overall view of how you can improve your dealings with others in the organization. As you read on, hopefully you'll discover ideas about dealings with people useful not only in the classroom situation, but possibly in your larger organizational effort or even in life as a whole.

2. A Philosophical Approach

What is a "philosophical approach"? How can it be best illustrated? Experience indicates that questions of this type can usually be handled by finding and analyzing several writings on the subject, and then either comparing the arguments of the writers or using their arguments as a basis for stating an original position. Unfortunately, formal thoughts on philosophical approaches to personal interaction are not easily found in administration and management. Hence, what follows are subjective opinion on this topic with corroborations drawn from several sources.

Perhaps the best approach to personal interaction (or one to one relationships), the most worth-while way of dealing with people for whom or to whom you are responsible, the best method for dealing with anyone, anywhere, anytime is philosophical in nature. Why? Taking a cue from Mr. Webster's definition of philosophical, we could define the philosophical approach as being based on the study of, or learning about, human beings.

Furthermore, we could say that not only should we take time to study our fellow homo sapiens, but we should become interested in them as individuals. We should attempt to understand, predict and interpret foibles and failings, gloatings and greatness. More importantly, these studies should be ongoing, with the subjects studied being those around us, as well as ourselves.

Departing from Mr. Webster still further, we can outline the philosophical approach through the following considerations:

1. An emotional time delay.

The philosophical approach has a certain delay built into interpersonal responses. It resists either external or internal, emotional cries for action by reflection on similar situations in which we may, or may not have been involved, before acting on the case at hand.

2. Emotional detachment.

Along with the time delay, a person using this approach can objectively detach him or herself from a situation, even those that are highly personal. This detachment not only affords a more unaffected view of a situation, but also allows a pause in which humor can creep into, lighten, and lubricate some otherwise closefitting encounters.

3. The good versus the bad.

By having a philosophical approach we subscribe to the notion that everyone, ourselves included, has negative attributes as well as affirmative, and that we must attempt not to be overcome, blinded, or disappointed by the former while awaiting or applauding the latter. Similarly, we must learn not to be appalled by the conflicts and ambiguities of life. We must rather accept the fact that man is a child of conflict and that we could not live without stress. Several eminent psychiatric workers emphasize this point by demonstrating that neurosis is often engendered, not by too much tension in life, but quite frequently it is found in the person who lives in a state of protection or isolation from conflict, with this isolation resulting in such a person's neurotically generating his own imagined tensions.

4. Fairness and the scientific method.

The philosophical approach should be one of fairness, with the derivation of this fairness analogous to one of the basic principles of science. This principle is the one which requires duplicated experiments to produce duplicate results under similar conditions. Referring further to scientific principles, we frequently make observations of others, we differentiate and catalog behavior; and we attempt to explain and predict it. However, where we sometimes err in social hypothesizing, is in failing to determine the correctness of our own hypothesis. What proportion of your time do you spend in thinking that the other person is wrong, compared to thinking that perhaps you have made an error(s)?

5. Human worth.

Each and every human being is worth a great deal. Certainly we are all made differently, but just as certainly, each person, when properly motivated and guided, has something of value to contribute to the total human condition. Another important point in the same vein is that of realizing how we cannot see good or worth in others, until we can recognize it in ourselves. Similarly, a significant percentage of what we notice in someone else is not only modified by our perceptions, but may indeed be self reflection.

6. Facta non verba. (Acts, not words)

In the final examination, a philosophical approach is neither truthfully nor completely characterized by heady preachments and readily proffered outlooks. A true philosphy is founded not so much in words as in deeds. Every day we repeatedly, and sometimes embarrasingly demonstrate what we really value and where our most assimilated beliefs lie. It is one thing to speak of understanding, and quite another to enact it.

In summation, the philosophical approach is characterized by learning, and an understanding of the isolated human; an appreciation of his or her needs; a taking of time to think through our actions or the actions of the institutions we represent, as interpreted, appreciated or resented by the individual; an attempt at building a total environment concerned with growth and development beyond the maintenance of an arbitrary, unimaginative, stagnant state of affairs; a respect for each person as an entity whose promise is something of great value; and a will to serve rather than an unthinking negation of the ego and experiences of learning, growing, mankind.

How much could be accomplished if Mr. Webster's definition, given at the beginning were altered by deletion of one word - archaic!

Dr. Alan Steinman
U.S. Coast Guard
Washington, DC

Medical specialties of Dr. Steinman are emergency and aviation medicine. While stationed in the Coast Guard as a physician at Port Angles, Washington, he became concerned with the treatment of hypothermia in rescue victims. His close proximity in Washington to Dr. Hayward led to his involvement with cold water physiology. He has also developed in-water cardio pulmonary (CPR) techniques. Dr. Steinman currently is Chief of the Special Medical Operations Branch of the Coast Guard. His medical training has been at the Stanford School of Medicine, the Mayo Graduate School of Medicine and the Naval Aerospace Medical Institute.

Dr. Alan Steinman
U. S. Coast Guard

Airway Rewarming and Afterdrop Panel

This panel discussed the efficacy of the administration of heated, humidified oxygen or air to patients suffering from hypothermia. This therapy had been proposed several years ago as a means of "core" rewarming appropriate to the pre-hospital management of the hypothermia patient and as an adjunct to definitive rewarming techniques in-hospital. The advantages of the technique are: 1) prevention of further heat loss through the respiratory tract; 2) efficient delivery of heat to the heart-lung-brain axis (i.e. the critical "core" organs) ; 3) stabilization of cardiac temperature (i.e. minimizing cardiac temperature "afterdrop").

Airway rewarming has been a highly controversial topic in the past several years. Its proponents claim it is the most logical technique for field management of hypothermia; its opponents doubt the ability of the technique to deliver sufficient calories to be of much use. Theoretical and experimental evidence appeared in medical literature supporting both sides of the argument. Clinical evidence began to accumulate, however, to support the use of the technique as originally proposed.

The panel participants and audience reached a concensus that the administration of heated, humidified oxygen or air is useful in the field management of hypothermia patients. Its primary goal is to prevent respiratory heat loss; it is not meant as a definitive means of rewarming. In this regard the technique fits well into the strategy of pre-hospital management of the profoundly hypothermic patient defined by a previous panel; 1) removal of the patient from the cold environment; 2) prevention of further loss by insulating the patient from the environment; 3) stabilization of vital signs; 4) transportation of the patient to a site of definitive medical management. In this latter regard, several conference participants presented clinical evidence of the usefulness of the technique to the in-hospital management of the profoundly hypothermic patient.

Effective use of airway warming requires the delivery of oxygen or air at 100% relative humidity. Temperature of the inspired gas should be at 42-44 degrees Celsius (108-111 degrees Fahrenheit and in no case greater than 45 degrees Celsius (113 degrees Fahrenheit). An accurate thermometer must be used to moniter inspired gas temperature. The patient should be allowed to breathe at a spontaneous respiration rate; he should not be vigorously ventilated because of the danger inducing ventricular fibrillation secondary to sudden changes in arterial pCO_2 levels. Theoretical contraindications to the technique are: 1) the possibility of upper respiratory tract burns from humidified gases at temperatures greater than 45 degrees Celsius; 2) the condensation of relatively large volumes of water into the respiratory tract of the hypothermia patient. Neither of these has proven to be a probelm in present clinical use.

The topic of "afterdrop" received little discussion; it was overshadowed by a debate on the merits of cardiopulmonary resuscitation (CPR) in the hypothermia patient. However, the panel and audience agreed that one component of "afterdrop" is the simple equilibration of temperatures between a cold periphery and a warmer "core." Whether a second component exists (due to the return of cooled blood from the periphery consequent to rewarming measures) remains controversial. Further experimental and clinical evidence is required before a consensus can be reached on this point.

The most controversial topic the panel and audience discussed concerned the administration of cardiopulmonary resuscitation to hypothermia victims. The profoundly hypothermic patient may appear to be apneic and pulseless, when in fact he may have bradycardia and very shallow respirations. CPR in this case will almost surely precipitate ventricular fibrillation in an irritable, cold myocardium. Furthermore, the cold myocardium may be injured by inappropriate CPR, making subsequent defibrillation attempts unsuccessful. On the other hand, the profoundly hypothermic patient may be in a state of cardiopulmonary arrest, and withholding CPR in this instance may also result in unsuccessful resuscitation attempts, due to prolonged anoxia of the brain and myocardium. Complicating the situation is the difficulty of accurately differentiating in the field the patient with extreme bradycardia from the patient in full arrest.

Several participants in the discussion presented case histories of patients given prolonged CPR in the field who were subsequently successfully resuscitated in-hospital. Other case histories were presented wherein pre-hospital CPR was associated with an inability to resuscitate in-hospital (although some of these latter patients received repeated defibrillation attempts while still profoundly hypothermic). A consensus was reached on the following points: 1) No hypothermia patient who demonstrates signs of life should be given CPR, even if measurable pulse rates and/or blood pressures are extremely low; 2) No hypothermic patient should be given CPR in the field if such efforts will endanger the rescue team (i.e. the rescue team being immobilized at the rescue site by the necessity of performing CPR); 3) No defibrillation attempts should be made if the cardiac temperature is below 30-32 degrees Celsius. No consensus was reached on the advisability of administering CPR to the profoundly hypothermic patient who either is or apparantly is in a state of full cardiopulmonary arrest. Members of the panel and audience agreed to continue present individual procedures, accumulate case histories over the next one to two years, encourage animal experimentation in these areas, consult existing literature for further clinical experience in these areas, and to re-open the discussion when more clinical and experimental data are avalable.

Stephen E. Suess
John D. Isaacs
Foundation for Ocean Research
San Diego, California

THE BREATH HEATER AND HUMIDIFIER FOR BREATHING APPARATUS

AN INITIAL TEST AND EVALUATION REPORT*

Stephen E. Suess and John D. Isaacs
Foundation for Ocean Research
San Diego, California

ABSTRACT

The Foundation for Ocean Research has conducted an eight month preliminary test and evaluation program of *The Breath Heater and Humidifier for Breathing Apparatus*, as developed and patented (patent #4,016,878) by the Foundation for Ocean Research.

This small and simple breathing-gas warmer and humidifier has been tested in over one-hundred SCUBA dives at depths ranging from two to sixty meters. The Heater has proven itself to be reliable, easy to maintain and repair, and to be almost foolproof in its use. Some very simple quantitative body temperature measurements with and without the Heater at shallow depths have thus far been inconclusive. Subjectively, it has shown itself to be a highly welcome and appreciated method for helping divers to stay warm and comfortable in the 10°C waters off southern California.

* Naval Coastal Systems Lab Contract #N61331-77-M-0459.

THE BREATH HEATER AND HUMIDIFIER FOR BREATHING APPARATUS

AN INITIAL TEST AND EVALUATION REPORT

Stephen E. Suess and John D. Isaacs
Foundation for Ocean Research
San Diego, California

INTRODUCTION

As man begins to spend increasingly more time beneath the ocean, the need for equipment to enable him to do so becomes ever more crucial. And too, as the type of work performed becomes more complex, so increases the need for low-cost, simple-to-use, light-weight and compact equipment. Yet, to cope with the problems of diving to greater depths and for longer periods of time, the necessary equipment has to become more and more sophisticated to insure the diver's comfort and survival.

When a person in cold air or water suffers a great loss of body heat through the skin, his body responds by cutting off the flow of blood to the skin surface and body's extremities. The body's heat is thus conserved in the core (i.e. brain, heart, lungs, and other central organs) which can withstand only slight cooling. However, in the breathing of cold and dry air, heat is lost through the respiratory system, and the body has no substantial defense against this loss; if the heat loss becomes too great, the mere act of breathing can drop the body core temperature to dangerously low and potentially fatal levels.

As air is inhaled it becomes saturated with water vapor and equilibrated to the body's temperature by the time it reaches the alveoli of the lungs. When air or a gas unsaturated with water vapor and below body temperature is inhaled, energy is expended in warming and humidifying the gas, while additional heat is devoted to warming it to body termperature.

In a comfortable, 20°C, 50-percent relative humidity environment, less than 10 percent of the body's metabolic energy production is expended in heating inhaled air. Most of the energy loss is due to vaporization of body water that is eventually expired. In a cold environment of, say,

-20°C and a relative humidity of 0 percent, almost one-third of the body's metabolic heat output is lost through the respiratory system. Colder environments will, of course, cause even greater respiratory heat losses, but there is no place on the surface of the earth where the environment is so harsh as to cause a healthy person to die solely of respiratory heat loss.

At high altitudes, i.e. lower atmospheric pressures, a breath of air contains a smaller absolute quantity of air, and thus requires less energy to warm it to body temperature. However, this savings in thermal energy is not very substantial since the quantity of water needed to saturate a volume of air is the same regardless of atmospheric pressure, and the energy needed to vaporize body water represents the bulk of the respiratory heat loss at atmospheric pressures found on land.

In a body of water the ambient pressure increases with depth. This causes a SCUBA diver to inhale denser air, thus each breath contains a greater absolute quantity of air and consequently requires more energy to bring it up to body temperature. As the diver's depth increases, so does his respiratory heat loss.

A diver breathing a dry gas mixture at 10°C, at a depth of about 270 meters would need his entire metabolic energy production just to warm and humidify his breath. (At this depth most of this energy is used in warming the breath, rather than in vaporizing water.) If the diver were to attempt to produce more body heat through physical exercise, he would also increase his respiration proportionately and would still require all of his metabolic energy output to warm and humidify the air he breathes. In such a situation, warm and humid breathing gases are vital to maintain the acceptable thermal balance of the diver and for his survival.

THE HEATER

The Heater is simply a small insulated canister, about four centimeters in diameter and ten centimeters in length, weighing as little as 100 grams. It is filled with pellets of alumina, about one-quarter of a centimeter in diameter, which are coated with a platinum catalyst. The gases that the user breathes contain a small and non-explosive concentration of hydrogen.

In use, the hydrogen mixture passes through the catalyst canister just prior to inhalation. The catalyst causes the hydrogen to react with a portion of the gas's oxygen, forming water and releasing heat. For each one percent hydrogen reacted in this way, one-half of a percent of oxygen is used. In air, this represents a negligible loss of oxygen, but in a saturation-diving atmosphere containing very small amounts of oxygen, additional oxygen may need to be added to make up for that used by the Heater.

For each percent hydrogen added to air, the Heater should produce a theoretical temperature rise of 80°C, and in a helium atmosphere, such as is used in saturation diving, this rise should be 110°C. The temperature rise is solely a function of the percentage of hydrogen in the gas and of the heat capacity of the gas, assuming sufficient oxygen content and complete combustion of the hydrogen.

Each percent of hydrogen, when combusted, also produces one-half percent water. The resultant relative humidity is a function of the temperature, ambient pressure and absolute amount of water, as described by the following formula:

$$r = \frac{\% H_2O \times P_a}{P_v}$$

r = relative humidity

P_a = ambient pressure in mm Hg

P_v = vapor pressure of H_2O at ambient temperature

When combusting one percent hydrogen, this yields a relative humidity of 18 percent when measured at body temperature (37°C) and at one atmosphere of pressure. For each additional atmosphere of pressure, the relative humidity increases by another 18 percent. Thus at a depth of 20 meters a diver's breathing air has a humidity of 55 percent, and at a depth of 45 meters the diver is breathing air that is saturated with water vapor when measured at body temperature.

Up to 4.15 percent hydrogen may be added to air or oxygen without reaching a flammable level of hydrogen. However, a 4.15 percent mixture would be warmed by more than 300°C when combusted, far hotter than anyone would care to breathe. Hence, any realistic breathing mixture will contain much lower concentrations of hydrogen than mixtures that are potentially explosive. The surplus heat produced by a hydrogen-rich mixture could be used for other heating needs, and thus such mixtures might be useful in special systems.

Four Scuba-Pro Mark V regulators, with Sea View gauges were purchased and fitted with Heaters. The Heater canisters were machined from brass, about four by ten centimeters in size, and contained about 25 grams of platinum-coated alumina pellets. The catalyst was held in place with fine meshed, stainless steel screens at either end of the canisters, and the whole unit was insulated with 1 cm (3/8 inch) foam.

Each Heater was then installed into the regulator's air line about 10 to 15 centimeters upstream from the second stage, by means of pipe-threaded brass fittings that were banded onto the cut air hose. The exposed metal parts of the second stage were also insulated with neoprene foam. With no insulation on the canister or second stage, all of the produced heat is lost when the system is immersed in 10°C water. With only the canister insulated, three-quarters of the theoretical heat production is lost and with the insulation of the second stage, half of it is lost.

Heat is lost through the thin rubber diaphragm of the second stage, and by imperfect insulation elsewhere. The temperature of the gas leaving the Heater is also reduced by adiabatic expansion as the air goes from 7 atmospheres (100 psi) above ambient in the air line to ambient pressure in the second stage. Tests of the efficiency of combustion of the hydrogen have shown that it was consumed to the limit of our measuring sensitivity (0.5 percent hydrogen).

Analyses for possible harmful by-products of the system have shown that only water is produced. Fine particulate-matter measurements show that the Heater expells a small quantity of fine particulate matter, but visually identical particulates are also expelled by other regulators without the Heater using the same air sources.

The first two Heaters built were tested for any added breathing resistance by Dr. Glenn Egstrom. These tests showed the Heaters to add no air flow resistance to the regulators down to a depth of 75 meters, and a tank pressure of 20 atmospheres (300 psi).

Before the start of this program, we had a number of failures with the Heater. Apparently water had entered the air line, and coated the catalyst, thereby inactivating it. This resulted in cold and dry air, with a small amount of unburned hydrogen in it. Simply drying the catalyst reactivated it and the Heaters again produced warm, humid air with no free hydrogen. Water can never enter the catalyst in use as it is always 100 psi above ambient water pressure, but can enter after the regulator is detached from the air tanks.

At the start of the Heater diving program, all users of the system were asked not to wash their regulators after dives, and to be careful not to get water into the first stage when attaching or removing the regulators from the air tanks. Since then, the Heaters have failed on only three of more than 100 test dives. Each time a Heater failed, it had been used previously by someone employing it for the first time.

These three failures were repaired by passing 3-percent hydrogen-in-air through the regulator. This caused what little catalyst was still active to get very hot, heating the surrounding catalyst and thus evaporating the water from the Heater. Letting the Heater exceed 100°C for a few minutes removed all traces of water and the Heater functioned again like new. (The first time this method of drying the catalyst was employed, the second stage refused to stop purging when the process was finished. Upon disassembly it was discovered that the plastic boot, upon which the teflon second stage seal sits, had melted from the heat. Thereafter the second stage was removed before running 3-percent hydrogen through the regulator.)

Another potential problem for the catalyst is oil. Any oil in the air supply or on the regulator upstream from the Heater could coat the catalyst and thus deactivate it. Since oil and silicon grease are very hard to remove, any catalyst contaminated with them would have to be replaced. (One of our early Heaters failed when some silicon grease used to assemble the first stage came loose and coated the catalyst.)

To avoid the complexities of mixing hydrogen in air, we purchased 170 m^3 (6000 cubic feet) of 3-percent hydrogen in breathing air from the Linde corporation. (3.2 percent is four-fifths of the explosive mixture and is the maximum concentration that the Linde Corporation will sell.)

This mixed gas was stored in 30 K-size gas cylinders holding about 5.6 m^3 (200 cubic feet) each. Five cylinders at a time were manifolded together and installed in the Scripps Institution of Oceanography's diving locker. From this we "cascaded" to fill SCUBA tanks with doses of about one-third hydrogen mix and two-thirds air, resulting in the desired 1.0 to 1.3-percent hydrogen-in-air concentration. This gas when passed through the Heater provided the diver with breathing air from 40°C to 55°C, depending on the concentration used.

A point to be emphasized is that once a proper gas mixture is made, there exists no possibility of explosion, and assuming the catalyst is active, the inhalation temperature has been fixed. (This temperature can be reduced by removing insulation from the Heater.) Thus, in use, the Heater requires no further supervision or controls. All the complexitites of proper gas mixing have been handled in the well-equiped shoreside gas mixing facilities.

THE HEATER IN USE

Between April 19, 1977, and the middle of August 1977, over 100 dives were made with the Hydrogen Heater by divers from the Scripps Institution of Oceanography at La Jolla, California. Most of these dives were working, research-oriented dives. They ranged from depths of as little as 2 meters down to 60 meters and durations of just a few minutes to over an hour. Water temperatures were between 8°C and 15°C. The divers were generally in their late twenties or early thirties, wearing neoprene wet suits of all types of cuts, thicknesses and states of repair (more often than not on the verge of disintegration).

Only divers with Scripps certification to dive to 20 meters or more were allowed to use the Heaters, and only one diver per buddy pair. Each diver was given a "Consent to Act as Subject" form to sign after the design and operation of the Heater were explained. The diver was basically told what to expect, what to watch out for, and to be careful with the Heater. Questionaires which were to be filled in at the end of each dive were also handed out. The diver was then given a Heater-adapted regulator for his personal use and the combination to the racks where specially-marked SCUBA tanks with 1.1-percent hydrogen-in-air were stored.

All tanks with hydrogen carried labels stating that they contained hydrogen and air and were dangerous, thereby dissuading unauthorized use. These tanks were only filled by Stephen Suess and they, as well as the large cylinders from which they were filled, were kept under lock and key.

When a diver was to use the Heater, the last thing he was supposed to do before entering the water was to hold the mouthpiece over his upper lips and gently purge air from his tank for a few seconds. Warm air was the test that the Heater was working. If the air became burning hot within seconds, too much hydrogen would have been accidentally added to the air and the dive would have been aborted. (This has never happened.) If the air did not get warm at all, the Heater would have been inoperative, perhaps from the entry of water after its last use.

A description of the general experiences of divers utilizing the Heater follows:

Upon entering the water, the diver feels his air to be warm, but not really any different than ambient atmospheric air on a nice day. It feels a bit dry, but not as dry as regular SCUBA air. As the diver descends, at about 7 meters, he may feel that suddenly his air is becoming very warm. It begins to feel rich and heavy, and penetrating, almost like a sauna. (This sudden surge of warmth is not the result of any sudden change in temperature or humidity and thus must be subjective.) Some divers report that the air begins to develop a taste at this depth. They describe it as a salty metallic taste at the rear of the mouth.

If the diver is working hard, and thus breathing rapidly at a depth of 10 to 12 meters, he may get a dry throat; but as he goes deeper the humidity keeps rising until at about 20 meters he reaches a depth below which no user has ever reported a dry throat. A dry throat is a very common complaint of regular SCUBA users.

As the diver descends further he may notice another apparent surge of warmth around 40 meters (again, there is no real temperature surge and so the sensation must also be subjective). Below this depth the air becomes supersaturated with water vapor and the diver may feel that he is breathing a fine spray of fresh water.

During the dive the diver will feel a warmth in his chest that will help him to tolerate the cold on his skin more. He may feel that his hands remain dexterous longer, and that the "stupid feeling" he gets from being cold is not there. The deeper he goes the more humid the air becomes and the richer it feels. Since he is breathing above-body-temperature air, as he goes deeper, each breath has more air and thus more heat, and so he gets warmer with depth.

Coming up from the dive the Heater may appear to be producing less and less heat. Some divers feel that it isn't even working near the surface. In reality this results from the high heat input at depth to which they have adjusted.

On the surface the diver will feel warmer, and on his second dive he will not feel that chill to the bones that is experienced upon reentering the water.

About a third of the divers report that they use more air with the Heater; that as the water becomes colder, they breathe the warm air faster. (One diver whom we subjected to a cold bath, exhausted a tank of air every 20 minutes with the Heater, whereas it normally took him an hour to exhaust a tank of air without the Heater.)

At shallow depths the Heater's output with 1.1-percent hydrogen is minimal, and the diver's heat loss is also minimal. On shallow dives, only those divers who get cold very quickly, or those who have to sit still in the water for long periods of time come to appreciate the Heater. However, as the diving depth becomes greater and the diver's wet suit thinner and the output of the Heater increases, even the most cold-insensitive diver begins to value the added warmth.

One Scripps diver who feels very sensitive to cold, and makes daily 15 meter dives with heavy insulation now dives only with the Heater, and wants increasing amounts of hydrogen, i.e. warmth. He has apparently become addicted to its use, and will not dive without it. Two other divers who generally feel insensitive to cold, at first saw no advantage in using the Heater. After their first 45 meter dive, however, they began to compete for the equipment.

The only common complaints, other than that there are not enough regulators and hydrogen-filled tanks to go around, concern the heaviness of the Heater unit itself. The brass makes these particular units quite heavy and negatively buoyant. This causes the regulator to pull at the mouthpiece and can be annoying to one not used to the Heater. A new set of Heaters has been built out of aluminum, and this seems to have solved the problem. Apparently neither the Heater's added bulk nor its drag seem to bother the divers.

In an attempt to obtain objective data on the physiological effect of the Heater body core temperature measurements were made with the help of Lt. Com. David Hall from the Naval Health Research Center, San Diego, California.

Nine divers volunteered to do two dives each, wearing minimal insulation at the bottom of a 10 meter deep tank filled with sea water at 17°C. The divers were told to remain relatively motionless, and were kept in the water until their core temperature dropped to 36°C or until they refused to stay in any longer. Dive times varied from 45 minutes with no insulation to 135 minutes with a well-insulating wet suit top on. Each diver did one dive with the Heater and another without, and was monitored for core temperature, EKG, and Heater temperature.

The measured temperature drops showed essentially no difference between the diver's rate of cooling with and without the Heater. Volunteers using the Heater during their first test-tank dive did not detect much help from the Heater in comparison to their second tank dive without the Heater; however, those using the Heater on their second dive (but not their first) felt that the Heater helped them greatly. Essentially all of the divers felt that the second dive was easier as they were more prepared mentally, having gone through it once before.

This result may ensue from differing physiological reactions. Yet at these depths, hydrogen does not make up for the respiratory heat loss nor help substantially with that lost through the skin. Our divers were losing heat at rates into the hundreds of kilocalories per hour, whereas at that depth the Heater was adding perhaps thirty to fifty kilocalories. Thus heat input in such a situation becomes small. Instrumental tests need to be performed at greater depths where the increased pressure results in more calories being added by the Heater and with adequate insulation of the divers to minimize body heat loss.

Further temperature measurements of divers working at 30-meter (100 ft) depths are being planned for this fall, and we still have sufficient mixture to make another one hundred dives with the Heater.

SUMMARY

It is our conclusion that the small and simple Breath Heater and Humidifier for Breathing Apparatus is a viable, appreciated and safe tool for helping divers stay warm and comfortable in cold waters. Subjective measurements, laboratory tests, and calculations have supported this conclusion. Physiological measurements limited to shallow depths were inconclusive. More detailed and carefully controlled experimentation at greater depths needs to be conducted.

The entire subject of respiratory heat loss is a relatively new field of study and the concept of maintaining one's heat balance by adding heat to the respiratory system is even newer. Since the Heater is such a simple way to provide divers with warmth, it might be timely to open up this field to detailed study.

We perceive the Heater as a device to keep SCUBA divers, divers from submersibles and perhaps even saturation divers with appropriate dry suits, warm and comfortable. It could also serve as a first-aid rewarming device for hypothermia victims.

Future work on the Heater will be directed towards the development of such uses and the technical aspects of perfecting mixing techniques for the hydrogen mixtures, toward finding better catalysts, and in the study of the effects of breathing warm and humid air in cold environments and at great depths.

figure 1.

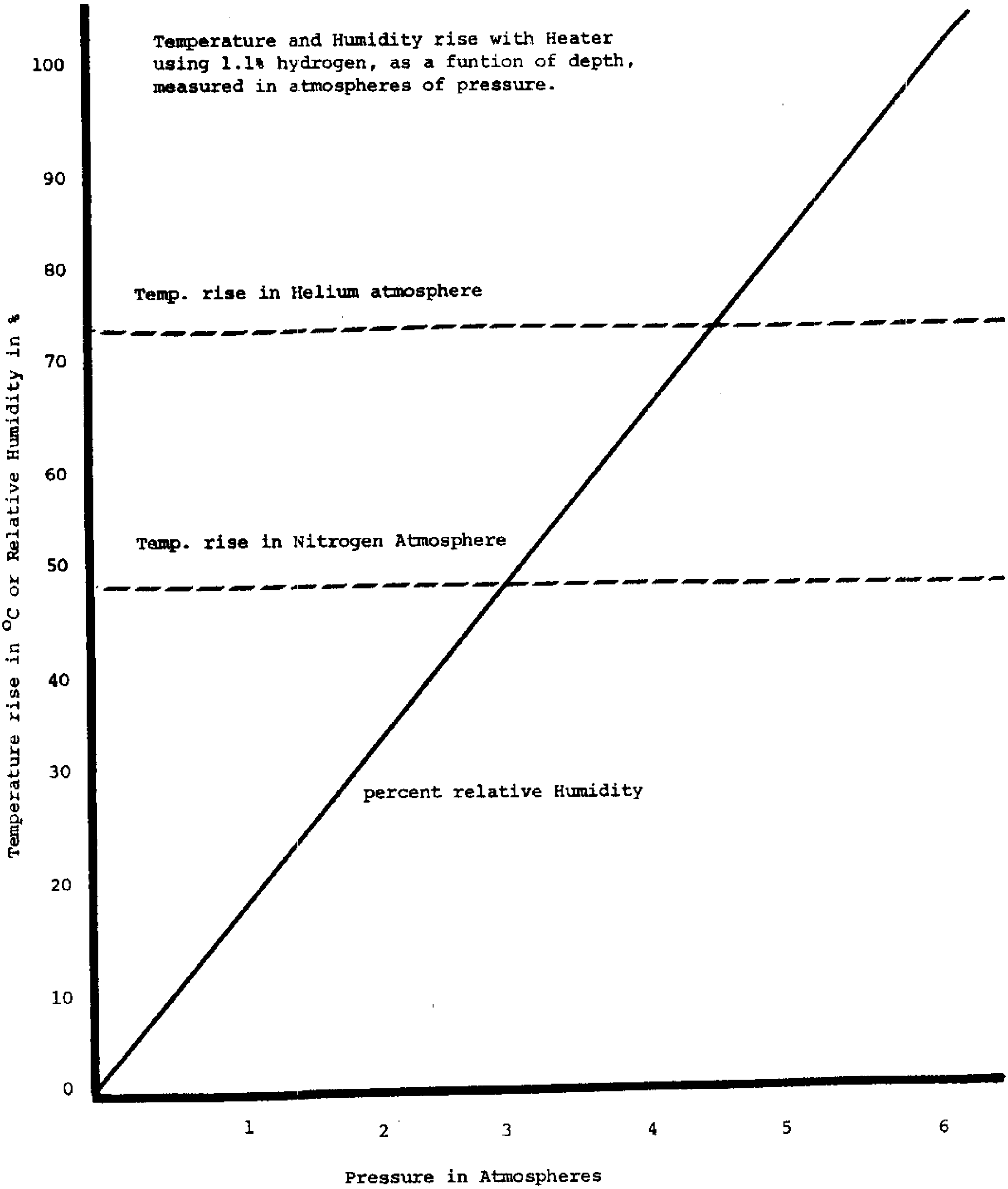
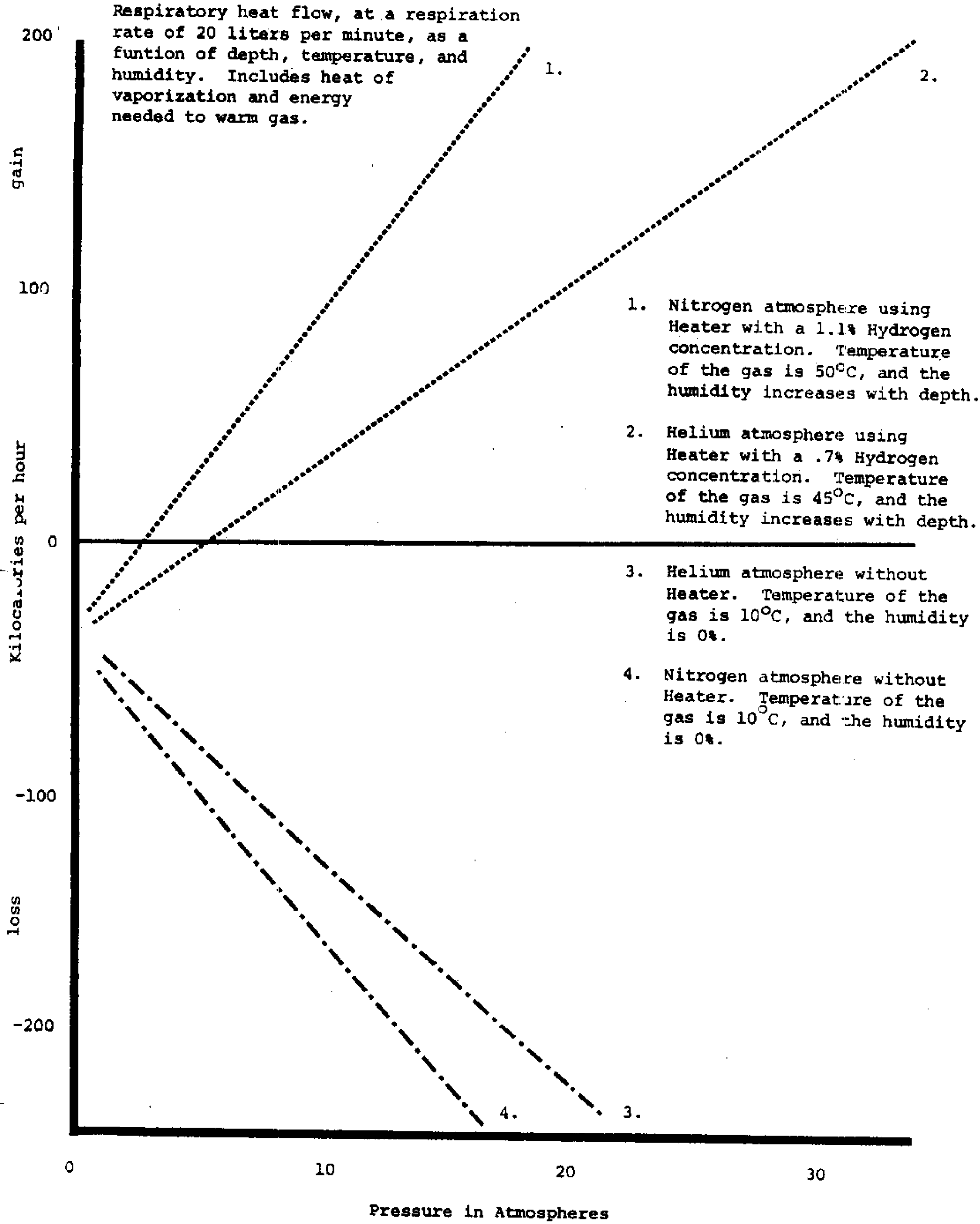

Temperature and Humidity rise with Heater using 1.1% hydrogen, as a funtion of depth, measured in atmospheres of pressure.
Temp. rise in Helium atmosphere
Temp. rise in Nitrogen Atmosphere
percent relative Humidity
Temperature rise in °C or Relative Humidity in %
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
Pressure in Atmospheres

figure 2.


Respiratory heat flow, at a respiration rate of 20 liters per minute, as a funtion of depth, temperature, and humidity. Includes heat of vaporization and energy needed to warm gas.
200
100
0
-100
-200
gain
Kiloca..ries per hour
loss
1.
2.
3.
4.
0
10
20
30
Pressure in Atmospheres
1. Nitrogen atmosphere using Heater with a 1.1% Hydrogen concentration. Temperature of the gas is 50°C, and the humidity increases with depth.
2. Helium atmosphere using Heater with a .7% Hydrogen concentration. Temperature of the gas is 45°C, and the humidity increases with depth.
3. Helium atmosphere without Heater. Temperature of the gas is 10°C, and the humidity is 0%.
4. Nitrogen atmosphere without Heater. Temperature of the gas is 10°C, and the humidity is 0%.

L. E. Wittmers
Department of Physiology
School of Medicine
University of Minnesota-Duluth

ABSTRACT

EFFECTS OF ALCOHOL ON THE DIVING REFLEX

L. E. Wittmers
Department of Physiology
School of Medicine
University of Minnesota-Duluth

The dive reflex is considered to be a life saving mechanism in situations where people fall into water. The water on the face triggers a decrease in heart rate and an increase in blood pressure. Since many water accidents involve the use of alcohol, human subjects were given alcohol to reach a level of 0.1% gm. Cardiovascular parameters were monitored during breath holding in air and with the face immersed in water ($4^{\circ}C$). Alcohol caused a significant decrease in the rise of blood pressure versus control response. In addition, certain subjects who were legally intoxicated were able to stay longer in cold water. These initial results indicate that alcohol has some effect on the cardiovascular regulatory systems when the dive reflex is activated.

Effect of Alcohol on the Diving Reflex

L. E. Wittmers, Jr., L. Fairbanks, S. Burgstahler, and R. S. Pozos
Department of Physiology, School of Medicine
University of Minnesota-Duluth, Duluth, Minnesota 55812

The cardiovascular adjustments which occur on submersion of diving animals have been studied extensively in non-human species. The major changes associated with the "diving reflex" are a) bradycardia; b) peripheral vasoconstriction; and c) increased blood supply to vital organs. Although not as well developed, this reflex has been demonstrated in man. The magnitude of the diving reflex in man is a function of numerous environmental and physiological parameters (posture, lung volume, venous return, extent of immersion, and water temperature). It has been suggested that even in man the diving reflex may act as an oxygen conserving mechanism.

Our interest in the diving reflex stems from attempts to evaluate the effects of alcohol ingestion on the cardiovascular function in man under altered environmental conditions with special consideration to cold exposure. Alcohol is often associated with hypothermic accidents. Rather than inducing cardiovascular changes by exercise or drugs, the subject's diving reflex (as elicited by face immersion) was monitored before and after consumption of alcohol.

The subjects for these experiments were healthy male and female volunteers, ranging in age from 20 to 38 years. Heart rate was continuously monitored by a single lead telemetry system and rate calculated over a 5 beat span or for very slow rates by R-R interval length. Blood pressure (systolic-diastolic) was measured with a semi-automatic pneumatic cuff and microphone system. The dive reflex was elicited by submerging the subject's face (up to level of the ears) in cold water ($4 \pm 2^{o}C$). Expired lung volumes were measured with a spirometer. Blood alcohol levels were estimated by sampling and analyzing end alveolar gas. All subjects were exposed to the test protocol at least once prior to the actual experiment in order to familiarize them with the equipment and experimental design. Prior to the experimental period (control + alcohol consumption) all subjects fasted for 12 hours. The subject was seated comfortably with his head bent forward over a pan of water. The subject took a breath to either vital capacity or some intermediate lung volume (70% vital capacity), and either held that lung volume (as long as possible) in air or submerged in water. The subject then exhaled into a spirometer. Subjects drank the alcoholic beverage of their choice at a comfortable rate until a blood alcohol level of 0.1 g% was achieved. At that point the breath holding maneuvers at both lung volumes in air and water were repeated. An overall summary of the experimental design is presented in Figure 1.

General physical characteristics and control mean blood pressures (mean) and heart rates for the experimental population are summarized in Table 1. Figure 2 contains a sample recording of blood pressure and heart rate of a dive reflex response in two individuals. Subject R. P. shows decrease in heart rate and a rise in blood pressure during face immersion. This subject is included in the experimental population as #8 (see Table 1). The second subject in Figure 2 (W. I.) responded to face immersion with a dramatic rise in systolic and diastolic blood pressure (the systolic values exceed the maximum range of the calibration) and an EKG pattern suggesting arrhythmias. No further experimentation was performed on this individual.

The experiments were designed to study the effects of alcohol on the dive reflex and in light of previous work that indicated that breath holding alone may cause considerable changes in heart rate and blood pressure and that alterations in these parameters may be affected by lung volume at the time of apnea. Heart rate response in air apnea is minimal whereas in water there is an initial increase in heart rate followed by a fall representing a 30% decrease from control levels. At vital capacity the heart rate changes in air or water apnea are not altered by alcohol ingestion. Water apnea results in an initial rapid rise (0-25 sec) in blood pressure of approximately 15 mmHg followed by a slow continual rise throughout the period of apnea. Mean blood pressure changes in these experiments were similar in profile both for control and after alcohol consumption; however, after alcohol consumption the mean blood pressures were approximately 10 mmHg lower than in the control studies. Air apnea is associated with a slow continuous rise in blood pressure.

Results obtained at the intermediate lung volume differ in the following respects. The initial increase in heart rate seen in water immersion does not appear. Further blood pressure changes in the control experiments show a delayed rise in both air and water apnea. After alcohol ingestion there is no increase in blood pressure following water immersion (see Figure 3).

Preliminary data presented here indicates that alcohol may alter cardiovascular response of the diving reflex but observing this effect depends on the lung volume at which the reflex is elicited.

This work was supported in part by a grant from Sea Grant (DOC/NA79AA-D-0025).

Ms. Fairbanks is supported by Indians Into Research Careers (IRC) NIH grants #78-GM1419 and #78-GM042.

Table 1

Physical Characteristics of Subject Population

Subject #	Sex	Age (yr)	Height (cm)	Weight (kg)	VC[1] liters	VC % N[2]	HR[3] (beats/min)	BP[4] (mmHg)
1	M	22	175	75.0	4.2	84	79	88
2	F	22	155	70.4	3.5	109	72	89
3	M	24	170	65.9	3.9	85	57	111
4	M	29	163	59.1	3.7	93	60	94
5	M	20	183	80.9	5.7	103	73	96
6	M	23	175	78.6	5.4	110	68	109
7	M	30	173	84.1	5.3	103	59	91
8	M	36	175	81.8	5.2	107	71	85
9	M	38	183	81.8	5.8	110	56	113

1. VC = vital capacity
2. VC % N = VC of subject divided by predicted normal value
3. HR = heart rate (control value)
4. BP = mean blood pressure (control value) = diastolic + 1/3 pulse pressure

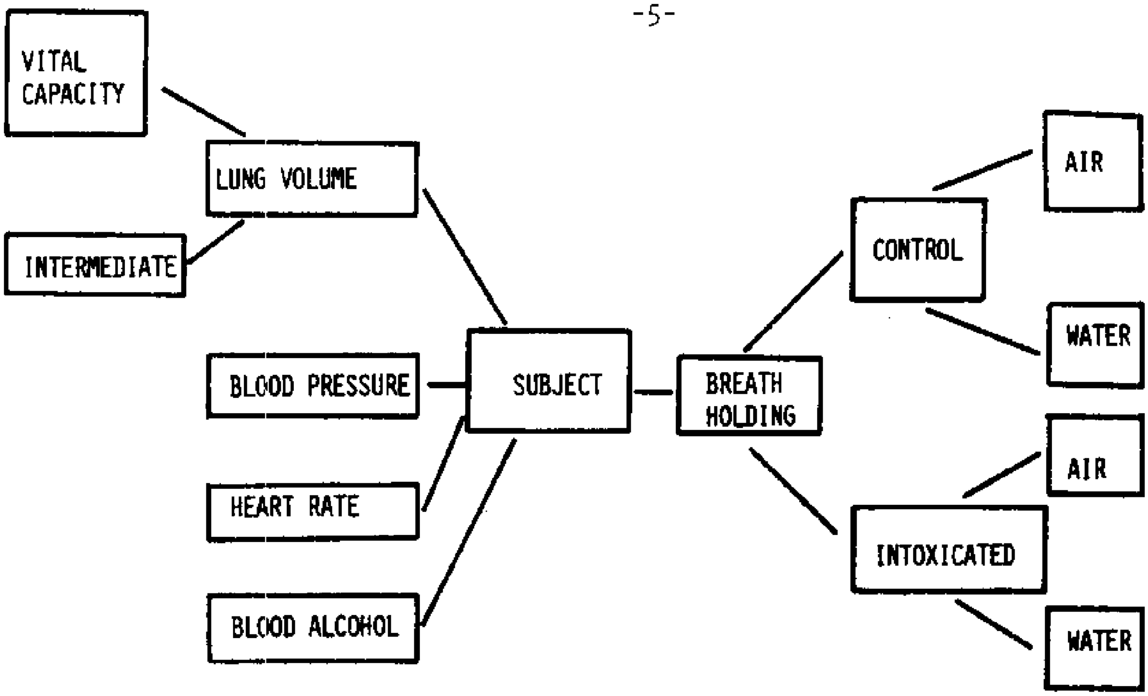


Figure 1. This is a summary diagram of the experimental design employed to study the effect of alcohol consumption on the dive reflex.

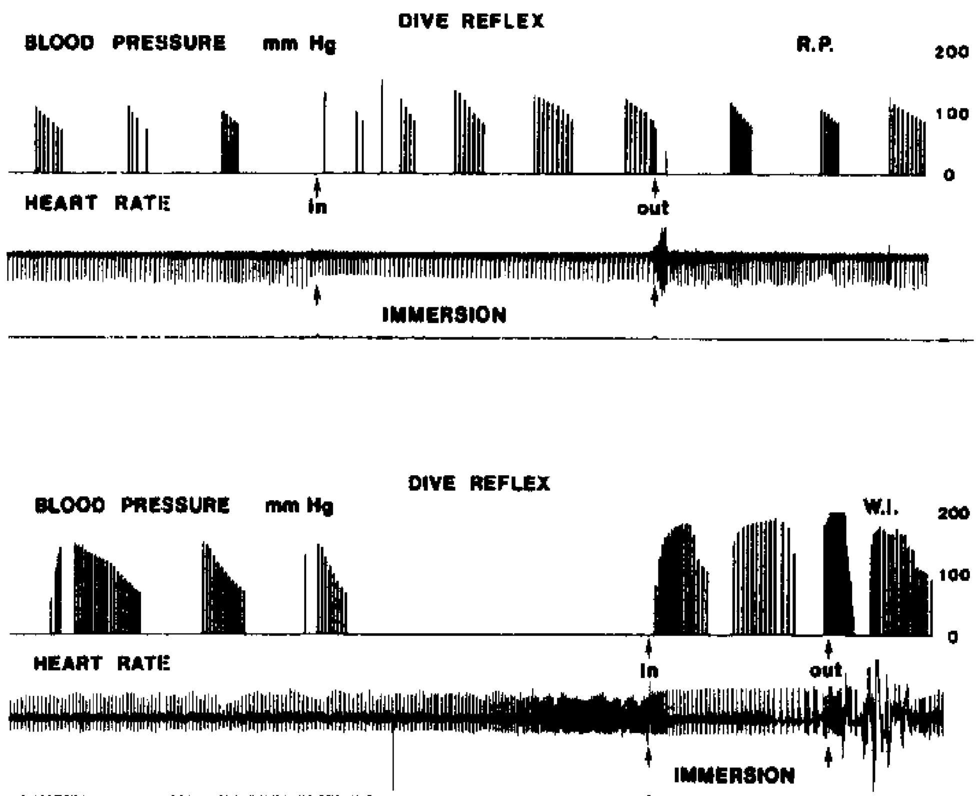


Figure 2. Examples of EKG's and blood pressure recordings on two subjects before, during, and after face immersion in cold water, without alcohol consumption. Note the drastic

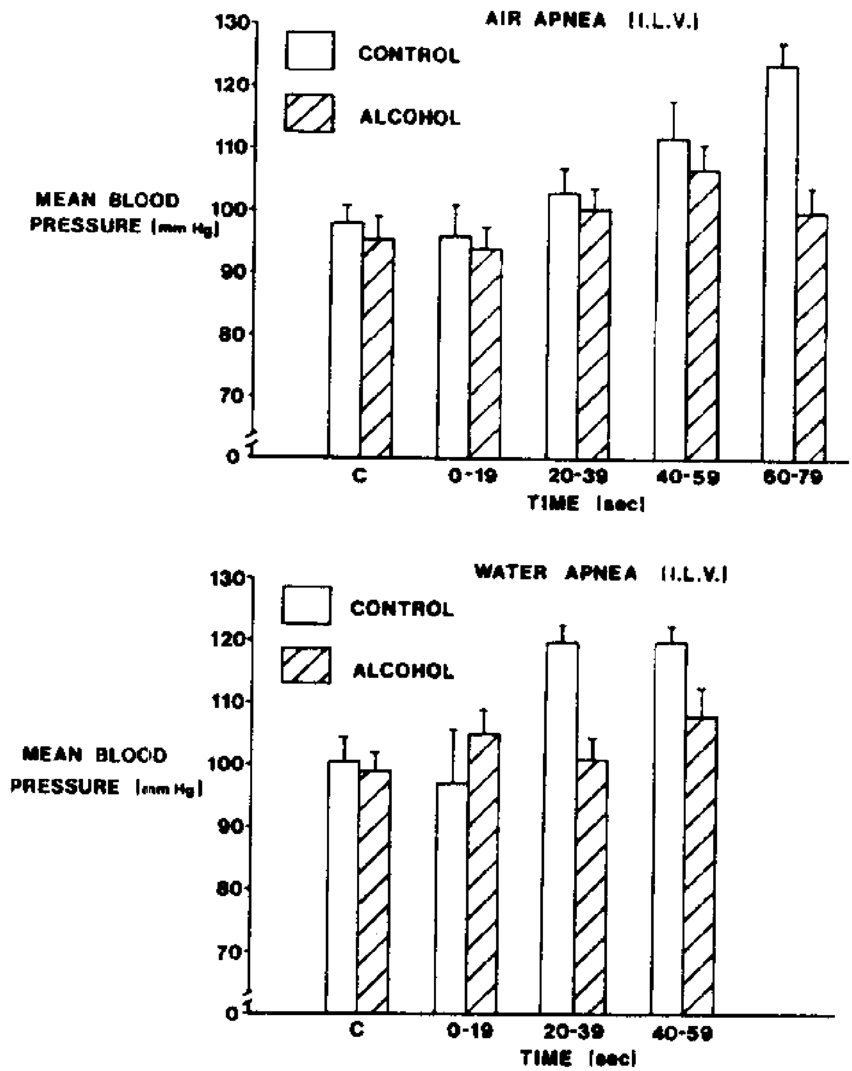


Figure 3. Mean blood pressure changes at intermediate lung volume for air and water apnea pre and post alcohol consumption. The bars represent mean values of the 9 subjects with a +1 SEM.

Immersion: Some advice on first aid and the nature of the problem

By Frank Golden (surgeon commander) senior medical officer (survival) Royal Navy Institute of Naval Medicine, who has made a special study of this subject.

Whether an immersion victim lives or dies, more often than not depends on the first aid given by his rescuers, rather than the intensive care he receives subsequently in hospital. For this reason it is essential that all those who may be engaged in the rescue of such victims should be absolutely clear on the correct first aid treatment to administer.

In recent years medical research has identified several factors which may result in death, either during immersion, or after rescue. An understanding of these different factors may assist the doctor in the medical management of the post immersion patient, but such knowledge should be considered to be 'icing on the cake' to the first aider. Unfortunately, details of the medical classification of immersion patients based on these different factors has led to considerable confusion in the minds of many who should be interested only in first aid. Terminology such as partial drowning, secondary drowning, dry drowning, fresh and salt water drowning, exposure, hypothermia, etc., is medical jargon which is irrelevant to the practice of good first aid. Although it may be 'nice to know' the underlying mechanisms of the problem one is endeavouring to treat, such knowledge will not improve the patient's chances of survival in the slightest, if the first aid measures employed are incorrect.

First aid

The first aid management of immersion victims is quite straightforward.

1 Is the patient breathing? If not, clear the airway, and if necessary start expired air resuscitation (EAR) as soon as possible. Having ensured that adequate ventilation (breathing) is being maintained – i.e. the chest wall is visibly rising and falling when air is blown into the patient – check the pulse.

2 Is there a pulse present in a large artery, e.g. in the neck? If not, and the pupils of the eyes are large, begin closed chest cardiac massage (CCCM) at a rate of five compressions to each EAR ventilation. If possible, the regular cardiac compressions should not be interrupted for the ventilation, but this technique requires much practice to perfect the timing. Having ensured that adequate ventilation and heart action are present (or while maintaining both) try and prevent further loss of body heat, by wrapping the patient in a blanket, and transport him to the nearest medical care.

The above basic advice may be regarded by many as an oversimplification, but it forms the necessary foundation on which the more specific advice detailed below can be built.

Clear airway

It is essential that everyone should understand what is meant by a 'clear airway', and how to ensure that one is maintained in an unconscious patient.

A clear airway means that there is no obstruction to the flow of air to and from the lungs. In an unconscious patient, lying on his back, the tongue collapses against the back of the throat and thus obstructs the airway. At best this may just produce a rattling, choking, sound during breathing, but frequently it blocks the airway completely.

Supporting the floor of the mouth with the fingers while at the same time gently pulling the jaw forward will pull the tongue away from the back wall of the throat. This simple technique is so important that it is worth having it demonstrated to you by a doctor or nurse who is familiar with it.

Kneeling behind the patient, the jaw is grasped on either side in the region of its angle beneath the ear, and gently pulled forward and upwards, while the tips of the fingers support the floor of the mouth beneath it. At the same time the neck should be extended backwards, gently but NOT FORCIBLY, until the chin and the front of the neck are almost in a straight line.

If, having done this, it is apparent that the patient is able to breath freely on his own, then he may be turned on his side and placed in the 'unconscious position'. This will free one to attend to other patients, or to summon help.

Alternatively, if the patient still has difficulty in breathing, start EAR, but first make a quick check of the patient's mouth and throat to ensure there is no vomit, dentures or other obvious cause of airway obstruction. If so, clear quickly, using one's fingers. There may be an accumulation of water in the throat, which in salt water immersions it is best to drain quickly before commencing EAR. However, time should not be wasted on this procedure, it is essential to start EAR as quickly as possible.

EAR

Whether one performs mouth-to-mouth, or mouth-to-nose EAR is largely a question of personal choice. Some may find it easier to support the floor of the mouth and jaw while performing mouth-to-nose. But the question of which is the best method is almost academic, provided whichever method is employed produces an adequate flow of air into the lungs.

Many immersion victims vomit during, or after, resuscitation. This is due partially to the large volume of water swallowed during the drowning, and/or partially to the inadvertent distension of the stomach by air during incorrectly administered EAR. In a relaxed unconscious patient, some air will enter the oesophagus (gullet) as well as the trachea (windpipe) during EAR, unless the neck is well extended. When the neck is fully extended, the air forced into the throat during EAR will follow the path of least resistance, ie. into the trachea. EAR should be given to all those who are not breathing, and maintained until the patient starts breathing spontaneously. If cardiac arrest has developed and there is no response to CCCM, EAR may be discontinued after 20-30 minutes.

EAR should also be given to unconscious patients, who are spontaneously breathing but whose lips are blue. These patients may have large areas of lung which are collapsed, where blood and air are not coming into contact, so that the blood is not fully oxygenated. This is a very common problem in drowning. Frequently, intermittent – one or two breaths – excursions of EAR are all that are necessary; the requirement for which is judged from the blue colour of the patient. One should, where possible, synchronise the EAR with the patient's breathing. This treatment is particularly required if the colour of the patient is not improving when breathing oxygen from a mask. Conscious patients should be encouraged to take deep breaths and to cough intermittently en route to hospital.

The advantages of EAR over other first aid methods of pulmonary resuscitation, eg. Holger-Nielsen, Sylvester etc., are such that instruction in these other methods should no longer be given. This is particularly true for immersion victims, where not only are the more voluminous air flows achieved with EAR more advantageous, but also the positive pressure of the air blown into the airways is essential to expand the collapsed lung.

Closed chest cardiac massage

When performed correctly, CCCM can undoubtedly be lifesaving, by maintaining a circulation until the patient arrives in hospital where more specific treatment can be given. It is a difficult procedure to perform correctly without frequent practice, and dangerous to do when not required. One cannot learn the technique from the written word and you are strongly advised to seek proper instruction before attempting it.

One immersion situation where it may be inadvisable to give CCM is to the apparently dead victim found floating in a lifejacket, or liferaft, where there was no question of water having been inhaled. This individual may be alive but suffering from profound hypothermia ie. an extremely low body temperature. If so, attempts at CCCM may well stop the heart (cardiac arrest). On the other hand, if he was already in cardiac arrest when rescued, it is probable that he had been dead for some time and CCCM is not likely to do much good. If it is considered possible that the patient might still be alive, then EAR should be given and the patient placed in a bath of stirred hot water, 41°C (hand hot) if naked, in 45°C if clothed. The whole body, except for the head, should be immersed. At one time it was considered that the arms and legs should be left out of the hot water, but this is no longer recommended. If a hot bath is not available, then insulate the body in a sleeping bag or blanket and transfer, slightly head down, to the nearest medical care.

The mechanisms of the problem

The temperature of the water around the coast of the UK, even in summer, can be classed as very cold in relation to body temperature. These temperature differences produce stress responses in the body, which may result in death directly, or cause incapacitation resulting in drowning.

In general there are four identifiable phases where the nature of the hazard threatening the life of the immersion victim is slightly different:

1 On initial immersion ie. the first two or three minutes.

2 Short-term immersion ie. three to 15 minutes.

3 Long-term immersion ie. 30 minutes and thereafter.

4 Post-immersion.

1 On initial immersion: The shock of cold water entry, to those unaccustomed to it, produces the most dramatic increase in heart rate, blood pressure and breathing rate. These changes may kill, or seriously incapacitate, many people, particularly the middle aged and elderly who may already be suffering from heart disease or high blood pressure. These responses decline after a few minutes' immersion, and the immersion victim has then to contend with the problem of remaining afloat.

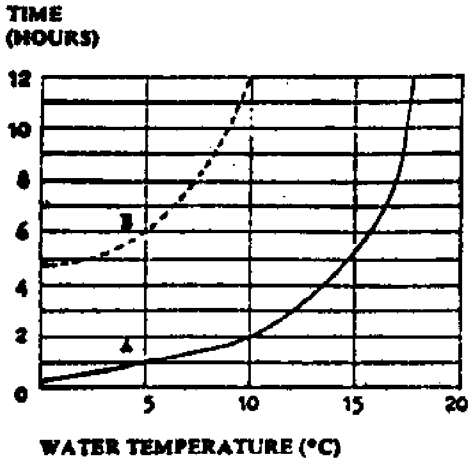
2 Short-term immersion: Many individuals who drown do so within 15 minutes of immersion. Many of these are competent swimmers who would have little difficulty in remaining afloat in a heated swimming pool. It has been shown however, that even competent swimmers who are unaccustomed to swimming in cold water, cannot remain afloat for very long in cold water (Keatinge etal 1969). That experiment highlights the importance to even competent swimmers of wearing some form of buoyancy aid – and preferably a lifejacket – when exposed to the risk of immersion. Although this problem is associated with very cold water, the duration of immersion is usually insufficient for hypothermia to develop. The precise reason why people have difficulty in remaining afloat remains a mystery.

3 Long-term immersion: If the immersion victim is wearing lifejacket, or has some other means to

Water safety

assist him in keeping his airway clear of the water, he will cool progressively while awaiting rescue. If his flotation aid is only a 'buoyancy aid', and not a 'lifejacket' he will drown when consciousness is lost (around body temperature of 33°C – normal body temperature is 37°C) ie. before hypothermia of a clinically significant degree develops. A lifejacket, on the other hand, will maintain the airway of an unconscious man clear of the water, except in rough or choppy seas. In such waters, the wave splash over the face may result in drowning even before consciousness is lost. In relatively calm water however, the individual wearing a lifejacket will cool progressively and eventually die from hypothermic cardiac arrest unless rescued.

Approximate survival times of immersion victims are shown in the graph. These estimates are based on data obtained from shipwrecked survivors (Molnar 1946) where the water temperature and duration of immersion were known. Curve A is the estimated 50 per cent survival time for individuals in outdoor clothing eg. after one hour in water at 5°C, 50 per cent of survivors will be dead. Some will die in the first few minutes, while others could survive for several hours depending on clothing worn, brdy fat content, physical fitness, lifejackets, sea state etc.



Estimated Immersion Survival Times

Curve A: Estimated time to 50 per cent mortality in outdoor clothing. eg. after one hour, 50 per cent of survivors in water at 5°C will be dead.

Curve B: Recommended minimum search times. Should be at least six times the time given in curve A.

Curve B is the *MINIMUM* recommended search times for immersed individuals. Obviously it is not intended to be used as a guide to search times for survivors who may be in liferafts or lifeboats.

4 Post-immersion: Somewhere in the region of about 20 per cent of people, who are rescued alive from cold water, collapse and die after rescue. Some of these die from the delayed effects of drowning, others from cold. If the first aid treatment outlined above is followed, a number of these deaths will be prevented. In recent years a number of cases have been reported in the medical literature of people being successfully resuscitated after being submerged in very cold water for periods of 20-40 minutes. Whatever the mechanism of these extraordinary cases is, the message from them is quite clear – always attempt resuscitation, and don't give up too quickly.

Finally, it is important that anyone who has inhaled water during an immersion incident be sent to hospital for a chest X-ray, even if he appears to have made a full and uneventful recovery. Coughing and spluttering, occasionally accompanied by chest pain, is usually an indication that a significant quantity of water has been inhaled. The inhaled water, or contained particulate matter, irritates the lung and can result in a sudden flooding of the lungs with body fluid resulting in death.

References

Keatinge W R, Prys-Roberts C, Cooper K E, Honour A J and Haight J (1969) *Sudden failure of swimming in cold water.* Brit. Med. J. 1:480-483

Molnar G W (1946) *Survival of hypothermia by men immersed in the ocean.* J. American Med. Assoc. 131:1046-1050

The views expressed in this article are those of the author and do not necessarily reflect those of the Royal Navy.

PHYSIOLOGICAL RESPONSES OF HUMAN SUBJECTS WEARING THERMAL PROTECTIVE CLOTHING ASSEMBLIES IN VARYING ENVIRONMENTS

LTJG David C. Johanson
Aerospace Physiologist

Mrs. Suzanne M. Reeps
Physical Scientist

Mr. Louis J. SantaMaria
Research Physiologist

Aircraft and Crew Systems Technology Directorate
Naval Air Development Center
Warminster, PA 18974

ABSTRACT A group of representative Free World anti-exposure suit configurations were selected for a test program designed to evaluate their relative effects on aviator performance in the areas of mobility loss, heat stress, and immersion hypothermia protection. Sequential testing was utilized to eliminate those configurations which did not meet predetermined requirements, as defined by CNO, to satisfy the operational need of Naval forces. Mobility loss and heat stress testing at 35°C have been completed. Immersion hypothermia testing in 7.2°C water is currently being conducted with tests in 0°C water to follow.

INTRODUCTION Background: In the early Spring of 1977 the Chief of Naval Operations hosted a water survival conference which was to examine all aspects of the Naval Aviation Water Survival Training Program. Such an examination resulted in an overview - although not intended - in both the associated Life Support Equipment (LSE) and accompanying Search and Rescue (SAR) operations.

As a result of this meeting, a coordinated effort was aimed at reducing the number of deaths which occur when aviators find themselves removed from their aircraft and placed in the water. Among the directives issued at the conclusion of this meeting were the following: revitalized efforts in updating a single training manual for LSE; formulate a SAR publication to include training, tactics, rescue equipment and LSE interface; and specifically for NADC, devise a test plan to evaluate various LSE configurations in the real environment.

As a part of that requirement, a series of meetings was held in the Spring of 1978 to develop an operational requirement (OR) for exposure system protection (W11597SL). It was recognized that several decisions had to be made in a logical manner in order to succeed in best meeting the present and future needs of the entire Fleet. A logic diagram identifying these decisions was therefore used to guide the meeting discussions. The first decision made was that land and sea requirements had to be determined separately, with sea requirements becoming the major thrust for the initial program. Design decisions were also to be made on the basis of wartime, with unique peacetime requirements being given consideration only after fully meeting the potential needs of war. An equal probability of going to war in any one geographical area was assumed, and it was then agreed that a graduated system of protection would best meet any potential operational need. Two hours is the current operational requirement already set for SAR operations, and this same two hour period was agreed upon for designing an exposure protection system. This decision was supported by Naval Safety Center statistics, which indicated that between 1969 and 1977, 91% of all rescues occurred in less than 60 minutes. Although fully recognized as peacetime statistics, the two hour goal was still felt to be adequate.

Water temperatures for the graduated system approach were set at two levels. The first level was 7.2°C and above. The second level was set at a range of 0 to 7.2°C. The 7.2°C cutoff point was chosen for two reasons. First, the majority of ejections/ditchings (greater than 95%) have occurred over water with a temperature of at least 7.2°C. Secondly, since the survival time of an unprotected man drops off rapidly in water temperatures lower than 7.2°C, it was agreed that this level would allow for the design of a clothing configuration offering the least encumbrance to the majority of crew members. Since the available SAR data already discussed was for peacetime, an extra margin of protection was included by requiring that the 7.2°C water system be capable of protecting a man for two hours of immersion, without consideration being given for any additional thermal protection. For the 0 to 7.2°C water temperature range, a flotation platform for subject removal from the water was considered as the best alternative. Such equipment must be an integral part of the system design, thereby guaranteeing its instant availability. Air temperature, for testing purposes, was set at 8.4 to 11.2°C below water temperature, with a 29 to 32 km/hr wind velocity.

Protection at both levels was defined in terms of preventing any permanent physiological damage, as well as maintaining sufficient physical capability to allow a survivor to aid in his own rescue. To meet this requirement, physiological limits were set at a minimum of 35°C core (rectal) temperature, a minimum of 10°C skin temperature for the hands, and a minimum of 0°C skin temperature for the feet. In addition to these levels of hypothermia protection, the system must: (1) not support combustion; (2) be compatible with all existing and proposed flight and survival equipment, crew stations, and overall mission accomplishment; (3) impose minimum body heat buildup during the mission; (4) impose minimum physical restrictions i.e. mobility loss on aircrewmen; and (5) be reliable, maintainable, and logistically supportable. Optimization of the system for use by crewmen in ejection seats, fixed seats, and for mobile crewmen is also required, with commonality being sought, but not being the driving force.

For the last few years, the U.S. Navy has been utilizing a variety of anti-exposure garments, specifically: (1) CWU-33/P wet suit - modified and unmodified; (2) CWU-21/P ventile anti-exposure assembly; (3) various commercially available wet suits; and (4) the QDI quick donning suit. Associated with these garments are various flotation devices. As in any situation, a large degree of dissatisfaction has resulted because these garments, in varying degrees, either do not meet all the mission-specific requirements or provide all the comforts and features desired by the wearer. Although all personal preferences cannot always be satisfied, it was felt that much of the dissatisfaction arising from operational insufficiencies could be alleviated if future design were to be based on a comprehensive test program to include investigations of mobility restriction, thermal degradation from heat buildup, and protection from hypothermia at two distinct levels, 7.2°C and 0°C water temperature.

Program Plan: The first area of concern in our T&E program was to be that of mobility. Any anti-exposure assembly that would significantly inhibit full range of motion would not be acceptable. Accordingly, reach measurements would be required which would apply to all Naval aircraft in which an individual is fixed in his seat position relative to the instruments and/or controls. Consideration was also to be given to those aircraft types which allow for aircrew movement relative to critical reach dimensions during unusual flight regimes.

In consideration of the hypothermia aspects of anti-exposure equipment, the following parameters were set as the upper acceptable limits: heart rate >180 beats/min (bpm) during moderate work load and >140 bpm during resting metabolic levels, and a maximum rectal temperature of 39°C, or a rate of rise of 1.6°C/hr during the three hour period.

The hypothermia levels were divided into two distinct phases, both with a two hour end point as previously described in the discussion of the OR. Results from the test phases would be used to develop a modular type exposure protection system.

METHODS To begin our program, we reviewed the current literature on the subject with specific consideration for the excellent study conducted by Dr. John Hayward at the University of Victoria. We then selected twenty-one available "Free World" anti-exposure assemblies for evaluation in the test phases of the program. These assemblies are identified as follows:

- WF1 Mustang UVic Thermofloat Jacket
- WF2 Australian UVic Flight Jacket
- WF3 Parkway Surfer Shorty Suit - Style MTS616
- WF4 Parkway One-Piece Jumpsuit - Style MS0412
- WF5 Parkway Two-Piece Full Wet Suit - Style MSS116
- WF6 CWU-33A/P Anti-Exposure Flying Coverall
- W1 CWU-27/P Summer Flying Coverall
- W2 CWU-48/P Knit Aramid Flyer's Coverall
- W3 ILC Vari-Temp Tube Suit
- DI1 Imperial "Bubble" Suit
- DI2 Imperial Survival Suit No. 1409
- DI3 ILC AE2 Anti-Exposure Coverall
- D1 CWU-21/P Anti-Exposure Assembly
- D2 MK-10 British (RAF) Immersion Aircrew Coverall
- D3 Swedish A.F. Immersion Suit - Style No. 82
- D4 Canadian MK-1 Constant Wear Immersion Suit
- D5 NADC Experimental "Goretex" Coverall (Plain Weave)
- D6 NADC Experimental "Goretex" Coverall (Twill Weave)
- D7 Danish Flyer's Anti-Exposure Coverall
- D8 Japanese Anti-Exposure Suit

In order to make our mobility test procedures similar to those done by others, we reviewed the reports by the Naval Air Test Center "Evaluation of Flight Clothing and Equipment Effects on Pilot Accommodation" and the NASA reference publication 1024 "Anthropometric Source Book". We then constructed an anthropometric measuring device with adjustable point-of-reference measuring sites to insure that our methodology would be similar to that of other authors. We used a set of 24 measurements to insure correlation with all the required movements of the aviator while operating his aircraft. These measurements were then used to eliminate any configurations which did not allow for full freedom of motion, as defined by aircraft type range-of-motion studies. In all mobility tests, the subjects wore full flight gear including boots, torso harness, survival vest with life preserver, mask, helmet and gloves.

Those suit configurations which passed the mobility test then entered the next phase of testing. Tests were conducted in a thermal chamber with a regulated environment. The ambient temperature in the chamber throughout the test run was maintained at 35°C, which was selected for the following reasons: (1)NATOPS requires use of an anti-exposure garment when the water temperature is 15.6°C or below; (2) since outside air temperature (OAT) changes fairly rapidly to match water temperature, it was assumed that the maximum OAT, when anti-exposure equipment is required, would not exceed 15.6°C; (3) according to data collected for the H-3 helicopter, the helicopter in Navy inventory having the highest ambient temperatures, internal cabin temperature can increase as much as 16.6 to 22.2°C higher than the OAT. The maximum internal cabin temperature would therefore range between 32.3°C and 37.8°C. The helicopter environment was chosen as a baseline since it was assumed to represent the worst case. It was further assumed that the suit configurations would perform better in fixed wing aircraft, where air conditioning is available, but that the relative performance levels of each suit configuration would remain the same.

A brief overview of a test run involved weighing a nude subject on a very sensitive beam balance, and application of four thermistor transducers in the area of the chest, upper arm (lateral), lower leg (lateral) and the anteromedial aspect of the upper leg. An appropriate thermistor probe was inserted some 8-10 cm rectally to measure deep body temperature. The subject was then dressed in the clothing assembly of the day. Just before entering the test chamber, where an ambient temperature of 35°C had been established, a blood pressure cuff containing an integral pressure transducer was wrapped around the left upper arm for measures of pre-test heart rate and blood pressure. The system used for these measures was the DINAMAP Model 845 and the Model 950 Trend Recorder/Printer. A preliminary scan of the body temperatures was made to assure the working order of the instrumentation.

Immediately upon entering the test chamber, the subject began a 20 minute cycle, which included in the main a five minute work task, three separate intervals of a tracking task (Atari), each lasting 2.3 min., and finally a rest period of 6.2. The 20 minute cycle was repeated throughout the course of the test run, which was scheduled to last, at the most, for a period of 180 min.. The planned work task was the same for all subjects and consisted of carrying a distributed 20 kg load suspended from the shoulders while pacing within the confines of the chamber at a rate of about 1.6 km/hr. The work task was intended to produce a metabolic output of approximately 262W (225 kcal/hr or 900 BTU/hr), which was considered representative of a moderate level work load, while the rest phase, that of a resting metabolic output. Heart rate and blood pressure measurements were taken five times throughout the test at 20, 60, 100, 140 and 180 minutes. At the end of the test run, either full term (three hour) or for a shorter period, following the attainment of subjective or objective endpoints, the subject was aided in the removal of the test clothing, dried with a towel and weighed once again on the balance. In the event that the rectal probe became dislodged in the course of the test activity, the subject was asked to re-insert it as soon as possible upon leaving the test cell, in order that a measure of deep body temperature could be recorded at the end of the test exposure. The subjects exercised the right to request termination of runs in less than three hours for reasons ranging from extreme discomfort to disorientation and nausea. Objectively, when heart rate levels during the working or sedentary phase and/or rectal temperature increases reached the pre-established tolerance limits mentioned previously, the run was terminated in less than three hours. Those suit configurations which prevented the subjects from attaining or exceeding thermal tolerance limits were then entered into the cold water immersion test phase.

RESULTS Mobility Testing: The subjects used in this evaluation were 12 males and 2 females representing a full range of body sizes. The mobility data is presented as percentage increase or decrease from a baseline consisting of the summer flight configuration, which included the CWU-27/P coverall (W1). Analysis of the data, revealed that no generalizations about mobility could be made by grouping the garment types. Rather, each garment must be considered individually for its affect on mobility.

Certain movements do seem to be more affected by the wearing of an anti-exposure garment. For instance, torso torsion, or the rotation of the body as a whole, is affected to a high degree by almost all of the garments tested. Eleven of the 15 tested garments decreased mobility in this area by 30% or more, with a maximum of as much as 44.9%.

Shoulder mobility was determined by four different measurements - flexion, extension, abduction, and adduction with the most critically affected ones being flexion and adduction. In general, the wet foam suits (WF) restricted these shoulder movements more than the dry suits, but the CWU-21/P Anti-Exposure Assembly (D1) also showed high mobility loss for both of these movements. The ILC AE2 Anti-Exposure Garment (D13) exhibited a marked decrease in shoulder flexion. In contrast, the critical movement of forward reach, which is a compound action involving both shoulder and torso movement, was more negatively affected by many of the dry suits with the wet foam suits performing somewhat better. An exception to this was the CWU-33A/P Anti-Exposure Flying Coverall (WF6) for which a greater decrease was measured than for most of the wet foam suits (WF). In general, neck rotation was more restricted by the dry suits than the wet foam suits presumably due to the neck seal, which is a common feature of all dry suits. Elbow flexion was not decreased greatly by any of the suits. Knee extension was most effacted by the CWU-33A/P Anti-Exposure Flying Coverall (WF6), which showed a decrease of 10.4%.

With all measurements being given equal weighting, the wet foam (WF) suits generally decreased mobility more than the dry suits. However, two of the wet foam suits, the Parkway Surfer Shorty Suit (WF3) and the Parkway Two-Piece Full Wet Suit (WF5), were among the least restrictive garments. The most restrictive garments were the ILC Vari-Temp Tube Suit (W3) and the CWU-33A/P Anti-Exposure Flying Coverall (WF6). In addition, for several critical movements, such as forward reach and neck rotation, the dry suits generally restricted mobility more than the wet foam suits. For this reason, each suit must be considered individually for its anticipated effects on mobility, depending on which specific mission it is intended.

Heat Stress Testing: The heat stress measurements of total weight loss, rectal temperature rise and index of strain are presented in the form of a ranking of the protective suit systems, according to the mean response of the parameter in question (Tables I, II and III). The suit assemblies are ranked in a decreasing order of the severity of response for each parameter considered. The standard deviation and range of response for each mean value are also shown.

Total Weight Loss (TWL): The observations regarding TWL in g/min ranged from a mean of 1.98 with the NADC Experimental "Goretex" Coverall (Plain Weave) (D5) to 8.09 using the Parkway Two-Piece Wet Suit (WF5). Reference to the ranking of all suits regarding TWL indicated that the wet foam suit types evoked an increase of TWL over the CWU-27/P Summer Flight Coverall (W1) by a factor of two to one. Although subjects wearing the Danish Coverall (D7) and suits D5 and D6 (both "Goretex") exhibited a lower TWL, because of the reduced number of tests in which these suits were used, comparisons with the remaining suits are difficult to make.

TABLE I

TOTAL WEIGHT LOSS (TWL IN G/MIN) OF ACTIVE SUBJECTS WEARING DIFFERENT SUIT ASSEMBLIES IN A WARM ENVIRONMENT

SUIT ASSEMBLY	MEAN, SD, RANGE
WF5	8.09 ± 1.55 (5.9 - 10.4)
WF4	7.35 ± 1.35 (5.2 - 10.6)
WF6	6.70 ± 1.27 (4.0 - 8.4)
WF1 (INSIDE OF HARNESS)	6.18 ± 1.60 (3.9 - 8.2)
WF3	5.88 ± 1.11 (4.4 - 7.5)
W3	5.10 ± 2.39 (3.0 - 9.5)
WF1 (OUTSIDE OF HARNESS)	5.01 ± 0.26 (4.7 - 5.4)
D1	4.38 ± 0.72 (3.2 - 5.1)
W1	4.04 ± 0.71 (2.3 - 5.2)
W2	3.88 ± 0.62 (3.0 - 4.5)
D7	2.65 ± 0.66 (2.0 - 2.7)
D6	2.04 ± 0.20 (1.9 - 2.3)
D5	1.98 ± 0.42 (1.5 - 2.2)

Rectal Temperature Rise: Regarding the rise in rectal temperature, (ΔT_r in °C/hr) the ranking of the clothing assemblies revealed that the WF suits produced increases in T_r greater by a factor of at least six over those values measured for the Summer Flight Configuration (W1). In all trails in the program, the level of rectal temperature attained during the heat exposure was below the predetermined limit (39°C) that would have dictated early termination.

TABLE II

RECTAL TEMPERATURE RISE (ΔT_r IN °C/HR) OF ACTIVE SUBJECTS WEARING DIFFERENT SUIT ASSEMBLIES IN A WARM ENVIRONMENT

SUIT ASSEMBLY	MEAN, SD, RANGE
WF5	0.38 ± 0.07 (0.29 - 0.50)
WF4	0.30 ± 0.04 (0.22 - 0.35)
WF6	0.21 ± 0.07 (0.08 - 0.29)
WF1 (INSIDE OF HARNESS)	0.18 ± 0.13 (0.04 - 0.45)
WF3	0.18 ± 0.08 (0.04 - 0.26)
D5	0.18 ± 0.07 (0.13 - 0.23)
WF1 (OUTSIDE OF HARNESS)	0.15 ± 0.04 (0.10 - 0.24)
W3	0.13 ± 0.07 (0.05 - 0.22)
D1	0.11 ± 0.03 (0.04 - 0.15)
D7	0.09 ± 0.02 (0.06 - 0.10)
D6	0.08 ± 0.09 (-0.03 - 0.17)
W2	0.07 ± 0.04 (0.00 - 0.13)
W1	0.02 ± 0.04 (-0.02 - 0.10)

Index of Strain: The index of strain ($Is = \frac{HR}{100} + \Delta T_r$ (°C) + TWL (kg/hr)) revealed that the WF suits produced responses that were greater by a factor of almost two over the responses produced by the Summer Flight Configuration (W1). As shown in the ranking of the various suit assemblies, the Parkway Two

Piece Wet Suit (WF5) induced the worst Is with a mean value of 1.99 ± 0.19 as compared to 1.12 ± 0.11 for the CWU-27/P Summer Flight Configuration (W1). Again, lower Is was attained using both types of "Goretex" suits (D7, D8) in a reduced set of exposure trials.

TABLE III

INDEX OF STRAIN (Is) OF ACTIVE SUBJECTS WEARING DIFFERENT SUIT ASSEMBLIES IN A WARM ENVIRONMENT

SUIT ASSEMBLY	MEAN, SD, RANGE
WF5	1.99 ± 0.19 (1.04 - 2.37)
WF4	1.79 ± 0.22 (1.55 - 2.11)
WF6	1.62 ± 0.18 (1.32 - 1.84)
WF1 (INSIDE OF HARNESS)	1.58 ± 0.33 (1.17 - 2.13)
WF3	1.49 ± 0.19 (1.30 - 1.89)
WF1 (OUTSIDE OF HARNESS)	1.39 ± 0.12 (1.22 - 1.54)
D1	1.31 ± 0.11 (1.16 - 1.45)
W3	1.29 ± 0.18 (1.09 - 1.61)
D7	1.14 ± 0.05 (1.11 - 1.19)
W2	1.13 ± 0.06 (1.06 - 1.21)
W1	1.12 ± 0.11 (0.91 - 1.32)
D5	1.10 ± 0.20 (0.90 - 1.30)
D6	1.04 ± 0.15 (0.87 - 1.15)

Duration of Exposure: Of the 168 test runs in the program, subjects tolerated the full exposure period of three hours in 108 cases. In the remaining tests, the duration of exposure was lessened as a result of heat discomfort, headache, impaired circulation, dizziness and an expressed unwillingness to continue in the thermal environment. In none of the tests which were less than three hours duration were critical physiological endpoints reached. Within the context of a voluntary duration of exposure, a ranking of the suit assemblies is appropriate. 12.5% (2/16) of test runs involving the Parkway Two Piece Wet Suit (WF5) lasted full term, followed by 31.2% (5/16) with the Parkway One Piece Jumpsuit (WF4) and 37.5% (6/16) when the Mustang UVic Jacket (WF1) (inside the integrated torso harness) was worn. The percentage of three hour tests using the CWU-33A/P (WF6) was 62.5% (10/16) followed by 64.2% (9/14) while wearing the ILC Vari-Temp Tube Suit (W3), and 68.8% (11/16) in tests using the Parkway Surfer Shorty Suit (WF3) and the CWU-21/P (D1). In tests using the Mustang UVic Jacket (WF1) worn on the outside of the integrated torso harness, 81.2% (13/16) of the tests conducted were of three hour duration. In all tests involving the use of D5 and D6, both types of "Goretex" suits (3/3), the CWU-48/P (W2) (15/15) and the CWU-27/P Summer Flight Suit (W1) (15/15), the subjects were able to tolerate the experimental conditions for the full three hours.

Hypothermia Test: Of the different suit assemblies used in the cold water phase (7.2°C water temperature, 0°C air temperature, 29-32 km/hr wind velocity), only the results using certain ones will be discussed at this time. These include the different suit types represented by the MK-10 British Coverall (D2), the CWU-33A/P (WF6), the Mustang UVic Jacket (WF1) and the CWU-27/P Summer Flying Coverall (W1). Mean weighted skin temperature (MST) will be used as a single indicator of the relative performance of the various suit types. In the tests conducted thus far, the following observations have been made: (1) MST in the British MK-10 (D2) ranged between 7-11°C (Δ) during a two hour run. In suits when leakage occurred, Δ MST was increased by 30%; (2) in the CWU-33A/P (WF6) Δ MST was observed as 14.5°C for the same two hours; (3) in the Mustang UVic Jacket (WF1), Δ MST was observed as 14.7°C for a 1 hour 20 min. exposure; and (4) the CWU-27/P Summer Flight Coverall (W1) showed a Δ MST of 20.5°C in a one hour exposure. The tests reported herein do not include those tests which by extrapolation of the rectal temperature might have successfully completed the two hours required before the attainment of a T_r of 35°C endpoint temperature, these tests were terminated at the request of the subject as result of extreme shivering levels, groin pain and muscular cramps.

Leaking dry suits effected mean skin temperature changes approaching the levels observed using the CWU-33A/P (WF6) and the Mustang UVic Jacket (WF1). In terms of subjective response, this type of leakage effected, in some cases depending on the extent of water intake, a more dramatic intolerance to the cold water environment than that response observed using either the wet foam suit or jacket protective suit assembly.

The majority of the tests conducted in the 7.2°C cold water environment were terminated at the request of the subject as noted heretofore. Only in two instances thus far did rectal temperature approach the endpoint temperature of 35°C and the observed rate of decrease dictated the termination of exposure by the Test Director. In one of these cases, a slight retraction of the rectal probe was confirmed during post-test observation.

SUIT SELECTION Three garment configurations were eliminated from the program during or prior to mobility testing. The Mustang Survival Suit (WF7) was found to be incompatible with required flight gear due to excessive bulk. The Imperial "Bubble" Suit (DI1) was fitted to three subjects but due to extreme discomfort in the neck seal area, mobility measurements could not be completed. The NADC Experimental "Goretex" Coverall (D3) fabricated with plain weave aramid fabric was not measured because its design is identical to D6 with the type of fabric weave being the only difference. The Imperial Survival Suit (DI2) was not measured because it is not intended for constant wear use. The remaining 17 suits were all measured for mobility loss. WF1 and WF2 were measured both inside and outside of the torso harness.

A total of 12 suits was evaluated during the heat stress testing. Of these, three suits (D5, D6, and D7) underwent only a limited number of runs. In addition, five other suits (D2, D3, D4, D8 and DI3) were planned for inclusion into this phase of testing but were received at NADC too late. Three of those five suits (D2, D4 and D8) were included in the 7.2°C water hypothermia testing. If their performance during this testing is outstanding, attempts will be made to obtain some limited heat stress data for these garments. Another suit which was not included during the heat stress phase was the Australian UVic Flight Jacket (WF2). This suit was eliminated since it was available in only two sizes and was similar to the Mustang UVic Jacket (WF1), which was available in a full range of sizes. The WF1 was tested both inside and outside of the torso harness. The Imperial Survival Suit (DI3) again was not included, since it is not intended for constant wear use.

At the initiation of the 7.2°C water hypothermia testing, it was required to limit the program to a maximum of ten garments. At this point, several garments were eliminated for the following reasons. The Parkway One and Two Piece Wet Suits (WF4 and WF5) were eliminated due to their very poor performance in the heat. The CWU-48/P Knit Coverall (W2) was eliminated due to its similarity to the baseline configuration (W1). The ILC Vari-Temp Tube Suit (W3) was eliminated due to restrictions. The Swedish A.F. Immersion Suit (D3) was eliminated since only a limited number of suits were available and it was similar to D2, D4, D7 and D8. The Imperial Survival Suit (DI2) was not eliminated, but was planned for testing in 0°C water only. The CWU-33A/P (WF6) should have been eliminated due to both poor performance in the heat and for excessively restricting mobility, but was included in the 7.2°C water testing since it is still extensively used by the Fleet. With these eliminations, the cold water testing was reduced to evaluating 11 suits. In order to limit the program to the maximum of ten suits, one more had to be eliminated from among four remaining suits, WF1 worn outside the torso harness, D1, D4 and DI3. All four of these suits performed about equally in restricting mobility. However, in forward reach, a critical movement for any aircrewman, the ILC AE2 Anti-Exposure Coverall (DI3) was the most restrictive of all suits tested. It was desirable to include the Mustang UVic Jacket (WF1) since it would provide data on hypothermia protection which would also be applicable to the Australian UVic Jacket (WF2). WF2, worn outside the torso harness, had scored quite well during mobility testing. The CWU-21/P Anti-Exposure Assembly (D1) was to be included since it is the primary anti-exposure garment of the Fleet. The Canadian Immersion Coverall ((D4) showed no critical mobility deficiencies and was therefore chosen for inclusion over DI3. As a result, DI3 was eliminated on the basis of its poor mobility rating.

The suits included in the 7.2°C water testing are as follows:

- WF1 Mustang UVic Jacket worn outside of torso harness
- WF3 Parkway Surfer Shorty Suit
- WF6 CWU-33A/P Anti-Exposure Coverall
- W1 CWU-27/P Summer Flying Coverall (Baseline configuration)
- D1 CWU-21/P Anti-Exposure Assembly
- D2 MK-10 British (RAF) Immersion Coverall
- D4 Canadian MK-1 Constant Wear Immersion Suit
- D6 NADC Experimental "Goretex" (Twill Weave)
- D7 Danish Flyer's Anti-Exposure Coverall
- D8 Japanese Anti-Exposure Suit

CONCLUSIONS The mobility testing indicates that no specific correlation between suit type and effect on general mobility exists. Although certain specific body movements are more restricted by some suit types than others, exceptions do exist, indicating the need to evaluate each suit individually. Therefore, in determining a final engineering design with regard to mobility, individual aspects of each suit design will be evaluated as they would apply to the specific operational requirement.

In general, results obtained from tests conducted in the heat were essentially those to be expected when WF suits are compared to the Summer Flight Suit Configuration (W1). More specifically, the WF suits, compared to the W1, caused twice the TWL, increased core temperature rise by a factor of six, and increased the index of strain by a factor of almost two.

As the hypothermia testing is incomplete, conclusions are considered inappropriate at this time.

Source: U.S. Coast Guard BOATING SAFETY NEWSLETTER Winter 1979

Cold Weather First Aid

HYPOTHERMIA WRAP

PA2 Rick Belanger, USCG,
Fifth Coast Guard District

Every year with the onset of cooler temperatures, a sense of urgency develops among water safety groups for the prevention and treatment of the cold water menace known as hypothermia. This year has proven to be no different. After many hours of first aid training, members of the Coast Guard's Boating Safety Team in Portsmouth, Virginia, noticed that their educational materials did not include a field method for the prevention of "after-drop," a malady caused by improper warming techniques.

Chief Warrant Officer Lonnie Hyatt, head of the team, decided that a collective "brainstorm" by the teams other 25 members might provide a practical remedy.

"We wanted a way to warm the trunk of the body without warming the extremities, but the method had to utilize what we had stored at hand."

In extreme hypothermia cases, the temperature of the limbs often becomes cold enough to drastically cool any blood passing through them. Already at a reduced temperature, the vital organs at the body's core cannot withstand the additional temperature variation caused by the blood circulating through the limbs thus jeopardizing the life of the victim. This is after-drop.

With this in mind, the wife of one of the Boating Safety Team members let her maternal instincts provide the solution. She suggested the use of a modified diaper wrap which would warm the trunk, but allow the limbs to warm at air temperature.

According to Les Fry, a Red Cross safety instructor and a 15 year veteran of a Virginia canoe organization called Coastal Canoes, the idea was a "stroke of genius."

"Although I haven't used the wrap in the field yet, I have always kept a blanket with my first aid gear, and I expect the hypothermia wrap to work very effectively."

Fry, a commercial artist, has implemented the wrap's step-by-step procedure in a slide program that he teaches to canoeists every two weeks. The procedure is:

Step 1

Step 2

Step 2 - cont'd

1. Lay the victim diagonally across the blanket on a flat surface placing the top corner of the blanket over the victims's forehead to prevent further heat loss.

2. Fold the left and right sides of the blanket horizontally over the trunk of the body.

3. Pull the bottom corner of the blanket upwards over the groin area.

4. Provide an external heat source (hot water bottle, heating pad, or hot water up to 115°F poured on).

Step 3

Report No. CG-D-26-79

RESUSCITATION FROM HYPOTHERMIA: A LITERATURE REVIEW

FINAL REPORT

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

FEBRUARY 1979

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard
Office of Research and Development
Washington, D.C. 20590

NOTICE

Technical Report Documentation Page

1. Report No. CG-D-26-79	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: Resuscitation From Hypothermia: A Literature Review		5. Report Date: 14 February 1979
		6. Performing Organization Code
7. Author(s): R.M. Harnett, F.R. Sias, J.R. Pruitt		8. Performing Organization Report No.
9. Performing Organization Name and Address: College of Engineering, Clemson University, Clemson, South Carolina 29631		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DOT-CG-72074-A
12. Sponsoring Agency Name and Address: Department of Transportation, United States Coast Guard, 400 Seventh Street, S.W., Washington, D. C. 20590		13. Type of Report and Period Covered: FINAL REPORT 17 Jan 78 - 14 Feb 79
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report summarizes medical and scientific aspects of the general literature debate over rapid versus slow rewarming and selected specific rewarming approaches. The specific approaches were selected largely on the basis of being difficult to evaluate with in vivo experiments with human subjects. Findings in basic medical literature, research reports and clinical medical literature are analyzed leading to recommendations of the suitability of each specific therapy for use as a first-aid treatment in the field.

17. Key Words: Hypothermia, Rewarming, Cold, Exposure	18. Distribution Statement: Document is available to the public through the National Technical Information Service, Springfield, VA 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified		61	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

This final report documents the work conducted under Task Number 5 of Contract Number DOT-CG-72074-A from January 17 to October 30, 1978. The work was performed at Clemson University under the auspices of the U.S. Coast Guard, with LTjg Steven F. Wiker serving as program monitor. The principal investigators were Drs. R. Michael Harnett, Fred R. Sias, and James R. Pruitt.

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	THE REWARMING PROBLEM	6
2.1	General Nature of the Problem	6
2.2	Fluid Shifts	7
2.3	Edema	8
2.4	Electrolyte and Acid-Base Changes	12
3.0	RAPID VERSUS SLOW REWARMING	15
3.1	General Discussion	15
3.2	Spontaneous or Passive Rewarming	17
3.3	Active Surface Rewarming	19
3.4	Conclusions	21
4.0	PERITONEAL IRRIGATION	23
4.1	Therapy Description	23
4.2	Advantages and Risks	23
4.3	Contraindications	24
4.4	Guidelines	25
4.5	Conclusions	25
5.0	INTRAGASTRIC AND INTRACOLONIC BALLOONS	27
5.1	Therapy Description	27
5.2	Advantages and Risks	28
5.3	Contraindications	28
5.4	Guidelines	29
5.5	Conclusions	29

TABLE OF CONTENTS
(Continued)

Page

6.0 EXTRACORPOREAL BLOOD REWARMING.. 30

6.1 Therapy Description.. 30

6.2 Advantages and Risks.. 30

6.3 Contraindications.. 31

6.4 Conclusions.. 31

7.0 INHALATION THERAPY.. 32

7.1 Therapy Description.. 32

7.2 Advantages and Risks.. 33

7.3 Contraindications.. 37

7.4 Guidelines.. 38

7.5 Conclusions.. 38

8.0 DIATHERMY.. 40

8.1 Descriptions of the Therapies.. 40

8.2 Advantages and Risks.. 42

8.3 Contraindications.. 43

8.4 Guidelines.. 44

8.5 Conclusions.. 45

9.0 APPLICATION OF THE THERAPIES.. 46

9.1 First-Aid Treatments.. 46

9.2 Simultaneous Treatments.. 47

9.3 Sequential Treatments.. 48

10.0 SUMMARY AND CONCLUSIONS.. 49

11.0 REFERENCES.. 51

LIST OF TABLES

		Page
Table 1.	Levels of Hypothermia	3
Table 2.	Requirements for Resuscitating Hypothermia Victims	4

RESUSCITATION FROM HYPOTHERMIA:

A LITERATURE REVIEW

for

UNITED STATES COAST GUARD
U.S. COAST GUARD HEADQUARTERS

Contract No. DOT-CG-72074-A
Task Number 5

from

Clemson University

by

R.M. Harnett, Ph.D., F.R. Sias, Ph.D., J.R. Pruitt, M.D.

February 14, 1979

1.0 INTRODUCTION

The literature on hypothermia resuscitation is voluminous. It includes a large number of clinical observations as well as basic physiological and medical experiments. As with much of clinical medicine, there are controversies concerning the proper choice of therapy for resuscitating patients from the hypothermic state.

Hypothermia could be defined as "the clinical state of subnormal body temperature..." (Benazon, 1974). However, "normal temperature" and "body temperature" are not precise terms since normal temperature has a diurnal variation of 1 to 2 degrees centigrade. In addition, measurements taken at different body locations show differences at any given time. Skin temperature (even in protected locations such as the armpit) is almost always different from deeper body locations such as rectal temperature, esophageal temperature, tympanic temperature, or the temperature control location in the preoptic area of the hypothalamus. Much of the experimental and clinical literature is based on rectal temperature measurement which is affected by probe depth and possibly external factors such as blood flow returning from the legs. Despite the inadequacies of rectal temperature, it has been used as a primary indicator of deep-core temperature of the body.

Most clinical and research investigators would probably agree that a rectal temperature below 35°C is indicative of "clinical hypothermia" and that a temperature below 32°C is indicative of "severe hypothermia".

The lowest recorded rectal temperature with survival from accidental hypothermia is 18°C. Patients with a rectal temperature above 32°C will normally recover spontaneously if removed from the cold environment and there are not other underlying factors causing hypothermia (Weyman, et al., 1974). Most resuscitation measures should be aimed at reviving hypothermia victims with rectal temperatures below 32°C.

Table 1 illustrates the levels of hypothermia and their associated physiological characteristics. The effectiveness of resuscitative measures will be closely coupled to physiological states at different rectal temperatures. It should be noted that there is some variation in the temperatures at which the literature indicates major changes to occur. Table 1 represents an attempt to distill a consensus from this variation.

Death due to hypothermia is generally attributed to ventricular fibrillation in man (Alexander, 1945; Hervey, 1973; Swan, et al., 1955) although this is not a proven fact since direct evidence, such as an EKG recording, is seldom available at the time of death. The Dachau experiments (Alexander, 1945; Gagge, and Herrington, 1947) and some animal experiments (Bigelow, et al., 1950a) strongly suggest that ventricular fibrillation is the terminal event if patients are not maintained by cardiac massage and artificial respiration. Some animal experiments (Popovic and Popovic, 1974; Hamilton, et al., 1937) point to respiratory failure as a terminal event but this is not considered to be the case in man. Resuscitation of a hypothermia victim involves a number of supportive and restorative measures some of which are conflicting. Table 2 lists the principal changes that must be affected in restoring a person to normothermia. Each rewarming therapy considered in this report will be examined from each of these viewpoints.

There is an extensive body of evidence indicating that seriously cooled hypothermia victims should be handled carefully (Burton and Edholm, 1955; Truscott, et al., 1973; Bigelow, 1959). By "carefully" it is meant that the muscular exertion of the victim should be minimized. Even the process of climbing aboard a ship may release pooled cold blood causing a continuing fall in core temperature (afterdrop) and possibly fatal ventricular fibrillation. Afterdrop is generally thought to be possible only when there is a source of

TABLE 1
LEVELS OF HYPOTHERMIA

°F	°C		
99.6	37.6	"Normal" Rectal Temperature	
98.6	37	"Normal" Oral Temperature	
96.8	36	Increased Metabolic Rate in attempt to balance heat loss	
95.0	35	Shivering maximum at this temperature	
93.2	34	Patients usually responsive and normal blood pressure	
91.4	33	<u>SEVERE HYPOTHERMIA BELOW THIS TEMPERATURE</u>	
89.6	32	Consciousness clouded	Pupils dilated most shivering ceases
87.8	31	Blood Pressure difficult to obtain	
86	30	Progressive loss of consciousness	
85.2	29	Increased muscular rigidity Slow pulse and respiration	
82.4	28	Cardiac arrhythmia develops Ventricular fibrillation may develop if heart irritated	
80.6	27	Voluntary motion lost along with pupillary light reflex, deep tendon and skin reflexes - appear dead	
78.8	26	Victims seldom conscious	
77.0	25	Ventricular fibrillation may appear spontaneously	
75.2	24	Pulmonary Edema develops	
73.4	23		
71.6	22	Maximum risk of fibrillation	
69.8	21		
68.0	20	Heart Standstill	
66.2	19		
64.4	18	Lowest <u>Accidental</u> Hypothermic patient with recovery	
62.6	17	ISO-ELECTRIC EEG	
48.2	9	Lowest Artificially Cooled Hypothermic patient with recovery	

TABLE 2

REQUIREMENTS FOR RESUSCITATING HYPOTHERMIA VICTIMS

1. Maintain adequate cellular respiration

    (a) maintain adequate circulation

    (b) maintain suitable ventilation

2. Minimize additional heat loss

    (a) remove patient from cold

    (b) prevent other routes of heat loss

3. Restore normal body temperature

    (a) apply heat

    (b) stimulate normal body sources of heat

    (c) restore all lost calories

4. Restore normal body homeostasis

    (a) establish normal pH

    (b) establish normal blood glucose levels

    (c) restore proper kidney function

    (d) restore normal fluid and electrolyte balance

5. Treat any non-environmental cause of hypothermia

6. Treat medical problems unrelated to hypothermia

blood significantly colder than the body core; that is, when a significant temperature gradient exists between body core and periphery.

There is also evidence from anecdotal clinical experience and surgical hypothermia which suggests that the only measure of death is whether or not a person can be resuscitated, regardless of the body temperature (Golden, 1973; Jessen and Hagelsten, 1972; Stewart, 1972, Nemiroff, et al., 1977).

During the three decades since World War II a number of rewarming therapies have been proposed for resuscitation of hypothermia victims. These range from simple hot showers, heating pads and trunk immersion in hot water to the inhalation of hot moist gasses, diathermy, peritoneal irrigation, intragastric balloons, extracorporeal blood warming and plumbed garments circulating warm fluids.

In addition to these specific rewarming therapies two general approaches to rewarming have attracted continuing debate. One pursues the rapid restoration of lost heat through the application of active measures. The other seeks to slowly restore body heat through the use of passive measures.

This report presents a picture of the rewarming problem and then summarizes the open literature debate over rapid versus slow rewarming. The significant literature information concerning selected specific rewarming therapies is presented.

The specific therapies addressed were selected because they are particularly difficult to evaluate by direct human research or because their application in profound hypothermia poses particular problems. The therapies are described in some detail, their advantages and risks are discussed qualitatively, known contraindications for the therapies are delineated and discussed, and specific guidelines for their application are summarized. Finally, conclusions are drawn concerning the use of the therapies as first-aid treatments by emergency medical technicians (EMT's). These conclusions are based strictly on scientific and medical considerations. No legal implications of these conclusions were considered. In addition to previously published facts and opinions, medical and scientific opinions of the authors have been included in this report.

2.0 THE REWARMING PROBLEM

This chapter presents the problems faced in rewarming victims of profound hypothermia. The problem is first characterized in general terms and then in detail by summarizing scientific and clinical observations relating to physiologic anomalies which may affect the choice of a rewarming therapy.

2.1 General Nature of the Problem

Based on the current literature, the total rewarming problem may be stated simply as the restoration of all lost heat without precipitating additional fatal side effects.

There is a growing body of evidence that hypothermia per se may not be fatal above a rectal temperature of around 25°C. Below about 25°C ventricular fibrillation may appear spontaneously. There is evidence in dogs (Hughes, 1956) that even ventricular fibrillation may not be fatal for periods of over one hour if appropriate rewarming and defibrillation is carried out. During cardiac surgery man has survived circulatory standstill for long periods of time. Nemiroff, et al., (1977) described 11 cases of cold-water near-drowning. They indicate that physiologic responses to cold-water immersion serve to prolong life, even during a 38-minute cessation of respiration. Their work is summarized in the August, 1977, Scientific American (page 57). Niazi and Lewis (1958) report recovery of a woman from 9°C with no cardiac activity or respiration for one hour.

If some circulation is maintained by closed chest massage and the lungs are ventilated, patients can survive for extended periods at very low temperatures. It has been concluded (Jessen and Hagelsten, 1972) that the only sure indication of death from hypothermia is the inability to resuscitate the patient. Nemiroff, et al., (1977) recommends continuing resuscitation efforts, "until the patient is rewarmed and still does not respond."

If a patient is unconscious with shivering suppressed or absent, it may be assumed that the patient is severely hypothermic and requires definitive treatment. A moderately hypothermic patient still shivering but with clouded consciousness may become severely hypothermic if left untreated or mishandled.

This report examines the effectiveness of methods for treating profound hypothermia as generally characterized by rectal temperatures below

$32^{\circ}C$, depressed rates of respiration, acidosis, hypovolemia (reduced blood volume), clouded consciousness or unconsciousness, generally cooled organ systems and irritable myocardium. It will be assumed that a significant temperature gradient exists in the victim's body between core and periphery and that he is therefore susceptible to afterdrop. The following paragraphs outline specific aspects of the rewarming problems with which a therapy must contend.

2.2 Fluid Shifts

In cold exposure, diuresis (increase in urine output) occurs in spite of diminished glomerular filtration and renal blood flow (Tansey, 1973). This serves to diminish blood volume; but Hervey (1973) cites Moyer, et al., (1956) and Kanter (1962) who observe that changes in renal function due to cold exposure tend to be masked by circulatory changes. According to Keatinge (1969) cold diuresis, "is probably a physiological mechanism for removing some of the blood volume when this becomes excessive as a result of constriction of blood vessels in the cold." Hervey (1973) called it, "a volume regulatory response to increased filling of deep capacitance vessels."

There is considerable evidence that blood volume decreases as patients and animals are cooled to low temperatures. According to Popovic and Popovic (1974) the blood volume decreases, "to 60 percent of normal volume after 6 to 8 hours at a body temperature of $15^{\circ}C$." They also indicate that, "the circulating blood volume increases during rewarming." The increase in volume may be up to 130 percent of the value prior to cooling.

A number of authors report that the decrease in blood volume is accompanied by an associated concentration of the blood (Popovic and Popovic, 1974; Hervey, 1973; Burton and Edholm, 1955; Keatinge, 1969). The hemoconcentration results in hematocrit approaching 60 percent (Hervey, 1973) and blood viscosity increasing 2 percent for each $1^{\circ}C$ decrease in temperature (Hedley-Whyte, et al., 1976). Barbour, et al., (1944) attribute hemoconcentration to shifts of fluid into cells. They suggest that increased cellular activity in the cold results, in the production of osmotically active metabolic end products that require the movement of water into the cells. However, Popovic and Popovic (1974) conclude, "the mechanism of hemoconcentration induced during cooling is not well understood."

There is also evidence (Barbour, et al., 1944) that fluid shifts into cells are reversed producing increased extracellular fluid when the central nervous system becomes sufficiently chilled to abolish reflex responses to cold.

Tansey (1973) cautions that, "While one expects a hemoconcentration both from contraction of plasma volume and from fluid shifts, hemodilution can occur with blood loss, with parenteral fluids, or with aspiration of hypotonic water."

There are indications that the severity of fluid shifts is directly related to the duration of cold exposure and, therefore, to the rate of onset of hypothermia. Tansey (1973) cites slow rewarming as appropriate for "prolonged cold exposure (greated than 6 hours)", in part, because of "hemoconcentration from fluid shifts". Keatinge (1969) indicates that excretion of water can produce a, "serious loss of blood volume during prolonged hypothermia." Burton and Edholm (1955) contrast acute and chronic hypothermia as follows: "In chronic hypothermia...the duration of exposure produces marked changes in blood volume and depletion of glycogen reserves." Any problems which arise from the shift of fluids, such as the tendency toward hypovolemia and hemoconcentration, may be expected to be worse if a given level of hypothermia was arrived at through slow onset than if through rapid onset.

2.3 Edema

Edema has been considered one of the complications of hypothermia and may be a significant factor in the choice of a rewarming therapy. Edema is a frequent finding in clinical medicine. Pulmonary edema, cerebral edema and peripheral edema, are three separate entities with different etiologies. Pulmonary edema is generally associated with either pulmonary capillary membrane damage, left-heart failure, or mitral valvular disease (Guyton, 1976; Beeson and McDermott, 1971) but also accompanies anoxia. Peripheral edema may have several causes including a decrease in plasma proteins, increased capillary permeability, right-heat failure, and "pore stretch" due to increased capillary pressure. Guyton (1976) points out that edema resulting from right-heart failure generally requires fluid retention by the kidneys. Cerebral edema commonly results from a direct injury to the brain.

Critchley (1943), in his study of Shipwreck Survivors, describes sailors having to cut boots off of swollen feet. However, "immersion foot" may be directly responsible for this edema rather than whole body hypothermia. Immersion foot results from, "prolonged soaking of limbs in water at 15°C or below" (Critchley, 1943).

The etiologies of the types of edema that are reported in hypothermia are not clear. It is also not clear whether edema, particularly pulmonary edema, is a consistent finding in acute immersion hypothermia, although pulmonary edema is a frequent complication in elderly individuals found in the hypothermic state.

Pulmonary Congestion and Edema

Barbour, et al., (1944) report earlier work (Walther, 1862) describing edema in the lungs of rabbits dying from hypothermia. They also cite Talbott (1941), who described a similar congested condition of the lungs in the body of a patient who died of hypothermia.

Woodruff (1941) describes experiments in hypothermia using dogs. He reports that one dog out of eleven showed acute pulmonary edema while the hearts of eight showed edema.

The Dachau experiments (Alexander, 1945) report:

> "a great number of experimental subjects showed a profuse oversecretion of mucus, with vesicular foam at the mouth reminiscent of that seen in pulmonary edema. However, there were not other definite clinical signs of pulmonary edema, and auscultation showed merely sharpening and impurity of breath sounds. This foaming at the mouth sometimes appeared as an early symptom at 32°C - 35°C of body temperature. It had no prognostic significance with regard to the fatal or non-fatal outcome of any one experiment...."

A monograph by Lathrop (1972) describes the terminal symptoms of a hypothermia victim on Mt. Adams in 1966: "A terminal event was labored breathing which produced a frothing foam at the mouth. This, we now realize was characteristic of the terminal pulmonary edema of acute hypothermia." Lathrop cites, "probable edema and hemorrhage in lungs" as associated with rectal temperatures below 78°F (25.6°C). He states that "The frequency with which pulmonary edema is present in fatal cases of acute hypothermia, is a new finding in the medical literature on this subject. Often one of the terminal events before death is labored breathing in which a whitish froth may well into the mouth from the congested lungs." He further states, without reference, that an Oregon pathologist, Dr. Warren Hunter, "found evidence of pulmonary hemorrhage and edema in each of 10 fatal cases of accidental hypothermia which he reviewed." He is also said to have, "found that pulmonary edema is very often present as a terminal symptom in such deaths."

Tansey (1973), in prescribing treatment for "whole body hypothermia", says that, "In view of depressed respiration and probably atelectasis with aspiration or anoxic pulmonary edema, oxygen supplement and cautious pulmonary toilet with endotracheal suction and intermittent positive pressure breathing should be initiated."

There is another possible explanation for the pulmonary congestion described by Talbott (1941), Alexander (1945) and Lathrop (1972). The ciliated cells which line the nasopharynx and the tracheobronchial tree, save for the terminal bronchioles and alveoli, serve to clean these respiratory passages by propelling mucus and waste material toward the mouth. They are normally very effective. Bouhuys (1977) indicates that, "In airways with mucus-secretory elements, the cilia move in thin fluid and are covered with a mucous layer. This two-phase liquid system ... is essential for mucociliary transport." Best and Taylor (1961) indicate that,

> "The efficiency of the cilia depends in part on the viscosity and stickiness of the material which is in contact with them. Their effectiveness may be varied by changing the properties of this material as well as by an increase or decrease in the rate or force of their beating."

Cherniack, et al., (1972), indicate that, "Ciliary activity carries particles and macrophages ... to the larger bronchi where the cough reflex is important in their clearance." They further indicate that the cilia beat, "at a rate of approximately 1000 to 1500 times each minute..." and that, "this causes the mucus to flow toward the glottis at the rate of approximately 10 to 20 mm/min." According to Best and Taylor (1961), "The cilia are not influenced by nerve impulses, but are very susceptible to chemical changes in the blood.... Ciliary action is depressed by cold and increased when the temperature of the cells is raised slightly above normal." Bouhuys (1977) cites Iravani (1967) indicating: "In a 0.2-mm diameter rat airway, beat frequency was 13/sec at 35°C, and 2/sec at 20°C..." and Hakansson and Toremaln (1965) indicating: "in the rabbit treachea, 20/sec at 37°C, and 7/sec at 20°C." Boujuys also indicates that, "mucus has plastic and elastic, as well as viscous, properties." He states that, "In conformance with a property of plastic materials, a certain minimum stress must be exerted before mucus moves at all." This supports the notion that a thermally-induced slowing of ciliary activity could not only slow mucociliary transport, but could actually stop it completely. Clearly, the depressing effects of hypothermia upon cilia activity can allow the accumulation of mucus secretions in the respiratory tree presenting a clinical picture resembling pulmonary edema. Of course, the possibility should not be overlooked of the simultaneous existance of pulmonary edema and mucus accumulation due to cold-induced cilia inactivity.

Cerebral Edema

The literature on cerebral edema is also conflicting. According to Popovic and Popovic (1974), "There are several reports that hypothermia protects against cerebral edema..," (Clausen, et al., 1970; Fay, 1959). The Popovics also cite Herrmann and Dittmann (1970) who mention indications of cold-induced swelling of the brain.

According to Khalil (1957), cerebral edema, "has been reported to follow the use of [extracorporeal blood cooling]."

The Dachau report (Alexander, 1945) also shows that autopsies revealed, "edema of the brain and marked congestion of all cerebral vessels" in "those cases where there had been additional cooling of the neck and occiput." The Dachau experiments also point to an increase in spinal fluid pressure in cases with marked additional cooling of the neck and occiput.

Hedley-Whyte, et al., (1976), cite Bloch (1967b) cautioning that,

> "Relapse into coma or confusion can occur with rewarming, but improvement occurs if the temperature is allowed to fall again. These changes appear to be the result of an increase in cerebrospinal fluid pressure. Patients who become increasingly drowsy during rewarming promptly become more alert when cerebrospinal fluid pressure is reduced by lumbar puncture with removal of cerebrospinal fluid. Some patients who develop acute pulmonary edema during rewarming experienced dramatic relief within a few minutes of reduction of cerebrospinal fluid pressure."

Peripheral Edema

Barbour, et al., (1944) concluded from experiments conducted with twelve monkeys (Macacca Mulatta) cooled to 23°C and rewarmed, "If any edema is present in monkeys at these low body temepratures, we were unable to establish it definitely, although some apparent swelling was noted about the shoulders and forearms in one case." Their results with rats were quite different. They report: "At 16°C, the rats were completely prostrated in a condition resembling deep anesthesia. At this point considerable edema of the face, eyelids, and jaw as described by Hamilton [1937], was a constant finding." They conclude: "Subcutaneous edema tends to occur and is augmented on rewarming the animal, which procedure increases greatly the hydration of blood, at least relatively."

A paper on accidental hypothermia (Duguid, et al., 1961) review twenty-three cases of hypothermia. Most were elderly individuals with associated, "states of disability and illness" including respiratory infection and heart failure. Duguid states: "Peripheral edema was present in over half the cases."

Summary on Edema

Edema per se is not mentioned in Burton and Edholm's monograph "Man in a Cold Environment' (1955) in regard to immersion hypothermia but they do mention a, "fluid shift from the plasma to the tissue." Keatinge (1969) acknowledges the possible contribution of "increased vascular permeability" to a, "loss of blood volume during prolonged hypothermia." As indicated in Section 2.2, Barbour, et al., (1944) attributed hemoconcentration to shifts of fluid into cells which may reverse themselves later in cooling producing increased extra-cellular fluid.

It is reasonable to speculate that edema observed in conjunction with hypothermia might be connected etiologically with the other fluid shifts discussed in Section 2.2. If this connection exists, one may anticipate that the severity of edema would be worse for hypothermia of long duration than short duration.

Edema, either pulmonary, cerebral, or peripheral is not consistently reported in the literature on immersion hypothermia. Yet there are sufficient references to observations of edema and to related mechanisms to preclude its dismissal as a physiological anomaly unrelated to cold exposure. An implication of this conclusion is that rewarming therapies intended for treatment of profound hypothermia should be analyzed for their effects on edema.

2.4 Electrolyte and Acid-Base Changes

Electrolyte Changes

There have been numerous studies of electrolyte changes during experimental hypothermia but the results are conflicting and controversial. Serum potassium has been found to increase in dogs (Smith, 1956; Bigelow, et al., 1950b) and in man (Langdon and Kingsley, 1964), to remain the same in dogs (Axelrod and Bass, 1956), and to decrease in dogs (Kanter, 1963; Gollan, et al., 1957) and in rabbits (Grote and Schweikhordt, 1969). If the potassium concentration could be shown to rise consistently, this might explain the increased cardiac irritability and the tendency toward ventricular fibrillation that is often found in hypothermia victims. Popovic and Popovic (1974) further point out, "The potassium ion concentration in hypothermia can be compensated by glucose administration which tends to return the excitability of the hypothermic heart to normal levels." The reference cited for this is Spurr, et al., (1959). Jessen and Hagelsten (1978) report that, "plasma electrolytes are usually normal when the treatment starts, but during the last phase of the rewarming, a severe hypopotassemia is often provoked." They conclude that, "it may well be responsible for some of the deaths which are reported after the active rewarming has stopped and the body core temperature has reached almost normal values."

Alterations in potassium distribution are generally assumed to be due to changes in membrane permeability and/or alterations in the sodium-potassium pump due to hypothermia (Popovic and Popovic, 1974). They further state, "In moderate hypothermia there is no change in serum sodium concentration, but the plasma level falls when the body temperature of an experimental animal is decreased below 25°C."

Hyperphosphatemia induced in rats by hypothermia has been reported (Popovic and Popovic, 1974). Calcium changes are as varied in the literature as potassium with serum levels found to be elevated in dogs (Axelrod and Bass, 1956; Smith, 1956), unchanged in rats (Nowell and White, 1963), and decreased in rabbits (Grote and Schweikhordt, 1969). The magnesium concentration in the plasma was reported to rise in rats during hypotheria (Nowell and White, 1963).

In summary, Popovic and Popovic (1974) state, "Hypothermia induces some changes in the electrolyte metabolism, but the overall picture is still quite obscure.... Different techniques of cooling, different species of animals, and the precooling state of experimental animals or patients greatly affect the results obtained during cooling.

Tansey (1973) cautions that, "Blood electrolytes must also be interpreted with cognizance of ...fluid shifts [which have occurred]."

Adic-Base Changes

The literature on acid-base balance has also been summarized by Popovic and Popovic (1974),

> "During cooling and rewarming the pH value of the blood of experimental animals or of patients decreases (cold acidosis), sometimes

> even when bicarbonate is adminstered. Both respiratory and metabolic acidosis develop during cooling. This acidosis is very pronounced but does not appear to be harmful. However, during surface cooling, a much decreased pH of the blood might be associated with the increased tendency toward ventricular fibrillation."

They also state, "During rewarming, metabolic acidosis occurs even if it were not observed during the cooling process. However, the acidosis disappears after rewarming is completed."

Keatinge (1969) cites as causes of acidosis:

1. failure of acid excretion,
2. respiratory depression,
3. increased solubility of CO_2, and
4. lactic acid forming faster than it can be metabolized during shivering.

He concludes that, "All these factors together do not normally cause dangerous acidosis while the body temperature remains low"; but he cites Fairley, et al., (1957) indicating that "severe acidosis may develop during rewarming."

3.0 RAPID VERSUS SLOW REWARMING

The two general approaches to rewarming loosely referred to as rapid and slow rewarming have been often debated. Each therapy has its proponents and its detractors. W.R. Keatinge and A.R. Behnke support rapid rewarming while H. Hillman advocates slow rewarming. This chapter presents a cross section of literature representing the continuing debate over the better approach to rewarming.

3.1 General Discussion

The effort to avoid side effects during rewarming has resulted in two general schools of thought, each with sub-categories. The two dominant approaches to hypothermia resuscitation may be termed "rapid rewarming" and "slow rewarming". There appears to be general agreement that intermediate warming rates should be avoided (Burton and Edholm, 1955, Hervey, 1973).

The extremes of viewpoints are illustrated by Bloch (1967a) who states "There does not appear to be any harm resulting from slow rewarming following prolonged hypothermia" and Meriwether and Goodman (1972) who state, "Rapid rewarming by water immersion is recommended for treating patients with severe accidental hypothermia." Fernandez, et al., (1970) point out that the main controversy is not between core rewarming and external rewarming but between "passive external rewarming" and "active external rewarming".

The review by Fernandez, et al., (1970) of the literature regarding fast and slow rewarming is particularly appropriate:

> "The major controversy has been between the use of passive external rewarming and active external rewarming. Active external rewarming means the direct application of exogenous heat directly to the surface of the body while passive rewarming utilizes the heat produced by the patient without the addition of artificial heat to the body surface. The authors with the greatest experience have favored slow, usually passive, external rewarming.
>
> "In 1958, Emslie-Smith, described eight patients with accidental hypothermia, all of whom died. In only three cases was the method of rewarming recorded. Those three patients were rewarmed by electric blanket. It is of note that rewarming was slow. No patient was rewarmed in less than 12 hours.

"Duguid and co-workers, in 1961, reported 23 cases of accidental hypothermia. Six patients were 'actively' rewarmed and all died. Seventeen patients were passively rewarmed. Ten patients died during rewarming and an additional four died later in the hospitalization, yielding a total mortality of 87%. Again, the important point is that none of the 23 patients were rewarmed in less than 24 hours. The authors concluded from these results that passive rewarming was the method of choice in their hypothermic patients.

"In 1962 Prescott and his colleagues, rewarmed nine patients passively over prolonged periods of time and six died.

"Fruehan [1960] treated eight accidentally cooled patients. Four were rewarmed actively and four passively. One of the eight survived. Although the survivor was passively rewarmed, the author emphasizes that this patient had the most rapid rate of rewarming.

"Recently, Maclean and associates [1968] reported enzyme changes in 25 accidentally frozen patients. Ten patients recovered. While the method of rewarming was not stated, all four patients who were rewarmed in less than 12 hours survived.

"The results of human experiments performed on persons of block 5 of Dachau in 1942 support the rapid active rewarming method. These sordid investigations proved to the satisfaction of the executioners that the best method of resuscitating hypothermic prisoners was by rapid and intensive rewarming."

A variation on the simplified rapid vs. slow debate are the following steps recommended by Bangs (1976) for treatment of chronic hypothermia (partial list):

1. Rewarm the victim only when it can be done properly.
2. Handle the victim gently.
3. Prevent further heat losses.
4. In the field do not rewarm too fast.
5. Rewarm the core first.

He recommends rewarming in a hospital, "If at all possible", or a, "safe environment where ...[the victim] can be rewarmed properly with proper monitoring, equipment and medicine...." Further he indicates that if rewarming has to be done in the field, "it is probably safest to do it slowly. Slowly means most anything <u>except</u> submerging the victim in hot water." His objective is to avoid, "blood vessel dilation and shock...."

3.2 Spontaneous or Passive Rewarming

Slow spontaneous (or passive) rewarming has long been advocated as the proper therapy for hypothermia at least in chronic hypothermia of a slow onset and long duration (Rees, 1958; Whitby, 1964; Maclean, et al., 1974). Talbott and Burton (1952) recommend slow rewarming at a rate of about 1/2°C per hour. Bloch (1967a) recommends even slower rewarming such as 1°C in 400 minutes. Bloch also recommends that too rapid spontaneous rewarming be slowed by drugs such as chlorpromazine.

The rationale behind such slow rewarming protocols is that it will avoid rewarming hypotension and afterdrop of deep body temperature perhaps due to cutaneous vasodilatation, and the return of cold peripheral blood to the body core. In addition, slow rewarming is said to allow fluid shifts due to hypothermia to be corrected.

Maclean, et al., (1974), referring to Talbott and Burton (1952), points out that the body tries to restore normal temperature at all levels of hypothermia above 23.8°C. Part of the corrective mechanism is shivering which may be present intermittently down to a temperature of 23.8°C.

Much of the literature supporting slow rewarming involves clinical cases where patients are either elderly and/or have consumed considerable alcohol. The survival rates in these populations are not good; but it is not reasonable to ascribe them to rewarming rate.

Spontaneous rewarming is certainly a viable therapy in mild hypothermia. Truscott, et al., (1973) state, "Bringing the patient into a warm environment and conserving body heat (passive rewarming) will usually suffice." He concludes, "The optimal method of rewarming is still controversial.... Most authors, however, believe that passive surface rewarming is less hazardous."

Tansey (1973) concludes that, "Slow rewarming becomes appropriate with prolonged cold exposure (greater than 6 hours) where hemoconcentration from fluid shifts, increased blood viscosity, exhaustion of glycogen stores, and acidosis all contribute to an upset 'milieu interieur' which will be aggravated by rapid rewarming and which will revive spontaneously if further cold is prevented."

Passive slow rewarming is not as simple as it might seem at first glance. In the hospital environment, a technique generally used is to place the person in a bed, lightly covered, at normal room temperature. Normal room temperature, of course, varies with British and European rooms being often maintained at lower temperatures than those in the United States. If the room temperature is close to the lowered body temperature of the patient and the air is still, little heat will be lost by convection, conduction, or radiation. Extremities may be below room temperature making possible a net gain in heat from the environment.

Some heat will be lost from the body through respiration due to the heat that must be expended to warm and humidify the room air. Heat loss by respiration will be moderate if the room humidity is high and room temperature is not much below body core temperature.

The heat that is to be used in passive rewarming is largely from metabolic activity, which may be less than 50 percent of normal at body temperatures below 25°C, with small amounts being contributed by the environment. At temperatures below about 30°C shivering will be largely suppressed and the sole source of heat is the depressed basal metabolism of the patient. At temperatures above about 32°C shivering will become the dominant source of heat for a spontaneously rewarming patient. The heat generated by shiverng may be several times greater than the resting metabolic rate if the patient did not exhaust his muscle energy supplies during cooling. If energy supplies were severely taxed during the patient's cooling period, shivering may not be able to contribute significantly to a spontaneously rewarming patient.

If spontaneous rewarming is being used as a first-aid measure, the situation may be quite different than described above. A blanket or a sleeping bag intended to prevent further heat loss will temporarily draw heat from the patient if it has not been pre-warmed. Generally, insulation does not conserve heat until the surface layer of the insulation has been raised to body temperature.

A second significant factor in a rescue scenario is that air temperature may be very cold. The heat lost through respiration may be a large part of the total heat production of the body under conditions of no shivering, a basal metabolic rate depressed below 50 percent, and continuing significant heat loss by warming and and humidifying cold, dry ambient air. Spontaneous rewarming would be most unsatisfactory under these conditions. If the patient is shivering, spontaneous rewarming may be completely adequate.

Another consideration is contrary to intuition. Mild surface rewarming methods such as hot water bottles, heating pads, and even body to body heat exchange in a sleeping bag, can suppress shivering, by warming the skin, and thereby remove a rewarming mechanism more effective than the mild surface heat. Of course, it is not possible to make a conclusive statement since such relatively mild surface heat might not suppress shivering in the middle temperature ranges of hypothermia. At lower temperatures, say below 28°C, shivering is already suppressed and mild surface heat will have little effect on the rate of spontaneous thermogenesis. At temperatures above about 30°C suppressing shivering may slow rewarming, but the patient will probably be in no danger anyway and the surface heat will make him feel better. Of course, in all of this discussion it has been assumed that major routes of heat loss are removed.

The major unanswered question is whether a rapidly cooled, deeply hypothermic patient with suppressed shivering can be helped by relatively mild application of surface heat as a first-aid procedure. Since human studies can not be extended to temperatures where shivering is suppressed, answers must be sought elsewhere. Clinical observations and animal research can give indications which are subject to some uncertainty.

3.3 Active Surface Rewarming

The objective of rapid surface rewarming is to introduce heat into a hypothermia patient at a very high rate. This seems to be intended to accomplish the following:

1. Minimize the time the victim is in the hypothermic state.
2. Quickly revitalize a weakened and irritable myocardium.
3. Avert afterdrop by overwhelming the temperature gradients within the victim's body by a massive infusion of heat.

Obviously active surface rewarming can be accomplished at a range of heat input rates. A widely recommended method is trunk immersion in hot water up to 42°C (Jessen and Hagelsten, 1972). Water heated thermal blankets (Cooper and Ross, 1960), plumbed garments (Webb, 1973) and simple heating pads or hot water baths could all be considered active surface rewarming but caloric input can vary by an order of magnitude.

Rapid rewarming by hot bath, according to Mills (1976), may cause, "tissue liberation of acid end products of metabolism and the sudden end result of metabolic acidosis may result in death by ventricular fibrillation...."

Hypotension may result (Keatinge, 1969) from the inability of the reduced blood volume to fill blood vessels which are suddenly dilated as a result of active rewarming measures. But according to Golden (1973) it is, "unlikely to have fatal consequences in immersion victims, as the duration of exposure is usually insufficient to permit the occurrence of major physiological adjustments of cirulatory fluid volume."

Weyman, et al., (1974) provide data supporting active rewarming. In studying 39 cases of hypothermia, some complicated by underlying disease, they conclude, "In our experience, neither a decreased core temperature, as manifested by the onset of ventricular fibrillation, nor shock resulted from active rewarming." They further indicate, "that the response to rewarming, as measured by the rate of rise in temperature, depends on the underlying metabolic state of the patient rather than the method of rewarming." Their final recommendation is:

> "In patients in whom the initial temperature is close to the threshold for ventricular fibrillation or in patients in whom response to passive and active rewarming is unsatisfactory, a more efficient method of rewarming is necessary. It has been shown that immersion in warm water at 104° to 108°F (40° to 42.2°C) offers such an alternative."

Tansey (1973) cautions that:

> "The rate of restoration of core temperature must be carefully balanced between the risk of anoxic damage from too brisk an increase in tissue oxygen requirement before circulation is improved and the risk of vascular collapse from the critical afterdrop in core temperature associated with the restoration of peripheral blood through cold deeper layers of subcutaneous tissue."

The major risks of hypoxia, metabolic acidosis, and hypotension may, according to Ledingham and Mone (1978), be controlled with oxygen and intermittent positive-pressure ventilation, sodium bicarbonate, and the administration of warm intravenous fluid.

3.4 Conclusions

When one examines the literature describing slow rewarming, it becomes apparent that the authors are usually considering a situation where the patient is allowed to rewarm himself spontaneously using the body's metabolic processes alone or in combination with a small amount of rewarming supplied by the environment. Rapid rewarming, on the other hand, generally connotes the application of external heat to the patient's body. Just as there is some variation in the details of the slow rewarming, fast rewarming encompasses quite a variety of protocols. The basic factor in common among the various rapid methods is that external heat is applied to the body. However, the rates of temperature rise vary considerably from a fraction of a degree per hour to several degrees per hour. Techniques that vary from body immersion in a tub of hot water to the application of hot water bottles and warm blankets create a wide range of rates of heat input to the body.

As Fernandez, et al., (1970) point out, many of the patients who were warmed with a method called "active" still required over 24 hours to rewarm. This rewarming regimen is clearly in a different class from warming in a tub of water or using a hyperthermia blanket with a total rewarming time under 8 hours.

Active rewarming is said to cause peripheral vasodilatation with resultant afterdrop and possible hypotension. However, quite a different situation results if heat is applied to the thorax with the periphery being allowed to remain cold and vasoconstricted until the central part of the cardiovascular system has warmed sufficiently to supply the metabolic needs and perfusion requirements of the extremities. Some advocates of fast rewarming specifically recommend that the arms and legs be allowed to remain cool.

Many examples of active rewarming in the literature appear to be actively rewarming both the central and peripheral vasculature. Under this circumstance, the periphery can vasodilate returning cold blood to the heart, causing accentuation of afterdrop, possible cardiac arrhythmia, and possible hypotension and shock. There does not seem to be experimental or clinical proof that properly applied rapid rewarming is dangerous any more than there is clear evidence that slow rewarming is dangerous.

Another factor that contributes to the difficulty in resolving the debate between advocates of fast and slow rewarming therapies is the fact that much of the clinical evidence involved is based on cases where the patient is suffering multiple medical problems such as drug overdose or acute alcohol intoxication in addition to hypothermia.

Because of the complexity of man's responses to cold exposure and because of the ambiguity of the meaning of the terms "rapid rewarming" and "slow rewarming", it is difficult to debate their merits in general terms. When specific rewarming protocols are proposed for application under specified conditions, discussion is possible. The remainder of this report addresses specific treatments for profound hypothermia.

4.0 PERITONEAL IRRIGATION

The desirability of core rewarming has been established in the earlier sections of this report. Since peritoneal dialysis is a fairly simple procedure commonly used in the hospital environment, a heated peritoneal lavage presents a means of introducing heat directly to the body core of a hypothermia victim. The procedure does not appear to have been widely used for treatment of hypothermia. Its use was reported by Lash, et al., (1967), Grossheim (1973), and Jessen and Hagelsten (1978) for treating frostbite and hypothermia patients. A case of rewarming by pleural irrigation using 40°C physiological saline is described by Linton and Ledingham (1966).

4.1 Therapy Description

The peritoneal cavity contains the liver, stomach, intestines, kidneys, pancreas, spleen, gall bladder, urinary bladder, inferior vena cava and other structures. This cavity is separated from the pleural cavity (which contains the lungs and heart) by the diaphragm. The peritoneal dialysis procedure involves inserting a large needle through the abdomen into the peritoneal cavity. A liquid dialysate is inserted directly into the cavity and allowed to bath the surfaces of the organs and the highly vascularized mesentery contained therein. When used for rewarming, the dialysate is heated above body core temperature before its insertion into the peritoneal cavity. It is left there until it has surrendered most of its excess heat to the surrounding organs, the inferior vena cava (with its blood supply returning directly to the heart), and the heart and lungs (by conductive heat transfer through the diaphragm). Then the dialysate is removed and replaced by a fresh, warm supply. Dialytic detoxification is accomplished through the diffusion of the toxic substances from the body into the dialysate which is periodically replaced to maintain a large concentration gradient and diffusion rate.

4.2 Advantages and Risks

A basic advantage of rewarming by peritoneal irrigation is that the procedure is fairly common and most hospitals could easily assemble the few items needed to rewarm a hypothermia patient. A distinct therapeutic advantage is the central application of heat. The greatest value of rewarming by peritoneal irrigation would be when dialysis is indicated, as with drug overdose. The dialysate could both supply heat and remove toxic substances.

Jessen and Hagelsten (1978) list the following as additional advantages of peritoneal dialysis:

1. Rewarming is rapid because of the large heat capacity of the liquid dialysate.
2. It facilitates correction of electrolyte imbalances, particularly hypopotassemia occurring late in rewarming.
3. It does not interfere with the concurrent treatment of other symptoms.
4. The treatment itself does not pose severe risk to the patient.

They base a conclusion that, "peritoneal dialysis is a better means of rewarming than immersion in hot water ...", upon their clinical experience with a rewarming from a 23.4°C core temperature in which the patient did not survive. Two and one-quarter hours in a 40°C bath raised core temperature to only 24°C. This was followed by 2.33 hours of peritoneal dialysis with 5 l/h of 40°C dialysate which raised core temperature to 30.2°C.

Direct warming within the peritoneal cavity offers the advantage of revitalizing the liver. This allows it to resume its functions of detoxification and conversion of lactic acid to glucose.

There is little danger in introducing a large gauge needle into the peritoneal cavity. Viscera tend to be pushed aside with little chance or perforation. Peritonitis and subsequent adhesions are the primary risks of using peritoneal irrigation as a core rewarming procedure. The incidence of these complications is minimal in a hospital.

4.3 Contraindications

Probably the only time when peritoneal irrigation could not be used as a rewarming technique would be if the patient were also suffering from massive trauma of the peritoneal cavity. Under this circumstance warm irrigation during direct surgical exploration would be a logical substitute.

4.4 Guidelines

Core rewarming by peritoneal irrigation should follow the same procedures as the technique applied for dialysis alone except that the dialysate should be warmed to a higher temperature. According to Doolittle (1977) a dialysate temperature of 40.5° to 42.5°C is satisfactory. The rate of heat input can be increased by changing the dialysate more frequently than is usual for dialysis alone. The time interval for exchanging dialysate should be determined by measuring the temperature of the fluid being removed and the victims core (rectal) temperature. A reasonable approach would be to begin with a short exchange interval and increase it until the removed dialysate is found to have lost much of its heat in relation to the core temperature. Detailed guidelines to maximize the therapeutic effect should consider the effects of the dialysate-victim temperature gradient on heat transfer rate and the capacity of dialysis equipment to remove and replace the dialysate.

Jessen and Hagelsten (1978) describe the use of a two-catheter dialysis system with suction at the outflow to achieve high throughput rates (12 l/h). The possibility exists to simplify the procedural aspects of the rewarming therapy by developing equipment to allow the continuous heating and circulating of dialysate through a closed-loop system. This would also reduce the dialysate volume needed to accomplish rewarming, but would disallow dialytic detoxification and electrolyte adjustments.

Jessen and Hagelsten (1978) suggest that hypopotassimia may be treated "automatically" by using a dialysate with a potassium concentration," corresponding to the normal serum-values." This remark seems unnecessary since Guyton (1976), in discussing a "typical dialyzing fluid," indicates that the concentrations of sodium, potassium, calcium and magnesium are normally matched to those found in plasma.

4.5 Conclusions

Core rewarming of hypothermia victims by peritoneal irrigation is a feasible technique that has been successfully used in the hospital. However, one would not expect to see it used as a first-aid measure. The major problems are the difficulty in carrying out a sterile procedure in the field as well as the necessity of a certain amount of diagnosis by an EMT to determine if the severity of the victim's condition warrants the use of peritoneal irrigation.

Probably the main use of peritoneal irrigation for core rewarming is when dialytic detoxification is necessitated as by drug overdose. If the occurrence of hypopotassimia in rewarming is ubiquitous then the attractiveness of peritoneal dialysis would be considerably enhanced.

The procedure does have the advantage that the equipment required for its application is minimal and is readily available at any hospital. Because of the lack of reliable data describing the rewarming effectiveness of peritoneal irrigation no conclusion may be drawn concerning its attractiveness when compared with other therapies. It might be speculated that higher rates of heat input to the core could be achieved with the liquid dialysate than is possible with inhalation therapy (discussed in Chapter 7). A conjecture involving trunk immersion in hot water is more difficult particularly in the context of the clinical experience reported by Jessen and Hagelsten (1978).

5.0 INTRAGASTRIC AND INTRACOLONIC BALLOONS

Heat may be transferred to the body core by intragastric and intracolonic balloons into which warm fluid is pumped. Both approaches supply heat through structures (stomach and large intestine) which are located in the peritoneal cavity. The use of balloons allows the closed-loop circulation of a fluid with high specific heat and which need not be bio-compatible.

5.1 Therapy Description

Both intragastric and intracolonic balloons have been used to transfer heat into or out of the body. Khalil and MacKeith (1954) first described an intragastric balloon for both raising and lowering body temperature. They particularly discussed rewarming advantages, including heating the liver to stimulate metabolic processes. Bernard (1956) described an apparatus for the induction of hypothermia and rewarming using an intragastric balloon. Later Khalil gave details for the construction of intragastric apparatuses for cooling dogs (1957) and for cooling humans with a 1.5 l balloon (1958). A double lumen tube transported fluid to and from the balloon. A provision was made for negative pressure removal of water from the balloon to keep its size constant in the stomach. In 1966, Moss described the use of an intragastric balloon for cooling dogs.

Intragastric balloons have been commercially available although their normal use is for cooling the gastric mucosa to control bleeding due to ulceration. No evidence has been found that this technique has been used to rewarm hypothermia patients.

Intracolonic balloons have been used for controlling the body temperature of animals (Ross, 1954; Cooper and Ross, 1960); but no evidence has been found of the use of the technique in humans. Rewarming by intracolonic balloon would have effects similar to peritoneal irrigation (discussed in the previous chapter) without the risks due to penetrating the peritoneum.

Warm enemas would be another alternative with a similar effect. No literature was found describing the use of warm enemas for rewarming from hypothermia. The use of warm enemas would necessitate larger amounts of fluid than the closed-loop balloon systems and the fluid would have to be bio-compatible.

5.2 Advantages and Risks

Intragastric or intracolonic balloons have the distinct advantage of supplying heat to the core of the body without penetrating the skin. Due to the fact that heat is carried by a fluid rather than a gas, more heat can be supplied to the core via an intragastric balloon than by hot gasses used in inhalation therapy. In addition, the rate of exchange of the rewarming medium is completely under external control.

The intragastric balloon might have an advantage over the intracolonic balloon or enemas in that heat is being supplied closer to the heart, even if the intracolonic balloon were inserted to the transverse colon.

The same advantages due to the stimulation of liver function attributed to peritoneal irrigation (section 4.2) pertain to the intragastric and intracolonic balloons as well.

The use of balloons inserted into the gastrointestinal tract from either end is generally without serious risk. At temperatures below 28°C, however, the heart is usually sensitive to mechanical irritation and the stimulation associated with the insertion of an intragastric balloon could trigger ventricular fibrillation (Hegnauer, et al., 1951). Recently Ledingham and Mone (1978) indicated that they had not observed reflex slowing of the heart precipitating ventricular fibrillation in 38 hypothermia patients treated with endotracheal intubation.

No outstanding danger is recognized in the use of intracolonic balloons or warm enemas for core rewarming. However, the membrances of the colon are thin and traumatic injury is possible, particularly with elderly patients. A potentially significant procedural problem is achieving and maintaining the deep colonic penetrations, desirable for deep core rewarming, against peristaltic attempts to eject the balloon.

5.3 Contraindications

Trauma or surgical intervention involving the gastrointestinal tract would be the primary contraindication to using intragastric or intracolonic balloons for core rewarming. If experimental work proves susceptibility of the heart to mechanical irritation during balloon insertion, use of the intragastric balloon might be restricted to temperatures above an experimentally determined level. Because of present uncertainties, an intragastric balloon probably should not be used at temperatures below 28°C.

5.4 Guidelines

In view of the recommendations of Doolittle (1977) of dialysate temperatures of 40.5° to 42.5°C for direct peritoneal irrigation, an intragastric or intracolonic balloon may be heated by water up to 40°C with impunity. Khalil (1958) suggested rewarming patients using water heated to 40°C.

Because of the possibility of heart irritability at or above temperatures of 28°C extreme care should be exercised in inserting the intragastric balloon assembly.

5.5 Conclusions

Intracolonic, and more particularly intragastric balloons, offer some promise as a core rewarming therapy without the requirement for sterile procedures attendant to peritoneal irrigation. The literature survey does not reveal that the procedures have received much clinical or experimental attention as rewarming therapies. Further experimental work is warranted since appreciable heat may be conveyed to the body core by these rewarming therapies.

6.0 EXTRACORPOREAL BLOOD REWARMING

Cardiac bypass in open heart surgery has become an almost routine surgical procedure during the past several years (Ionescu and Wooler, 1976). Cooling is used to protect tissue from anoxia during cardiac standstill. External rewarming of the blood and body follows surgery before the patient is removed from the bypass equipment.

6.1 Therapy Description

Extracorporeal blood rewarming may be accomplished using several circuits as discussed by Cooper and Ross (1960). Systemic heparinization is required. The simplest extracorporeal circuit (involving the least surgery) uses large bore cannulas to remove blood from the femoral veins. It is oxygenated, warmed, and returned to the circulatory system via the femoral artery. According to Truscott, et al., (1973), a disposable oxygenator and heat exchanger may be primed with only 70 ml of a solution containing no blood.

As a rewarming therapy, the objective is to return warm blood directly to the heart such that this organ may be heated sufficiently to meet the cardiac output demands of the rest of the body as rewarming progresses. The method has been used successfully to rewarm victims of accidental hypothermia (Davies, et al., 1967; Truscott, et al., 1973). The case reported by Truscott and his associates involved a woman cooled to 22°C with ventricular fibrillation and respiratory failure.

6.2 Advantages and Risks

The primary advantage of extracorporeal rewarming is that the heart is rewarmed almost directly by heated blood. This has the immediate advantage of reducing the irritability of the weakest link in the hypothermic "chain". As long as the heart is rewarmed prior to rewarming of other body tissues shock due to depressed cardiac function is unlikely. While peripheral vasodilatation should be controlled, hypovolemic shock due to peripheral vasodilatation can be compensated for more successfully by a warm heart. According to Barnard (1956) extracorporeal blood cooling (and presumably rewarming) is faster than surface treatments as a means of controlling body temperature. The procedure produces almost ideal rewarming conditions as mentioned above.

The risks of extracorporeal rewarming primarily relate to the use of extracorporeal techniques rather than its effect on hypothermia recovery. Complications and risks are associated with the need to heparinize the patient, damage to red cells by the bypass equipment, arterial cannulation, and others. In addition there is always the problem of blood hemolysis and of air leaking into the circuit. The requirement for arteriovenous punctures involve risks of vessel destruction, release of plaque material, and ischemia due to spasm of the vessel. In the proper hands, the procedure can be reasonably safe but it is a complicated, highly invasive procedure that requires special training and equipment.

6.3 Contraindications

Specific contraindications for extracorporeal blood rewarming include all conditions which would be compromised by the use of anticoagulants such as heparin. These include bleeding, both internal (e.g., ulcers) and external (e.g., trauma).

6.4 Conclusions

Extracorporeal blood rewarming is a procedure that has been used successfully in the treatment of accidental hypothermia (Davies, et al., 1967). There is little question that the technique can be used quite successfully in the hospital environment by properly trained personnel. It involves a significant surgical procedure; requiring a high level of medical competence. Consequently, hypothermia rewarming by extracorporeal bypass should be considered only in a hospital and only as a final lifesaving measure in cases that do not respond to more conservative methods.

7.0 INHALATION THERAPY

The desirability of rewarming the core of a hypothermic patient has been discussed repeatedly in this report. Most core rewarming methods (such as extracorporeal circulation, peritoneal irrigation and direct warming of the heart after thoracotomy) are either major surgical procedures or are, at best, invasive. Recently, groups working independently in England, Australia, and Canada have advocated core rewarming by the inhalation of hot moist gasses. Emphasis is placed on the suitability as a first-aid treatment although the techniques differ somewhat.

7.1 Therapy Description

Lloyd originally mentioned inhalation therapy in The Lancet (1971) and later Lloyd, et al., (1972) and Lloyd (1973) described an apparatus in some detail and reported its use on seven hypothermic patients. The device is based on the well known exothermic reaction of soda lime and carbon dioxide. A canister of soda lime is pre-heated by "firing" CO_2 cartridges through it. The heated canister then serves to heat and humidify oxygen breathed through it using a to-and-fro Water's anesthesia circuit. Expired carbon dioxide continues to heat the soda lime, and the incoming oxygen supply.

Shanks and Marsh (1973) described the rewarming of a patient on a Bird respirator using heated water-bath humidifier. They used hospital equipment and did not emphasize the technique as a first-aid measure for use in the field.

More recently Hayward and Steinman (1975) and Collis, et al., (1977) have reported experiments specifically aimed at developing suitable first-aid procedures. They used Bennett Cascade humidifiers to humidify oxygen and warm it to be inspired at temperatures from 40° to 45°C and 43° to 48°C, respectively. Hayward and Steinman (1975) compared inhalation therapy to wholebody rewarming in a hot whirlpool bath. They indicated no significant difference in the afterdrops of rectal and tympanic temperatures with the two therapies; but the level of significance of this conclusion is not given.

Collis, et al., (1977) compared these two therapies with three others - electric heating pads, inhalation therapy combined with heating pads, and shivering. In a comparison based on afterdrop in rectal and tympanic temperatures, the only difference found to be statistically significant at the 0.005 level was between shivering and oxygen inhalation therapy. They conclude inhalation rewarming to be, "an effective emergency therapy for accidental hypothermia." No indication is given of what additional differences might have been significant at more commonly-used levels of significance, say 0.01 or 0.05.

Most recently Marcus (1978) studied inhalation rewarming at "44±1°C from a Marshall Spalding water bath humidifier...." He used an open loop system with the subjects inspiring air. Inhalation rewarming was compared to three other therapies - hot bath (arms out), piped suit, and spontaneous (shivering). He reports no significant differences in the afterdrop of auditory canal temperatures among the four rewarming therapies; but the level of significance of this conclusion is not given. Some differences were found in the rates of restoration of heat. Hot bath rewarming was found to be significantly quicker than the piped suit at the 0.01 level and the piped suit was found to be significantly quicker than inhalation therapy and spontaneous rewarming at the 0.001 level. He concludes that, "in the absence of some powerful method of central rewarming, the most effective way of raising a depressed core temperature is by actively applying heat to the skin, and inhalation rewarming should not be employed if it entails a delay in a patient reaching some means by which this can be carried out." He continues, "[if] the patient is insulated within a heated shelter, inhalation of hot air will not be significantly beneficial, it will not prevent an afterdrop...."

7.2 Advantages and Risks

Breathing hot moist gas offers several advantages as a first-aid measure:

1. The technique warms lungs and heart first.
2. The procedure offers a curtailment of respiratory heat loss.
3. Thermal stimulation of ciliary activity is afforded.
4. The equipment is simple and inexpensive.
5. The equipment is easy to transport.
6. Lloyd's device requires no external power source.

It should be pointed out that the techniques described in Lloyd's and Hayward's groups require the patient to be breathing spontaneously. The rate of heat input is a strong function of respiratory minute volume. The Lloyd apparatus and the Hayward system can be "bagged" to apply forced ventilation. The Shanks system is, of course, attached to a respirator.

Oxygen Inhalation Therapy

Collis, et al., (1977) cite as an advantage of oxygen inhalation therapy an, "increase in coronary arterial oxygenation." This is expected to forestall, "ventricular fibrillation from a limitation of myocardial energetics...." It may also be expected to counter the tendency toward anoxic pulmonary edema.

The specific gas mixture to be used in inhalation rewarming is an important part of the overall therapeutic formulation. The use of 100 percent oxygen may not be desirable. Negovskii (1962) summarizes some evidence supporting this proposition. He cites a histological examination, by Romanova (1956), of the brains of 20 dogs. Pure oxygen was used to resuscitate the dogs after being clinically dead for 5 minutes. Oxygen therapy was continued after the resuscitation of some of the dogs. Fifteen died within the first 5 days and 5 were sacrificed 14 to 90 days after resuscitation. In the 15 animals dying within the first 5 days, characteristic findings included, abundant small hemorrhages in all divisions of the brain, swollen vascular endothelium, and separation and homogenization of the walls of some vessels. These changes were not seen to such a pronounced extent in animals not receiving oxygen, even after longer periods of clinical death. Hemorrhages and changes in vascular walls were also found in the heart, lungs and liver. Circumscribed changes in the brain, including structural disturbances, death of nerve cells and scar formation, were found in animals dying in a moderately prolonged period of time only when oxygen therapy was given. He suggests that oxygen concentration during artificial respiration should not exceed 30 to 40 percent. He cites Dembo (1957) who suggests that oxygen therapy is best performed at a concentration of 50 percent and Swann (1950, 1951) indicating that, "very small doses of oxygen are needed for resuscitation (3 to 4 percent in acute anoxia)." The single exception of carbon monoxide poisoning is mentioned.

Alexander (1945) summarizes the results of oxygen inhalation after the cooling of 4 subjects at Dachau:

"Oxygen inhalation, however, had no effect either upon respiration or upon heart action. The authors [Holzloehner, Rascher, and Finke (1942)] feel that the markedly bright color of the arterial blood [observed in other human experiments] made it unlikely that additional oxygen would have any beneficial effect."

The oxygen therapy was examined because of, "the clinical picture of dyspnoea, with formation of foam at the mouth...reminiscent of early oedema of the lungs...."

Hedley-Whyte, et al., (1976) observe that, "Pure oxygen probably causes [in normothermic patients] marked depression of ciliary activity. Mucus flow is impaired. Tracheitis, as noted by bronchoscopy, is apparent after only six hours of 100% oxygen."

Thermal Considerations of Inhalation Gas Mixture

A wide variety of physiologically acceptable gas mixtures could be used in inhalation rewarming. Constituent gasses with high molar heat capacities will transport more heat per breath at a given temperature than those with lower molar heat capacities. Molar heat capacity is largely determined by the number of atoms in a molecule of the gas. For example, triatomic gasses have higher molar heat capacities than diatomic gasses. Unfortunately, the effects are not large and the opportunities to use gasses with complex molecules are limited due to the requirement for physiologic acceptability. The water vapor in the inhalation gas carries considerably more heat than the warm gas itself.

Inhalation Therapy With a CO Gas Fraction

A gas mixture containing some CO_2 might be expected to offset the depressing effects of profound hypothermia on respiration thereby enhancing the early thermal benefit to be derived from inhalation rewarming. In experiments reported by Morrision, et al., (1978) volunteers with rectal temperatures depressed by 2°C were given inhalation therapy at 44 ± 1°C with two different gas mixtures. One rewarming was performed with air, the other with air combined with a variable amount of CO_2 adjusted to maintain respiratory minute volume at 45 to 50 l. With air-inhalation rewarming, respiratory minute volume averaged 21 l over the test period. The difference between the afterdrops observed with the two therapies was not significant at the 0.05 level. However, the rates of increase in both rectal and tympanic temperatures were greater at this level of significance with the CO_2-induced hyperventilation. This was asserted by one of the researchers (Hayward, personal communication, June 15, 1978) to support the proposition that inhalation therapy affects the rate of core rewarming since a variation in the respiratory minute volume produced a corresponding significant variation in core rewarming rate. Even so, no claim is made for the efficacy of performing inhalation rewarming of victims of profound hypothermia using a CO_2 gas fraction. Indeed, one would expect CO_2 inhalation to accentuate the acidosis described in section 2.4 of this report. Whether or not a small CO_2 gas fraction might, on balance, improve the chances of successful resuscitation from profound hypothermia remains unknown.

<u>Therapeutic Effects of Humidification</u>

As was indicated earlier, the water vapor in the inhalation gas carries much more heat than the gas itself. Much of this heat content is due to the 540 cal/g latent heat of vaporization of water. But for this heat to be imparted to the lung tissue the water vapor must condense in the lung. Shanks and March (1973) estimated that the heat input to the body is less than 10 kcal/hr at a respiratory rate of 10 l/min. However, it should be recognized that respiratory heat <u>loss</u> could be as high as 13 kcal/hr in cold weather. This heat loss could be a significant portion of the patients depressed metabolism and would be prevented by the use of inhalation therapy. Thus the patient's heat balance would be improved by 23 kcal/hr as a result of receiving inhalation rewarming.

As discussed in Section 2.3 there may be pulmonary congestion of some severity present in the victim of profound hypothermia. Unfortunately some effects of water vapor inhalation may depend upon the nature of this congestion. If the congestion is due to pulmonary edema, the condensation of additional water may compound the problem. Collis, et al., (1977) cite Toung, et al., (1970) describing the ability of the respiratory tract to transfer large amounts of fluid into the vasculature. The ability to absorb fluids is predicated upon a favorable balance between osmotic and hydrostatic pressures and upon the normal functioning of blood vessel membranes. The existence of pulmonary edema is prima facie evidence of the failure of one or more of these elements to preserve the fluid contents of the vasculature. Therefore, there is reason to doubt the reliability of the fluid transfer mechanism to contend with condensing inhalation vapor in addition to pulmonary edema existing in a victim of profound hypothermia.

The preceding situation contrasts markedly with that of the alternative source of pulmonary congestion discussed in Section 2.3. When the congestion results from the accumulation of mucus and other secretions due to cold-inhibition of ciliary activity, inhalation rewarming may have desirable non-thermal therapeutic effects, in addition to the direct thermal stimulation of ciliary activity. No treatment recommendation has been found for this specific condition. However, the treatments recommended for related conditions suggest that humidification may be helpful. Potter (1976), in prescribing treatment of mucopurulent bronchitis (inflammation of the bronchial tree accompanied by a marked exudative process), states: "Ancillary measures include nebulization therapy to add water to the secretions for the purpose of reducing their viscosity." He observes that there is continuing debate over the usefulness of the nebulization therapy with some contending that it does not reach the deep areas where it is most needed. It should be noted that inhalation rewarming deposits water by condensing vapor on the relatively cool lung tissues. This may reach deep tissues better than would suspended water particles. Potter concludes that, "The nightly use of a unit which generates cold mist has also been found to be at least of subjective value, but the particle size is such that only the upper airways are benefited." Bouhuys (1977) argues that, "water and mucus do not mix to form a homogeneous liquid, and addition of water, therefore, does not liquify mucus." He cites experiments by Parks, et al., (1971) which indicated that, "exposure to mists...caused no change in tantalum clearance rate in dogs." Bendixen, et al., (1965) describe mist therapy as, "often effective in short-term treatment of laryngeal edema or in cases of very thick tracheobronchial secretions." They also indicate that, "Large amounts of secretions are produced by most patients with chronic pulmonary disease. Treatment with abundant humidity...is required." Ashbaugh (1971) in prescribing care for tracheostomy patients observes that, "bronchial secretions become more viscous and tenacious, leading to atelectasis and infection. Both prevention and treatment of this condition depend on the maintenance of a constant source of moisture in the breathed air or oxygen."

7.3 Contraindications

The major contraindication for inhalation rewarming would be traumatic injury to the face. In this circumstance other first-aid measures might take precedence. However, the technique can be applied by tracheostomy but the temperature must be more carefully controlled.

It is not presently clear if pulmonary edema of some severity might be a contraindication for inhalation rewarming. The notion is sufficiently plausible to warrant further investigation.

7.4 Guidelines

Heated gas at the mouth should be limited to an inspired temperature of less than 45°C to protect the mouth. A conscious patient can complain of heat discomfort but when used with a patient less than fully conscious instrumentation is probably needed to monitor temperatures delivered by heat humidifiers. The temperature of the soda lime canister described by Lloyd can be monitored by touch, as 45°C is about the maximum that the bare hand can withstand.

Collis, et al., (1977) point out that distilled water is routinely used in clinical humidification and was used in their inhalation device.

The equipment should be discarded after use or thoroughly sterilized between uses to preclude the spread of communicable diseases.

7.5 Conclusions

It has not been clearly established that inhalation rewarming alone can prevent or significantly reduce afterdrop in a seriously cooled patient. Experimental results based on mildy cooled volunteers are conflicting. The positive findings of Hayward and Steinman (1975) and Collis, et al., (1977) are supported by a larger base of experimental data than are the negative findings of Marcus (1978). The hot-bath therapy formulations used as bases of comparison for inhalation rewarming by the Canadians (arms and legs in) and by Marcus (arms out, legs in) were less likely to prevent afterdrop than a formulation with arms and legs out of the bath. Therefore, their results with that particular therapy may be regarded as pessimistic bounds on its potential performance when applied only to the body trunk.

As a practical matter, the question of gas mixture reduces to a choice of oxygen concentration. Based on the experience of Negovskii (1962) and others, the oxygen tension should be no larger than can be expected to be fruitful. Air may be sufficient for most inhalation rewarmings from immersion hypothermia due to its oxygen partial pressure at low altitudes and based on the observations of Holzloehner, et al., (1942). An open loop, air-inhalation circuit is certianly the simplest from a sterilization point of view; but it may require greater heating capacity and may produce inhalation temperatures which are more difficult to control than a closed loop system.

Little can be said concerning the magnitude of the problems arising from applying inhalation rewarming to victims of profound hypothermia who exhibit pulmonary edema. Further experimentation with animals in profound hypothermia and systematic clinical observations are needed to establish the nature and severity of any pulmonary edema and the interaction of inhalation rewarming with this condition. There are, of course, treatments for the edema which could be used to clear the way for the application of inhalation rewarming. These treatments are generally directed toward the cause of the edema, which is not presently known. Furthermore, this treatment of edema could involve significant delays in the initiation of inhalation therapy. During this time the patient should, as always, be handled so as to minimize afterdrop during the treatment of pulmonary edema. Rewarming could be initiated with another therapy during this time with inhalation therapy added when the pulmonary congestion has been cleared.

Inhalation rewarming provides direct thermal stimulation of ciliary activity which would tend to clear congestion from the pulmonary tree. Although there are dissenting views, the majority opinion seems to be that humidification tends to liquify tenacious congestion and mobilize it for transport.

The inhalation rewarming of a victim of profound hypothermia (with depressed respiration) could be accomplished in two ways. The simplest approach would be to allow natural respiration to cause heat to be infused at a very low rate. A more aggressive approach would involve bagging the inhalation gas to elevate respiratory minute volume and the resulting heat transfer. This could tend to offset existing acidosis, perhaps to the point of precipitating alkalosis which, in turn, could be corrected by increasing the CO_2 content of the inhalation gas mixture. This more aggressive approach would be less simple and could necessitate relativey complicated monitoring of variables. The potential also exists for bagging to produce mechanical irritation of a weakened myocardium increasing the tendency toward fibrillation.

It is not necessary that inhalation rewarming be as effective as torso immersion in a hot bath for it to be useful as a first-aid treatment. The inhalation of warm, moist gasses prevents respiratory heat loss, infuses a small amount of heat into the deep body core near the heart and stimulates ciliary activity. This alone is probably sufficient justification for its use.

8.0 DIATHERMY

The word diathermy comes from the greek dia, meaning through and therme, meaning heat. It has come to include several varying ways to transmit heat. Lehmann (1971) defines it, for therapeutic purposes, as "deep heating". He discusses three modalities which are used for therapeutic purposes -- ultrasonic, short-wave and microwave diathermy. They share the characteristic of accomplishing heating by conversion. This implies that various types of energy are transmitted through superficial tissues to deeper ones where they are converted into heat.

8.1 Descriptions of the Therapies

Ultrasonic Diathermy

Ultrasonic diathermy utilizes high frequency acoustic vibrations (0.8 to 1.0 MHz) propagated in the form of longitudinal compression waves. The heating in response to therapeutic intensities (1 to 4 watts/cm^2) derives from tissue particle movement as a result of the wave propagation. These waves will not propagate through air, so physical contact with the transducer is required. Wave intensity diminishes exponentially with depth in a homogeneous tissue. According to Lehmann and Johnson (1958), the ultrasound absorption per unit of tissue thickness in fat is about twice that in muscle and in bone is over 10 times that in muscle. Reflection can occur at the interface between materials of different acoustical impedances. This effect is particularly pronounced with bone and surgical implants. Carstenson, et al., (1953) and Piersol, et al., (1952) showed that absorption and conversion to heat occur primarily in the tissue proteins. According to Schwan (1958) relatively little energy is converted into heat in the subcutaneous fat and much more is converted in the musculature. One half of the energy available at the fat-muscle interface is available 3 cm into the muscle.

Short-Wave Diathermy

Short-wave diathermy utilizes high frequency current (13.56 to 40.68 MHz) to establish a current within the "patient circuit". This current is tuned to resonance, usually with a variable capacitor, by maximizing a power indication. The therapy may be applied either with a capacitance device or an induction device. According to Lehmann (1971) short-wave diathermy produces heating at a tissue depth which is, "between that produced by superficial heating agents... and [that produced by] low frequency microwave or ultrasound...." He cites short-wave diathermy as, "an efficient agent to heat musculature up to a depth of 1 to 2 centimeters." Swan, et al., (1955) report the regular use of a standard diathermy unit with the induction coil wrapped around the pelvis for rewarming surgery patients. Their data shows the method to be as rapid for rewarming as immersion in water at 45°C. They also state, "Occasionally, for reasons not apparent, the diathermy has also proved inefficient." In 1952 Bigelow, and his associates described a series of experiments on dogs and monkeys with the specific objective of developing, "a safe radio-frequency resuscitation procedure requiring only a small portable radio-frequency generator and power supply with a simple technique of application." The complete summary of the paper follows:

"1. A radio-frequency induction cable technique has been developed which has successfully rewarmed dogs and monkeys from near-lethal hypothermia of 21°C to normal body temperature.

2. The short wave therapy range was found most effective for heating the deep tissues of large animals.

3. Spacing of coils from body was the most critical rewarming factor. Using one-half inch spacing, adequate heat generation was obtained without burning the subcutaneous tissue.

4. A frequency of 13.56 megacycles and an insulation of one-half inch was finally selected as the safest and most effective combination and became a standard technique.

5. A final series of animals was resuscitated by this technique. They all survived with no burns, no signs of vascular collapse, and no post-rewarming change in behavior or intelligence."

Alexander (1945) summarized the results of human rewarming experiments conducted at Dachau employing "short wave" diathermy of the heart.

> "The treatment had no demonstrable beneficial effect. It was likewise considered unsatisfactory because in view of the loss of skin sensation due to the cold, the danger of extensive burns exists even though a physician may exercise constant supervision."

The wave lengths, modes of application and energy levels used were not reported. Equipment available at the time did not permit whole-body treatment of the human subjects. The experiments had been prompted by previous successes with whole-body animal rewarming which, according to Holzloehner, et al., (1942), "...leads to a recovery of the animal with puzzling rapidity."

Microwave Diathermy

Microwave diathermy transmits energy in the form of electromagnetic radiation in the 915 to 2450 MHz range. Heat is created in the tissues as a result of their resistance to the impinging radiation. Guy, et al., (1974) indicated that the longer wave length associated with the industrial, scientific and medical frequency (915 MHz) gave more power transferred to deep tissues than with 2450 MHz. They summarize the deficiencies of 2450 MHz diathermy:

"1. absorption is so great in the muscle layer that the depth of penetration is only 1.7 cm.

2. the severe discontinuity at the fat-muscle interface produces a large standing wave resulting in a "hot spot" in the fat layer one-quarter wave length from the muscle surface.

3. the absorbed power density in the deep tissues varies considerably with fat thickness making it difficult to predict the proper therapeutic level for different patients having a wide variation of fat thickness."

Concerning 915 MHz diathermy they observe, "The penetration and minimal fat heating compare favorably with those of the short-wave diathermy, with the additional advantage that the heating pattern is reasonably uniform in contrast to the undesirable toroidal pattern of the latter." Lehmann (1971) indicates that 50 percent of energy available at muscle surface is available at a 3 cm depth with 900 MHz microwaves while it was available to only a 1 cm depth with 2450 MHz.

8.2 Advantages and Risks

The primary advantage for diathermy rewarming is its ability to heat tissues below the subcutaneous fat layer. This advantage pertains particularly to ultrasound and low frequency microwaves; but short-wave diathermy is also capable of some deep tissue heating. Swan, et al., (1955) point out that rewarming by diathermy is particularly valuable since coils can be positioned over the pelvis, if necessary, so that manual cardiac compression can be applied to support circulation until a patient can be rewarmed sufficiently for spontaneous defibrillation to take place or until a defibrillator can be used effectively (core temperature above 28°C).

A risk with diathermy, particularly short-wave and microwave, is superficial burns. These can result from application of excessive energy, moisture on the patient's skin, improper positioning of the applicator or movement of it during treatment. The problem is reduced in short-wave diathermy by the use of the induction coil applicator. Advances in ultrasound equipment have provided the capability to detect transducer movements which could increase the transducer load intensity and automatically reduce the system output.

A more difficult problem is the determination of proper treatment dosage. Verbal feedback from the patient is generally used in physical medicine to determine control settings on a diathermy unit. A semiconscious or unconscious hypothermia victim would be unable to provide information about the heating effect of the treatment. Dosage can be approximated by knowing the dosage energy input and dosage time; but the exact distribution of thermal effects will not be known. The therapy will have to be applied conservatively with close monitoring of rectal temperature.

The fact that Swan, et al., (1955) regularly used the technique on surgical patients suggests that the overheating problem can be controlled. They applied the therapy intermittently, two minutes on and one minute off.

8.3 Contraindications

The complete lists of contraindications for the three diathermy modilities are given by Lehmann (1971). The following are contraindictions for both short-wave and microwave diathermy.

1. any question of hemorrhage
2. areas of sensory loss
3. moist dressings or adhesive tape
4. regions of suspected malignancy
5. presence of phlebitis
6. tuberculosis
7. joints with effusions
8. areas of occlusion arterial disease

9. areas containing metallic implants
10. during pregnancy or menstruation
11. on patients with pacemakers.

Additional specific contraindications given for microwave diathermy are the area of the eye and edematous tissue. As indicated in section 2.3 of this report edema may be a consequence of hypothermia. Regarding short-wave contraindications Lehmann (1971) states, "It remains to be investigated whether fluid accumulation in the body cavities, such as the joints and pleural cavity, represent an indication for decreasing the dosage since selective heating of these may occur." Item 2 above addresses the problem of dosimetry which must be solved to permit treatment of unconscious patients.

There are fewer specific contraindications for ultrasonic diathermy, as follows:

1. avoid therapeutic dosage to the eye
2. spinal area after laminectomy
3. hemorrhagic diatheses
4. regions or suspected malignancy
5. area of vascular insufficiency.

Since the eye is contraindicated because of the danger of damage caused by cavitation of the fluid contained therein, it is surprising that pulmonary edema is not listed for the same reason.

8.4 Guidelines

For short-wave and microwave diathermy, wet clothing should be removed and the patient should be thoroughly dried so that hot spots and burns do not develop on the body surface. Terry cloth is usually used with short-wave diathermy to absorb any residual mositure or perspiration and to help space induction heating coils at least 1/2 in from the skin. The latter spacing is recommended to prevent burns. Short-wave therapy by induction coil heating is recommended rather than capacitive heating with large plates.

Since metallic implants or pacemakers are contraindications for short-wave and microwave diathermy, any patient to be rewarmed by these methods should be thoroughly checked for thoracic or hip scars that would suggest implants in or near the regions to be heated. Also, due to the danger of strong, local induced heating, all metallic objects such as rings or bracelets should be removed prior to treatment.

Ultrasonic diathermy should be applied with a heavy oil as a mediator between the transducer and the patient's skin.

8.5 Conclusions

Because of the potential for delivering significant amounts of heat to relatively deep tissues, diathermy, particularly ultrasonic and low-frequency microwave, should receive serious consideration for possible use as a rewarming therapy.

The primary obstacle to diathermy rewarming is the development of dosimetry guidelines which are effective yet safe in the absence of reliable feedback from the patient. The seriousness of the edema contraindications should be determined. Research is also needed to determine the best way to apply each modality to accomplish core rewarming. Pelvic application has been suggested and would probably advance rectal temperature most quickly; but an application nearer the pleural cavity might produce better therapeutic results. The location of bone structure will differentially affect the performance of the three modalities.

Diathermy requires equipment of some sophistication; but it is commonly operated by technicians. The equipment may be made reasonably portable; but it requires a supply of electric power.

9.0 APPLICATION OF THE THERAPIES

Three points regarding the application of the rewarming therapies considered in this report are of paramount importance. They are the suitability of the therapies for use as first-aid treatments in the field (out of a hospital environment or its equivalent) and their suitability for use either simultaneously or sequentially during the restoration of normothermia. These points are addressed in this chapter.

9.1 First-Aid Treatments

The selection of first-aid therapies for which EMT's are to be trained and equipped involves a tradeoff between the therapeutic advantage of a therapy versus the risk to the patient of receiving the therapy from technicians under the conditions prevailing at the accident site or in route to a hospital environment. This risk should not be confused with a risk to the patient of receiving no treatment at all. This latter risk is involved in the determination of therapy benefit. If quantitative measures could be obtained for the benefit and risk inherent in each of a number of candidate rewarming therapies, the best could be selected by comparing the benefit/risk ratios of the therapies. Ignoring morbidity due to the therapies, this could be formulated as the selection of the therapy (counted $j = 1, 2, \ldots, n$; where there are n candidate therapies under consideration) which maximizes the expression:

$$\left[\frac{\Pr(\text{survival with treatment } j) - \Pr(\text{survival without treatment})}{\Pr(\text{death due to treatment } j)}\right]$$

These probabilities, indicated by Pr, would be difficult to estimate accurately with information presently available. Therefore this report is restricted to a delineation of the views of the authors concerning the suitability of the therapies for use as first-aid treatments.

Of the potential first-aid measures, rapid surface heating by trunk immersion in hot water offers good potential on shipboard or wherever a bathtub is available. Hot water immersion is not likely to be a viable procedure aboard a small boat or rescue helicopter although special plumbed garments or body suits filled with hot water offer a possible alternative. Systems could be developed which utilize the waste heat from the vehicle engine.

Of the therapies which have been examined in this report, the following four may reasonably be performed by EMT's outside of a well-equipped medical facility:

1. Surface rewarming
2. Intragastric balloon
3. Inhalation rewarming
4. Diathermy

Passive slow rewarming, intragastric balloons, inhalation rewarming, and diathermy are rewarming techniques which could be initiated in a small boat, helicopter, or some other small rescue vehicle. Either no equipment is required (as in the case of passive rewarming) or else compact emergency equipment exists or could easily be developed.

Peritoneal irrigation offers some potential for use as a first-aid procedure under reasonably controlled conditions by specially-trained EMT's with special equipment to facilitate monitoring of dialysate and core temperatures and to control dialysate replacement.

Extracorporeal blood rewarming should remain a hospital-based procedure that is reserved for serious hypothermia cases that cannot be rewarmed by more conservative means or that must be used if the patient develops ventricular fibrillation. Indeed extracorporeal blood rewarming should probably be performed only by specially-trained physicians.

9.2 Simultaneous Treatments

Some of the therapies examined in this report should not be applied simultaneously. Diathermy should not be applied in the area while either an intragastric or intracolonic balloon is being used or while the peritoneal cavity is being irrigated. This is particularly the case for ultrasonic and low-frequency microwave diathermy due to the penetration depths they can achieve and their undesirable effects on accumulations of water. It would probably be prudent to withhold short-wave diathermy as well.

There is no immutable reason why inhalation therapy and the intragastric balloon could not be administereed simultaneously. However, because of their requirements to access the body through the pharynx, special equipment may be needed to enable their simultaneous application.

The remaining combinations of pairs of the therapies under consideration are all quite feasible.

9.3 Sequential Treatments

Because treatment is sometimes initiated but not completed in the field, it is reasonable to ask if the initiation of a particular therapy might preclude the later use of another therapy when the victim is transported to a facility capable of a more intense level of care. In short, no specific contraindications have been identified which would preclude sequencing these therapies in any order. It should be noted that this finding does not address the question of the therapeutic desirability of these sequences. The conclusion is only that the therapies may be safely sequenced in any order.

10.0 SUMMARY AND CONCLUSIONS

The literature on resuscitation from accidental hypothermia is split between advocates of fast active rewarming and slow passive rewarming. Survival statistics do not permit a definitive evaluation of the various methods at present. Some experimental evaluations of simple, non-invasive therapies have been performed using volunteers with mild induced hypothermia (rectal temperatures around 35°C). The need still exists for more systematic and comprehensive studies of this type. Of course these studies are limited in that they can not reveal the effects of the therapies when applied to a profoundly hypothermic patient who is unconscious, not shivering, acidotic, subject to hypovolemic shock, and perhaps exhibiting one or more types of edema. Information concerning the performance of the therapies under these conditions can only come from conjecture, clinical observations, and experiments with deeply cooled animals. Conjecture, even when based on good knowledge of fundamentals is the weakest basis for conclusions because of the complexity of the interactions in biological systems. Clinical observations are useful in suggesting lines of scientific inquiry but are a weak basis for conclusions because of their uncontrolled nature. Experimentation with deeply cooled animals is an imperfect source of information, as is experimentation with moderately cooled humans. However, it also should be drawn upon for indications of the safety and efficacy of rewarming therapies before forming conclusions about their suitability for use.

Rapid external rewarming by immersion of only the torso in warm water is commonly regarded as safe and effective. There are obvious physical limitations on its usefulness as a first-aid treatment. A large tub of hot water is not a highly portable item.

When patients cannot be rewarmed by conservative means or when ventricular fibrillation occurs at a body core temperature below 28°C, aggressive measures must be taken. Diathermy, peritoneal irrigation and extracorporeal blood rewarming have all been employed successfully.

Diathermy has good potential for use as a first-aid treatment. It should be investigated further to determine the best modality and protocol for application to safely achieve best core rewarming and organ system revitalization. Its sensitivity to edema as a contraindication must be determined.

Peritoneal irrigation offers limited use as a first-aid treatment. Its best use is when dialytic detoxification is desired as with drug overdose.

Extracorporeal blood rewarming requires surgical invasion which would be very dangerous in the field. The requirement to administer anticoagulants would counterindicate its use in all cases involving trauma.

Rewarming by inhalation of warm humid gasses offers distinct potential as a first-aid treatment since it at least prevents further respiratory heat loss and stimulates ciliary activity. Its interaction with the pulmonary edema possible in profoundly hypothermic patients warrants investigation.

The use of an intragastric balloon offers some potential as a first-aid rewarming treatment. It introduces heat into the core while necessitating less need for sterilization than other invasive treatments. Its clinical effectiveness has not been determined but appears promising.

11.0 REFERENCES

Alexander, L. (1945), "The Treatment of Shock from Prolonged Exposure to Cold, Especially in Water", Report No. 250, Office of the Publication Board, Department of Commerce, Washington, D.C.

Ashbaugh, D.G. (1971), "Establishment and Care of the Airway," Chapter 2 in Intensive and Rehabilitative Respiratory Care, by T. L. Petty, Lea & Febiger, Philadelphia.

Axelrod, D.R., and Bass, D.E. (1956), "Electrolytes and Acid Base Balance in Hypothermia", Am. J. Physiol. 186:31-34.

Bangs, C.C. (1976), "Early Recognition and Treatment of Chronic Cold Injuries", Eighth NASAR Conference, September 9-12, 1976, Cheyenne, Wyoming, Paper No. M 76-104.

Barbour, H.G., McKay, E.A., and Griffith, W.P. (1944), "Watershifts in Deep Hypothermia", Am. J. Physiol. 104:9-19.

Barnard, C.N. (1956), "Hypothermia: A Method of Intragastric Cooling", Brit. J. Surg. 44:296-298.

Beeson, P.B. and McDermott, W. (1971), Cecil-Loeb Textbook of Medicine, Saunders, Philadephia.

Behnke, A.R. and Yaglou, C.P. (1971), "Physiological Responses of Men to Chilling in Icewater and to Slow and Fast Rewarming", J. Appl. Physiol. 3:591-602.

Benazon, D. (1974), "Hypothermia", Chapter 5 in Scientific Foundation of Anesthesia, Ed C. Scurr and S. Feldman, Wm. Heinemann Med. Books, London, pp. 344-357.

Bendixen, H.H., Egbert, L.D., Hedley-Whyte, J., Laver, M.B., and Pontoppidan, H., (1965), Respiratory Care, C.V. Mosby Company, St. Louis.

Best, C.H. and Taylor, N.B. (1966), The Physiological Basis of Medical Practice, 8th Ed., Williams & Wilkins, Baltimore.

Bigelow, W.G., Lindsay, W.K., Harrison, R.C., Gordon, R.A., and Greenwood, W.F. (1950a), "Oxygen Transport and Utilization in Dogs at Low Body Temperatures", Am. J. Physiol. 160:125-137.

Bigelow, W.G., Lindsay, W.K., Greenwood, W.F. (1950b), "Hypothermia, Its Possible Role in Cardiac Surgery: An Investigation of Factors Governing Survival of Dogs at Low Body Temperatures", Ann. Surg. 132:849-866.

Bigelow, W.G., Hopps, J.A., and Callaghan, J.C. (1952), "Radio Frequency Rewarming in Resuscitation from Severe Hypothermia", Canada J. Med. Sci. 30:185-193.

Bigelow, W.G. (1959), "Methods for Inducing Hypothermia and Rewarming", Annals of N.Y. Academy of Sci. 80:522-532.

Bloch, M. (1967a), "Accidental Hypothermia", Brit. Med. J. 1:564-565.

Bloch, M. (1967b), "Cerebral Effects of Rewarming Following Prolonged Hypothermia: Significance for the Management of Severe Cranio-cerebral Injury and Acute Pyrexia," Brain, 90:769-784.

Bouhuys, Arend (1977), The Physiology of Breathing, Grune & Stratton, New York.

Burton, A.C., and Edholm, O.G. (1955), Man in a Cold Environment, Edward Arnold Ltd., London.

Carstenson, E.L., Li, K., and Schwan, H.P. (1953), "Determination of the Acoustic Properties of Blood and Its Components", J. of Acoustical Soc. of Am. 25:286-289.

Cherniack, R.M., Cherniack, L., and Norimark, A. (1972), Respiration In Health and Disease, W. B. Saunders Co., Philadelphia.

Clasen, R.A., Pandolfi, S., and Hass, G.M. (1970), "Interrupted Hypothermia in Experimental Cerebral Edema", Neurology 20:279.

Collis, M.L., Steinman, A.M., and Chaney, R.D. (1977), "Accidental Hypothermia: An Experimental Study of Practical Rewarming Methods", Av. Space and Environ. Med. 48:625-632.

Cooper, K.E., and Ross, D.N. (1960), Hypothermia in Surgical Practice, F.A. Davis, Philadelphia.

Chritchley, M. (1943), Shipwreck Survivors, A Medical Study, J & A Churchill Ltd., London.

Davies, D.M., Millar, E.J., and Miller, I.A. (1967), "Accidental Hypothermia Treated by Extracorporeal Blood-Warming", Lancet 1:1036-1037.

Dembo, A.G. (1957), "External Respiratory Failure", Medgiz, p. 299.

Doolittle, W.H. (1977), "Disturbances Due to Cold", In Current Therapy 1977 Conn, H.F., Editor, Saunders, Philadelphia.

Duguid, H., Simpson, R.G., and Starners, J.M. (1961), "Accidental Hypothermia", Lancet 2:1213-1219.

Emslie-Smith, D. (1958), "Accidental Hypothermia", Lancet, 2:494-496.

Fairley, H.B., Waddell, W.G., and Bieglow, W.G. (1957), "Hypothermia for Cardiovascular Surgery: Acidosis in the Rewarming Period", Brit. J. Anesth. 29:310.

Fay, J. (1959), "Early Experience with Local and Generalized Refrigeration of the Human Brain", J. Neurosurg. 16:239-259.

Fernandez, J.P., O"Rourke, R.A., and Ewy, G.A. (1970), "Rapid Active External Re-Warming in Accidental Hypothermia", J. Amer. Med. Assoc. 212:153-156.

Fruehan, A.E. (1960), "Accidental Hypothermia", Arch. of Internal Med. 106:218-229.

Gagge, A.P., and Herrington, L.P. (1947), "Physiologic Effects of Heat and Cold", Ann. Rev. Physiol. 90:409-428.

Golden, F.St.C. (1973), "Recognition and Treatment of Immersion Hypothermia", Proc. Royal Soc. Med. 66:1058.

Gollan, F., Rudolph, G.G., and Olsen, N.S. (1957), "Electolyte Transfer During Hypothermia and Anoxia in Dogs", Am. J. Physiol., 189:277-280.

Grossheim, R.L. (1973), "Hypothermia and Frostbite Treated with Peritoneal Dialysis", Alaska Med., March: 53-55.

Grote, W., and Schweikhordt, F. (1969), "Electrolytes in Serum and Lactic and Pyruvic Acid in Blood Under Normothermia and Hypothermia Conditions in Rabbits", Pfluegers Arch., Ges Physiol. 305:351-360.

Guy, A.W., Lehmann, J.F., and Stonebridge, J.B. (1974), "Theraputic Applications of Electromagnetic Power", Proc. of IEEE 62:1:55-75.

Guyton, A.C. (1976), Textbook of Medical Physiology, 5th Edition, W.B. Saunders, Philadelphia.

Hakansson, C.H., and Toremalm, N.G. (1965), "Studies on the Physiology of the Trachea. I. Ciliary Activity Indirectly recorded by a New 'Light Beam Reflex' Method", Ann Otol Rhinol Laryngol, 74: 954-969.

Hamilton, J.B. (1937), "Hypothermia and Nervous System Activity", Yale J. of Biol. and Med. 9:327.

Hamilton, J.B., Dresbach, M., and Hamilton, R.S. (1937), "Cardiac Changes During Progressive Hypothermia", Am. J. Physiol. 118:71-76.

Hayward, J.S. and Steinman, A.M. (1975), "Accidental Hypothermia: An Experimental Study of Inhalation Rewarming", Av. Space and Env. Med. 46:1236-1240.

Hedley-Whyte, J., Burgess, G.E., III, Feeley, T.W., and Miller, M.C. (1976) Applied Physiology of Respiratory Care, Little, Brown and Co., Inc., Boston.

Hegnauer, A.H., D'Amato, H., and Flynn, J. (1951), "Influence of Intraventricular Catheters on Course of Immersion Hypothermia in Dogs", Am. J. Physiol., 167:63-68.

Herrmann, H.D., and Dittmann, J. (1970), "Examination of the Metabolism of Oedematous Brain Tissue and Alterations of the Metabolism in Cold-Induced Oedema of the Rabbit Brain Measured Monometrically in Vitro", Acta. Neurochir. 22:167.

Hervey, G.R. (1973), "Physiological Changes Encountered In Hypothermia", Proc. of Royal Soc. Med. 66:1053-1058.

Hillman, H. (1972), "Treatment After Exposure to Cold", Lancet, 1:378.

Holzloehner, E., Rascher, S., and Finke, E. (1942), "Report of 10 October 1942, On Cooling Experiments on Human Beings", Partial translation of Document No. 428, Prosecution Exhibit 91, in Trials of War Criminals, Vol. 1, U.S. Gov. Print. Ofc., Washington, DC, pp. 226-243.

Hughes, C.W. (1956), discussion in Physiology of Induced Hypothermia, R.D. Dripps Ed., Pub. 451 Nat. Acad. Sci. - Nat. Res. Council, Washington.

Ionescu, M.I. and Wooler, G.H., (1976) "Current Techniques in Extracorporeal Circulation", Butterworths, London.

Irravni, J. (1967), "Flimmerbewegung in den intrapulmonalen Luftwegen der Ratte," Pfluegers Arch, 297:221-237.

Jessen, K., and Hagelsten, J.O. (1972), "Search and Rescue Service in Denmark with Special Reference to Accidental Hypothermia", Aerospace Med. 43:787-791.

Jessen, K., and Hagelsten, J.O., (1978), "Peritoneal Dialysis in the Treatment of Profound Accidental Hypothermia", Av. Space and Env. Med., 49:426-429.

Kanter, G.S. (1962), "Renal Clearance of Sodium and Potassium in Hypothermia", Canada J. of Biochem. and Physiol. 40:113-122.

Kanter, G.S. (1963), "Regulation of Extracellular Potassium in Hypothermia", Am. J. Physiol. 205:1285-1289.

Keatinge, W.R., (1969), Survival In Cold Water, Blackwell Press, Oxford.

Khalil, H.H., and MacKeith, R.C., (1954), "A Simple Method of Raising and Lowering Body Temperature", Brit. Med. J. 2:734-736.

Khalil, H.H. (1957), "Hypothermia by Internal Cooling", Lancet 1:185-188.

Khalil, H.H. (1958), "Hypothermia by Internal Cooling in Man", Lancet 1:1092-1094.

Langdon, L., and Kingsley, D.P.E. (1964), "Changes in Serum and Urinary Potassium Levels During Profound Hypothermia in Man", J. Clin. Path. 17:257-259.

Lash, R.F., Burdette, J.A., and Ozdil, T. (1967), "Accidental Profound Hypothermia and Barbituate Intoxication, A Report of Rapid 'Core' Rewarming by Peritoneal Dialysis", J.A.M.A. 201:269-270.

Lathrop, T.G. (1972), Hypothermia: Killer of the Unprepared, Mazamas, Portland, Oregon.

Ledingham, McA., I., and Mone, J.G. (1978), "Accidental Hypothermia", Lancet 1:391.

Lehmann, J.F., and Johnson, E.W. (1958), "Some Factors Influencing the Temperature Distribution in Thighs Exposed to Ultrasound", Archives of Physical Med. 39:347-356.

Lehmann, J.F. (1971), "Diathermia", in Handbook of Physical Medicine and Rehabilitation, 2nd Ed., W.B. Saunders, Philadelphia.

Linton, A.L. and Ledingham, I. McA. (1966), "Severe Hypothermia with Barbituate Intoxication", Lancet 1:24-26.

Lloyd, E.L. (1971), "Treatment After Exposure to Cold", Lancet 2:1376.

Lloyd, E.L., Conliffe, N.A., Orgel, H., Walker, P.N. (1972), "Accidental Hypothermia: Apparatus for Central Rewarming as a First Aid Measure", Scot. Med. J., 17:83-91.

Lloyd, E.L. (1973), "Accidental Hypothermia Treated by Central Rewarming Through the Airway", Brit. J. Anaesth. 45:41-47.

Maclean, D., Griffiths, P.D., and Emslie-Smith, D. (1968), "Serum Enzymes in Relation to Electrocardiographic Changes in Accidental Hypothermia", Lancet 2:1266-1270.

Maclean, D., Griffiths, P.D., Browning, M.D., and Murison, J. (1974), "Metabloic Aspects of Spontaneous Rewarming in Accidental Hypothermia and Hypothermic Myxoedema", Quart. J. of Med., New Series 43(171):371-387.

Marcus, P. (1978), "Laboratory Comparison of Techniques for Rewarming Hypothermic Casualties", Av. Space and Env. Med., 49:692-697.

Meriwether, W.D., and Goodman, R.M. (1972), "Severe Accidental Hypothermia with Survival After Rapid Rewarming", Am. J. Med. 53:505-510.

Mills, W.J., Jr. (1976), "Summary of Treatment of the Cold Injured Patient", Mountain Medicine Symposium, Seattle, Washington (Oct. 9-12, 1976).

Morrison, J.B., Conn, M.L., and Hayward, J.S. (1978), "An Evaluation of Inhalation Rewarming in Treatment of Cold Water Hypothermia", Presented at Undersea Medical Society Meeting.

Moss, G.(1966), "Systemic Hypothermia Via Gastric Cooling", Arch. Surg., 92:80-82.

Moyer, J.H., Morris, G.C., and DeBakey, M.E. (1956), Physiology of Induced Hypothermia in Dipps R.D. (Ed), Pub. 451 Nat. Acad. Sci. - Nat. Res. Council, p. 199.

Negovskii, V.A. (1962), "Resusciation and Artificial Hypothermia", Consultants Bureau, New York.

Nemiroff, M.J., Saltz, G.R., and Weg, J.G. (1977), "Survival After Cold-Water Near-Drowning; The Protective Effect of the Diving Reflex", Presentation at American Thoracic Society Annual Meeting, San Francisco, CA, May 17, 1977.

Niazi, S.A. and Lewis, F.J. (1958), "Profound Hypothermia in Man", Ann. Surg. 147:264-266.

Nowell, N.W., and White, D.C. (1963), "Season Variation of Magnesium and Calcium in Serum of the Hypothermic Rat", J. Appl. Physiol. 18:967-969.

Parks, C.R., Woodrum, D.E., Graham, C.B., Cheney, F.W., and Hodson, W.A., "Effect of Water Nebulization on Normal Canine Pulmonary Microciliary Clearance", Am. Rev. Respir. Dis. 104:99-106.

Piersol, G.M., Schwan, H.P., Pennell, R.B., and Carstenson, E.L. (1952), Archives of Physical Med. 33:327.

Popovic V. and Popovic, P. (1974), Hypothermia in Biology and Medicine, Grune and Stratton, New York.

Potter, J.L. (1976), "Mucopurulent Bronchitis and Bronchiectasis", in Current Therapy, W.B. Saunders Co., Philadelphia.

Prescott, L.F., Peard, M.C., and Wallace, I.R. (1962), "Accidental Hypothermia", Brit. Med. J. 2:1367-1370.

Ross, D.N. (1954), "Venous Cooling, A New Method of Cooling the Blood Stream", Lancet 1:1108-1109.

Romanova, N.P. (1956), "Histopathological Changes in the Brain in Experimental Hypoxia", Zhur Neuropat. i Psikhiat. 1:49.

Rees, J.R. (1958), "Accidental Hypothermia", Lancet 1:556-559.

Schwan, H.P. (1958), "Biophysics of Diathermy", in Theraputic Heat, by S. Licht, Elizabeth Licht, New Haven, p. 55.

Shanks, C.A. and Marsh, H.M. (1973), "Simple Core Rewarming in Accidental Hypothermia", Brit. J. Anaesth. 45:522-525.

Smith, R.T. (1956), "Electrolyte Studies in Experimental Animals During Hypothermia", Am. J. Surg. 92:228-232.

Spurr, G.B., Barlow, G., and Lambert, H. (1959), "Influence of Prolonged Hypothermia and Hypothermia on Cardiac Response to Inject Potassium", Am. J. Physiol. 196:696-702.

Stewart, Thomas (1972), "Treatment After Exposure to Cold", Lancet 1:140.

Swann, H. (1950), "Studies in Resuscitation", AF Techn. Rep., p. 6006.

Swann, H. (1951), "Studies in Resuscitation", AF Techn. Rep., p. 6696.

Swan, H., Virtue, R.W., Blount, S.G., and Kircher, L.T. (1955), "Hypothermia in Surgery: Analysis of 100 Clinical Cases", Ann. Surg. 142:382-400.

Talbott, J.H. (1941), "The Physiologic and Theraputic Effects of Hypothermia", New England J. Med. 224:281-288.

Talbott, J.H., and Burton, A.C. (1952), "Cold Injury", Transaction of the 1st Conference, Josiah May, Jr., Foundation, New York, June 4-5, 1951, Ed. M.I. Ferrer, p. 145.

Tansey, Wm. A. (1973), "Medical Aspects of Cold Water Immersion", Naval Submarine Medical Res. Lab Report No. 763, September 19, 1973, NTIS Document AD-775-687.

Toung, J.K., Alvaran, S.B., Shakoor, M.A., Graff, T.D., and Benson, D.W. (1970), "Alveolar Surface Activity Following Mechanical Endotracheal Ventilation with High-Density Water Mist", Anesthesia and Analgesia 49:851-858.

Truscott, D.G., Firor, W.B., and Clein, L.J. (1973) "Accidental Profound Hypothermia", Arch. Surg. 106:216-218.

Walther, A. (1862), "Beitrage zur Lehre von der Thierischen Warme", Virchows Arch., 25:414.

Webb, Paul (1973), "Rewarming After Diving in Cold Water", Aerospace Med., Oct. 1973, 1152-1157.

Weyman, A.E., Greenbaum, D.M., and Grace, W.J. (1974), "Accidental Hypothermia in the Alcoholic Population", Am. J. Med. 56:13-21.

Whitby, J.D. (1964), "Dangers of Cold Immersion", Brit. Med. J., 1:1441.

Woodruff, L.M. (1941), "Survival of Hypothermia by the Dog", Anesthesiology, 2:410-420.

The Boating Rules Of

10's, 3's And 4's

RULES OF 10's

10 seconds to make a life or death decision upon sudden, unexpected immersion.

10 feet is the average distance from safety that most drownings occur.

10 minutes is the average minimum time that a full suit of hunting clothing will support a non-panicked person in the water without a PFD.

10 to 1 are the approximate odds the Spring or Fall fisherman/hunter has in dying from a boating accident compared to the summer recreational boater.

RULES OF 3's

3 modes of death in the water:
1. Some drowning victims die from suffocation (dry drowning).
2. Some drowning victims die from hypothermia (exposure).
3. Some drowning victims die from the displacement of air by water in their lungs. Almost all drowning victims die from their own ignorance and/or panic. (There are very few acts of God or unconscious drownings).

3 ways that alcohol or drugs kill boaters:
1. They drink too much beer, or other alcoholic beverages, (frequently in the hot sun) and impair their balance.
2. They stand up or move toward the gunwale to relieve themselves and fall overboard and/or capsize the boat.
3. They become hypothermic much more rapidly due to alcoholic dilatation of the blood vessels once they hit cold water; and/or they cannot think clearly; they are uncoordinated and disoriented; panic and drown, frequently an arm's length from safety.

3 reasons why more people die out of the normal boating

season (June, July, August):

1. The water is much colder.
2. There are far fewer people around to help.
3. The fisherman/hunter who is the predominate "out of season" recreational water user does not think of himself as a "recreational boater", hence he blocks out or ignores the majority of the safety information directed at the general boating public. Additionally, he has generally been "doing his thing" safely for years.

RULES OF 4's

4 minutes under (without oxygen) and a person is dead or at least is permanently reduced to a mental incompetent.

This may not be true for the following reasons:

1. All mammals (including humans) have what is known as a "diving reflex".
2. This reflex, normally involuntary, occurs infrequently yet it definitely exists and occasionally is mastered by humans.
3. A person in dive reflex looks dead, yet is very much alive.
4. Recently, presumed drowning victims of all ages, sizes, sexes, and races who have been completely underwater for as long as 38 minutes, have been revived with no ill effects.

4 suggestions for resuscitation/revival of a drowning victim:

1. Treat as alive, insulate from environment, take to a hospital and rewarm.
2. Apply moist warm air inhalation or rescue breathing to all victims.
3. Use CPR (Cardio Pulmonary Resuscitation).
4. Treat all near drownings as serious, take victim to a hospital fast.

4 rules for dealing with hypothermia (body core heat loss) in the water:

1. Minimize movements.
2. Assume the help (Heat Escape Lessening Position) position.
3. Don't swim.
4. Don't remove clothing.

4 suggestions for dealing with hypothermia out of the water:

1. Insulate hypothermia victims from the environment.
2. Attempt to warm core of victim.
3. Rewarm slowly, treating victim gently.
4. Get victim to a hospital as soon as possible.

4 suggestions to prevent drowning:

1. Learn to swim or to float.
2. Wear a PFD.
3. Don't panic.
4. Don't go in the water alone.

BOATING SAFETY NEWSLETTER
U.S. Coast Guard
Spring 1979

BOATING SAFETY NEWSLETTER
U.S. Coast Guard
Spring 1979

Boating Accidents....

A CLOSER LOOK

No boater wants to be involved in a boating accident. To avoid accidents that damage property and cause injuries, the boater needs to take a closer look at some of the causes of boating accidents and what he can do to prevent them from happening to him.

The person who kills himself is not a recreational boater in that he does not think of himself as such. He is a hunter, fisherman, canoeist, etc. If we talk to him specifically from this point of view, he is much more likely to respond to our information.

Coast Guard studies indicate that the "Sudden Drowning Syndrome" or disappearance within fifteen minutes, affects three out of every four boating drowning fatalities (This may also be true of swimming fatalities. Proof lies in further research). The primary parts of this syndrome are: (1) cold water (under 70 degrees F), (2) lack of flotation devices (or inappropriate knowledge of their use, only 7% of available PFD's are employed by people falling or thrown into the water), and (3) overuse of alcohol or similar harmful drugs.

Fatalities are mostly found in smaller (under 16 feet) boats with no engine or with engines under 10 horsepower. The victims tend to be males, in their mid to late thirties, who generally have appreciable experience in their type of activity; be it hunting, fishing, canoeing, water skiing, or some other water related sport.

Ten out of eleven fatalities occur in the water rather than prior to entering the water. The five major causes of death:

1. Massive heart attacks which are usually found in older, out of condition, non-swimmers who have a manifest fear of the water, but do not wear PFD's.

2. Dry drowning where the victim's throat closes due to laryngeal spasms. Hence the victim dies by suffocation, but is frequently found floating on the surface, and if found in time, may be revived. (Fifteen percent of

water accident fatalities fall with in this category.)

3. Wet drownings where the victim actually inhales water into his lungs and dies of asphixiation.

4. Hypothermia, or reduction of internal body temperature due to body heat loss to cold air or water. (One third of all boating fatalities fall into this category.)

5. Being struck by a circling boat, usually empty, from which the victim has been thrown.

To summarize - boating fatalities tend to happen to experienced, freshwater boaters in small low powered craft involved in an activity (usually fishing) on cold water, or to boaters in powered craft which can't be automatically stopped. The victim frequently does not know how to swim, has no PFD available (or doesn't know how to use one properly) and has consumed some alcoholic beverages or drug shortly before, or while engaged in, a water related activity.

INJURIES

Injuries tend to occur to occupants of boats larger than 16 feet, with appreciable horse power, moving at high speed. In fatalities, the victim either falls or is thrown from the boat, or the boat capsizes. Injury victims, being in larger boats, are not as likely to be thrown into the water. However, they are injured, some quite seriously, when they are thrown about inside their boat or struck, still inside their boat by another craft.

The primary causes of boating injuries are collisions with an object on or under the water, or with another boat. Collisions are overwhelmingly caused by operator error or inattention, especially when moving at high speeds.

Operator vision impairment, or increases in reaction time (response) after receipt of visual stimulae, are involved in most injury cases.

Stressors such as vibration, glare, exposure to wind and weather, heat, noise and alcohol, can in an average boating day, (approximately 3 hours) increase an operator's reaction time to twice that of his normal, rested state. (Note: this does not take into account additional fatigue induced in many inland boaters by their trailering boats many miles before or after a day of boating activity).

Impairment of peripheral vision, frequently a factor in many after dark, high-speed collisions, is especially prevalent due to alcohol consumption and/or operation for long periods involving high, in-boat vibration exposure.

DEFENSES

Three general concepts should be involved in protecting yourself or your family from fatal, injurious, or damaging accidents. They are:

A. Awareness of Outcome
Most boating accidents, no matter if they involve fatalities, injuries, or property damage, can "easily" be prevented if the person or persons involved simply stop to think, for even a minimal period of time, about the possible, undesireable outcomes of the potentially dangerous activity in which they are

becoming involved. Our minds respond to patterns of behavior that are far from random. We both consciously and unconsciously plan and repeat our activity. By simply thinking where a certain action or activity may eventually lead us, we have taken the first, somewhat automatic step toward programming ourselves not to go in a less desirable direction.

B. Chains of Circumstances Accidents do not happen randomly. More than we would like to admit, they are willed. We set up and participate in the chain of events that end in someone or something getting bent or hurt or both. We continually carry the six-pack aboard the canoe; we continually boat in cold water, but put off learning about hypothermia, or buying a float coat; we continue to drive long distances before and after a day of boating activity, and we routinely expect to get away with it. Fortunately (or unfortunately) we do. However, much grief, anguish, hurt, pain, and loss could have been saved, or can be saved, if we'd only pay attention to these small, yet profound points.

C. Think Survival In far too many instances, accident victims have planned for emergencies in advance and have responded to that planning, but found, to their great sorrow, that their planning hadn't quite gone far enough. For instance, when you buy a set of PFDs for your boat, you are moving in the right direction. But, when you stow them in a locked space; don't take them out of the plastic bag they were purchased in; don't try to get them identified for fit; don't learn how to use them yourself, or don't teach passengers how to use them; you have a large potential for trouble. Also, when you plan to have another fallible human, even the Coast Guard or State Water Patrol, come along (by chance) and pull your particular chestnuts from the fire, you may be sadly disappointed. Take time to think through each particular unpleasant experience that might logically happen to your boat and you. Then figure what you will do without any outside help to insure that no one gets hurt or killed, from the second the accident occurs until you are home, laughing about the experience.

UNITED STATES DEPARTMENT OF
COMMERCE
NEWS
WASHINGTON, D.C. 20230

NOAA 79 - 59

RELEASE: Thursday
June 21, 1979

Cold Water "Drownings"
Need Not Be Fatal

With summer weekends at the beach approaching, and thousands of swimming pools being filled for the season, the National Oceanic and Atmospheric Administration (NOAA), has advice that could mean the difference between life and death.

If statistics hold up, scores of men, women, and children will drown during the next few months in water accidents. But research supported by NOAA's National Sea Grant College Program shows that not all the drownings need result in death. The lives of some "victims" can be saved.

Dr. Martin J. Nemiroff, a University of Michigan researcher funded by the Commerce Department agency, has determined that if a person "drowns" in cold water -- water cooler than 70 degrees Fahrenheit -- he or she stands a good chance of being saved without brain damage, even after prolonged submersion.

A reflex common to marine mammals also occurs in humans in cold water, Nemiroff said. The body shuts off the flow of oxygen in its system to all but the vital parts -- the heart, lungs, and brain. His conclusions are based on investigation of more than 200 drowning cases in the past three years.

Nemiroff has been involved personally in 22 of the cases. In each instance the victim had been submerged in cold water for at least five minutes, and most had no pulse, were not breathing, and had dilated pupils -- all signs of death. Prior to Nemiroff's findings, it is doubtful resuscitation attempts would have been made.

In these cases, however, after prolonged resuscitation of the 22 victims, 17 recovered fully, three did not respond, and two responded but suffered physical damage.

-more-

One of the victims, a college student who had been underwater for 38 minutes, not only recovered fully, but went on to establish an A-minus record in college, evidence that no brain damage was done.

In cold water drowning cases, Nemiroff said, it is important that resuscitation be started as quickly as possible, using any of the standard techniques taught by the American Red Cross, the Heart Association, or other organizations.

It is also important that the resuscitation effort continue as long as the person administering it can physically perform the task, or until professional medical assistance arrives and takes over.

Nemiroff said the drownings he has studied have happened not only in lakes, oceans, or rivers, but in swimming pools, as well.

Many children fall into pools while they are being filled, he noted, and in most cases the water temperature during filling is about 60 degrees Fahrenheit, cold enough to trigger the "mammalian response" which raises survival odds.

One child revived recently by Nemiroff had fallen headfirst into a water-filled diaper pail while the mother was out of the room. The child was in the less-than-70-degree water for at least 10 minutes before the mother returned and started resuscitation. Through her efforts and those of a medical team called to the home, the child made a full recovery.

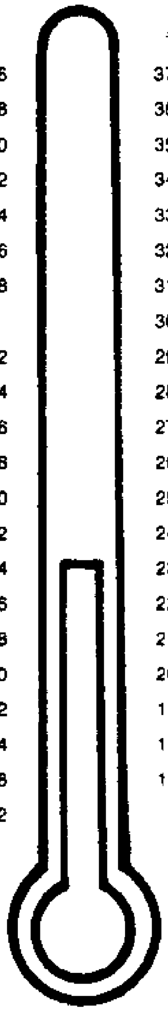
#

James C. Elliott - Sea Grant
(301) 443-8975

NOAA Public Affairs
Rockville, MD 20852
(301) 443-8243

Levels of Hypothermia

Adapted from Hamett et al. (1979)



°F	°C	
99.6	37.6	— "normal" rectal temperature
96.8	36	— metabolism increases
95.0	35	— maximum shivering
93.2	34	— normal blood pressure, victim responsive
91.4	33	— severe hypothermia below this temperature
89.6	32	— clouded consciousness, diminished respiratory rate, shivering ends, blood pressure difficult to obtain (32–31)
87.8	31	
86	30	— unconsciousness begins, ventrical fibrillation may occur (irregular heartbeat), slow pulse and breathing, increased muscular rigidity (30–28)
85.2	29	
82.4	28	
80.6	27	— victim appears dead, loss of movement and reflexes
78.8	26	— victim seldom conscious
77.0	25	— ventricular fibrillation may appear spontaneously
75.2	24	— pulmonary edema develops (swelling of lungs) (24–21)
73.4	23	— maximum risk of fibrillation (24–21)
71.6	22	
69.8	21	
68.0	20	— heart standstill
66.2	19	
64.4	18	— lowest accidental hypothermia recovery
62.6	17	— ISO Electric EEG (flat brain-wave pattern)
48.2	9	— lowest artificially cooled hypothermia recovery

University of Rhode Island PRESS RELEASE 12/20/78

POLAR BEARS WARNED:
KEEP AWAY FROM ALCOHOL

For those rugged individuals who brave chilly waters on New Year's Day for polar bear swims, there's a word of caution--don't drink alcohol first.

That "one to warm you up" in reality, when mixed with cold water can kill you, warns Neil W. Ross, of the University of Rhode Island Marine Advisory Service.

The deadly combination of cold water and alcohol will be one of the topics covered in a R.I. Boating Council workshop, Jan. 13-14 at URI, on techniques for cold water survival and hypothermia treatment.

"Alcohol opens up the small blood capillaries near the body's surface. As the warm blood circulates to the skin it loses heat. This cooled blood then returns to the heart and can begin to cool down the inner body. If the inner body temperature drops twenty degrees, heart attacks and death usually result," Ross said.

When alcohol is not present in the blood stream, the body's capillaries close down in an instinctive body defense. This keeps the blood deeper inside the body to delay the chilling effects when someone is thrown into cold water, he continued.

Alcohol can also decrease one's swimming ability and diminish judgment. Ross pointed out that cold water clouds one's thinking and thus combining cold water and alcohol can be doubly dangerous.

"It's not just the drink before the plunge that can put someone in danger," he said. "It takes time, about an hour per ounce of liquor, for the body to metabolize the alcohol. Someone who drank heavily New Year's Eve might still be intoxicated the next day. Therefore, those interested in a cold water dunking on New Year's Day ought to take it easy the night before."

For a safer swim in chilly waters, he suggested drinking a warm, non-alcoholic beverage beforehand and making sure someone is around to help if trouble arises.

"After the swim, when you're thoroughly warmed up and your body surface is back to room temperature, then you can celebrate with alcohol," Ross concluded.

For Further Information: Christi Duerr, Marine Affairs Writer
401-792-6211

Hypothermia and Survival

Seagrant '70s
Virginia Polytechnic Institute and State University
Volume 9, No. 11
ISSN 0048-9875
November 1979

A Case History:

Near the Dodge Ridge Ski Resort on Sonora Pass highway in central California, two sisters aged nineteen and twenty-five parked their jeep and went for a short loop-like trip on cross-country skis the afternoon of December 29, 1978. Expecting to be gone only a short time, they failed to notify anyone of their plans and as the afternoon was warm at 3:00 P.M. they left their jackets in the car. About two miles from the lodge area they made a wrong turn and subsequently became exhausted. They were overcome by darkness and increasing cold. The older sister, Barbara, was unable to continue so the girls attempted to dig crude snow caves to protect themselves during the night.

About 10:00 A.M. the following day the sisters were discovered by another cross country skier and his wife. Leaving his wife with the girls he headed for the highway to seek help. On the way he encountered three other cross-country skiers, one of whom was former professional Ski Patrolman, Alan Bernat. The party of three hurried to assist and arrived shortly before 11:00 A.M. Bernat recognized the seriousness of the situation. The older sister was unconscious but breathing. He fashioned a bed from ski jackets and space blankets carried in the survival pack of a woman member of the party. Bernat had the woman member of his party undress and lie against the bare skin of the adbomen and legs of the unconscious girl and covered them both with the jackets and blankets available. He then checked the younger girl, Debbie, and found that her feet were frozen. No sooner had he done that, when Barbara, the unconscious girl, stopped breathing. Bernat immediately checked her and started CPR at an estimated time of 11:17 A.M. Bernat was assisted by the other skiers with mouth-to-mouth respiration but continued the cardiac massage by himself.

In the meantime, the original skier who found the girls reached Dodge Ridge Ski Resort, whose management notified the Sheriff's Office and called for an ambulance. The resort management then dispatched two Thiakol snow vehicles, the first, with U.S. Forest Ranger Merritt Lovejoy and Bruce Fisher, a Sonora Pass Ski Patroller who is a physician. The second Thiakol containing a stokes litter and additional supplies followed with professional Patroller Danny Miller and Sonora Pass patroller Fran Conlan, also a physician. The snow vehicles arrived at approximately 12:05 P.M. While CPR continued, Dr. Bruce Fisher checked the unconscious girl for heart tones, pupillary reactions, carotid and femoral pulses and finding none, sent for a rescue helicopter which had been placed on stand-by twenty minutes earlier.

Patroller Fisher relieved Bernat until Dr. Conlan arrived, who confirmed the state of cardiac arrest and relieved Patroller Fisher who took over mouth to mouth respiration. A Tuolumne County Search and Rescue paramedic arrived and relieved at cardiac massage, freeing Patroller Conlan to attend to the younger sister. Placing blankets, jackets and victim in the stokes litter, Dr. Conlan tied the stokes on the back of the Thiakol for transport to the highway one-half mile away. CPR was continued by paramedic Ben Shifflin and Patroller Fisher. The litter was then carried to the ambulance and transported 6.1 miles to an area suitable for helicopter landing. Arriving at 1:10 P.M. an electrocardiogram recorded with equipment from the rescue helicopter indicated ventricular fibrillation.

In preparation for helicopter transport, the victim was given an I.V., placed in a shock suit, given an esophageal airway and mechanical heart compressor with bag ventilation and oxygen. Interestingly enough, the helicopter, an Allouet III, equipped with an emergency nurse and paramedic trained for helicopter evacuation had been put into service only 30 days previously and information concerning its availability had been posted at the Sonora Pass Ski Patrol First Aid Room.

At 2:15 P.M., after three hours of continuous CPR, the victim arrived at the Emergency Ward of Doctors Hospital, Modesto, California, 64 air miles away. Physical examination revealed that her core temperature was 68.9 degrees Farenheit (20.5 centigrade) and ventricular fibrillation was the only sign of "life". Endotracheal intubation was performed and CPR continued as she was transported to the operating room. At 3:10 P.M. surgery was begun to perform extracorporeal rewarming with a heart lung machine and cardiopulmonary bypass was instituted at 3:31 P.M. and continued until 6:12 P.M. Her temperature rose to 32 degrees C. and spontaneous defibrillation occurred at 4:17 P.M., five hours after the onset of cardiac arrest. Doctor James MacMillan, who now directed the care of the two girls, performed a femoral bypass using the heat exchanger of the heart lung machine. As her temperature became more normal, her reflexes returned, her blood pressure and pulse were stabilized and with assisted ventilation she was taken off the heart lung machine and sent to Intensive Care.

Another thirty days of intensive medical care, included tracheotomy, respiratory assistance, kidney dialysis, multiple blood transfusions and physical therapy. Barbara's mental powers were happily found to be normal, and she was discharged to convalesce at her parents' home.

Barbara, the rewarmed girl, experienced only slight skin loss on the knuckles and some fingers while her sister, though requiring only brief hospitalization, had considerable loss of skin from her toes and loss of toenails with prolonged impairment of walking. Possibly the internal rewarming exerted a protective effect on the peripheral tissues.

The moral to this story is in cases of hypothermia, **KEEP TRYING!!** Training, execution, cooperation and determination can be successful. Don't think of "death" until resuscitation and rewarming have been performed and have failed.

Alan Bernat, Ben Schrifrin, Francis Conlan and Bruce M. Fisher have been awarded the Red Cross Certificate of Merit, the highest award given by the American Red Cross to a person who saves or sustains a life by using skills learned in a Red Cross first aid, small craft, or water safety course. These men are receiving the award "for selfless and humane action in saving the life of a cardiac arrest victim." This action exemplifies the highest ideal of the concern of one human being for another who is in distress.

Virginia Polytechnic Institute and State University
Volume 9, No. 5 May 1979

Surviving in Cold Water:

A Study of Immersion Hypothermia

Roland Lovstad and Lynn Furlong
University of Minnesota, Duluth

When the luxury liner Titanic sank on April 15, 1912, about 700 survivors climbed into lifeboats and sought rescue by other ships in the area. But only one person is said to have survived from those who jumped or were thrown into the icy cold North Atlantic waters that night. About 1,500 passengers and crew perished with the ship or in the waters.

Sixty-seven years later, that lone individual's ability to survive is of interest to scientists. Among those seeking the reason are researchers at the University of Minnesota-Duluth School of Medicine.

They are studying immersion hypothermia—how the body reacts in cold water—in a project funded by the University of Minnesota Sea Grant Program. Stearns Manufacturing Company, St. Cloud, has provided some funds to support the research. The investigators hope the results of their research will be useful in developing survival techniques and rescue procedures, as well as in designing lifesaving gear that will not only float the victim but also protect the body from hypothermia.

An understanding of how the body reacts in cold water will greatly enhance a person's chances of survival in cold water, according to Robert Pozos, associate professor of physiology at the medical school.

SIMULATING a Lake Superior plunge, research assistant Scott Burgstahler tries out a test tank for hypothermia research at the University of Minnesota, Duluth School of Medicine. Taking the tank's temperature is Paul Iaizzo. The tank is kept at 39°F, the average temperature of Lake Superior.

Shivering

The human body must regulate a constant temperature (98.6°F is considered normal), but when immersed in cold water the body rapidly loses heat and begins to shiver. "Shivering appears to be one of the body's mechanisms for adjusting to the heat loss—the muscle movements produce heat," Pozos says. But, he adds, "shiver can also inhibit motion needed for the person to get out of the water, and consequently he becomes weaker."

The mechanics of shiver are not really understood, but Pozos hopes his research will help to discover what triggers the shivering impulse and what can be done to control it.

A person's physical condition may be one determinant of the shivering mechanism and the body's ability to withstand cold temperatures. Both physically fit and obese individuals are better able to endure cold water than unfit or lean persons, and women have been reported to be able to endure cold temperatures for a longer period of time than men, according to Pozos. "Not surprisingly, fatigued individuals cannot tolerate cold water as well as rested persons," he adds.

Alcohol's Effects

Pozos is also interested in the effect alcohol has on a person's ability to withstand cold temperatures. "When a person has had a few drinks, his body becomes warm and if he falls into water his body may lose heat much faster than usual. However, the alcohol content may subdue his shock reaction, making him more relaxed. Interestingly, the Titanic survivor who fell into the water was a drunken sailor."

To conduct this research, Pozos has designed a water tank in which male and female volunteers will be immersed and their physiological responses measured. Larry Wittmers, assistant professor of physiology, will take respiratory measurements, and John LaBree, dean of the medical school and a cardiologist, will monitor heart rate and stress levels of the volunteers.

Since he has access to the coldest of the Great Lakes, Pozos will concentrate his efforts on Lake Superior. The water in the tank will be kept at approximately 39°F—the temperature of Lake Superior.

Know What To Do!

Because northern Minnesota's many lakes offer both summer and winter recreation, Pozos believes that the public should be informed of the dangers of immersion hypothermia. He cites the examples of a snowmobiler whose snow machine plunges into the icy waters of a northern Minnesota lake, and of a sailboat capsized on Lake Superior. "The survival of these people may depend on what they do while in the water. We hope our research will provide an answer," says Pozos.

One offshoot of the hypothermia research is experimentation with different kinds of life preservers or personal flotation devices (PFD). If it can be determined what exactly happens to the body in cold water, then a device could be developed to help correct the body's limitations, Pozos believes. In Lake Superior, a special kind of PFD may be required to tolerate the extremely cold water.

The New York Times Magazine

June 10, 1979

Health

SURVIVAL TECHNIQUES IN COLD WATER

By Elisabeth Keiffer

One sparkling May morning a few years ago, a party boat called the Comet left Point Judith, R.I., carrying a crew of three and 24 passengers who had paid for the pleasure of a day's deep-sea fishing. The sea kicked up, the boat was unseaworthy and an hour out of port it broke up and sank.

Four hours later, a passing yacht found only 11 survivors clinging to the wreckage. The other 16 died, not all of them from drowning but rather from hypothermia, a fatal chilling of the body's vital organs. They died because they didn't know how to keep themselves alive in water that was only 58°F. "It just got colder and colder," a survivor told reporters. "The guys lost strength and one by one they began slipping under."

Elisabeth Keiffer writes frequently on marine subjects from her Rhode Island home.

Until recent years, all water-related deaths were assumed to be the result of drowning, or the inhaling of water into the lungs. Now it is recognized that many of the 8,000 yearly in-water deaths in this country may be caused not by drowning per se but by hypothermia — particularly in cold water.

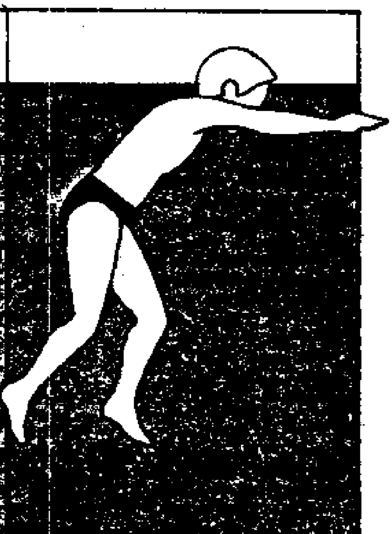
Drowning (which includes hypothermia) is now the third leading cause of accidental death in the United States and, as more Americans spend more time around open water every year, the number of accidents is bound to increase. They don't just happen to people at beaches in summertime or to babies left unattended in bathtubs, but to commercial fishermen, seamen, offshore oil-rig workers, duck hunters and pleasure boaters (whose numbers increased an astonishing four million in the past two years).

Springtime is especially dangerous for boaters, according to the Coast Guard. "We lose a lot of people in May and June. The air is warm and they can't wait to get out on the water, probably wearing inadequate clothing," says Lt. Cmdr. David S. Smith. "They don't think about how cold the water is."

Most open water in the northern half of this country is under 70°F for most of the year. Now new understanding of the body's reactions has led to the development of a science of cold-water survival that could have saved the lives of those aboard the ill-fated Comet and many other victims. In fact, this new knowledge, combined with a variety of life-saving techniques and equipment, can not only extend survival time in cold water by as much as eight hours, it can decrease the number of people who die of radical temperature "afterdrop" following rescue.

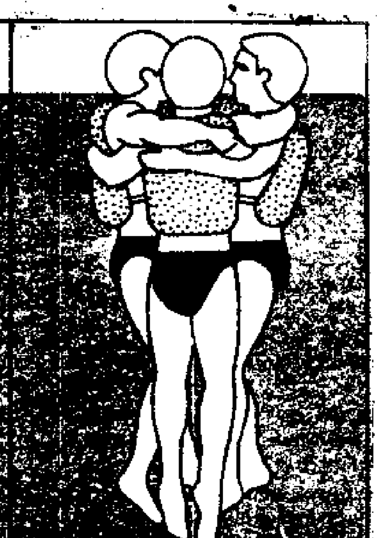
The word hypothermia began appearing in the newspapers with some regularity last winter. In plain language, it is a physiological state in which the body's core temperature is lowered to a point at which vital organs can no longer function. This can take a while. Skin and peripheral tissues cool very quickly (especially in cold water), but it may take 10 to 20 minutes before the heart and brain even begin to cool. At 89.6°F, a victim usually loses consciousness; below 86°F, heart failure usually causes death.

TREADING WATER: This technique can prevent drowning in warm water, but in cold water it causes the body to lose heat very rapidly.



DROWNPROOFING: This face-down technique may keep non-swimmers afloat in warm water, but it hastens hypothermia in cold water.

HELP: This fetuslike Heat Escape Lessening Posture, used with a life jacket, can increase a person's cold-water survival time by half.



HUDDLING: People wearing flotation jackets who huddle together chest-to-chest can increase their survival time by close to 50 percent.

Until this decade, there were little scientific data on hypothermia, presumably because the experiments involved are so unpleasant: A person is cooled one-third of the way to death and then has his core temperature measured by electron thermometer deep in the rectum, ear canal or esophagus. What skimpy literature there was before 1970 described studies of chilled fighter pilots who had to be rewarmed in World War II.

Then, in 1971, Dr. John Hayward, a 42-year-old physiologist at the University of Victoria in British Columbia, who had spent five years studying animal hibernation, began to look at the human body's response to immersion in cold water.

His research was aimed simply at trying to determine how long a human could stay in water under 70°F before becoming hypothermic. The doctor's location was ideal: Sea temperatures off British Columbia range between 40°F and 50°F all year.

With a research team, Dr. Hayward had each volunteer subject stay in the sea until his core temperature dropped to about 95°F — "the greatest amount of cooling we can do ethically," Dr. Hayward explains, "but enough to give us a cooling rate." The team monitored the volunteers from shipboard, much as astronauts would be from a control tower, to provide a second-by-second picture of human response to cold stress: deep body temperature, temperature of blood flow to the brain, heart activity, oxygen uptake and electrical activity of specific muscles, both as the subjects were chilled and then rewarmed. Infrared photography was used to map the areas of the body which, in addition to the head, are the major routes for heat loss.

After 800 experimental submersions, Dr. Hayward's team found that humans could extend their survival time considerably. He began developing and testing a science of cold-water survival.

Meanwhile, at the University Hospital of the University of Michigan in Ann Arbor, Dr. Martin J. Nemiroff, a 38-year-old specialist in lung disease and diving medicine, began to study another aspect of cold-water survival. He had been fascinated by the case of a college student who, having been trapped in his car under lake ice for 38 minutes, was successfully revived and found to have suffered no brain damage. Until then, it had been generally believed that the human brain could not survive undamaged without oxygen past four minutes.

With support from the Michigan Sea Grant Program, Dr. Nemiroff began to review every case of drowning and near-drowning that had taken place in Michigan waters in the past several years. Narrowing his inquiry down to 15 victims who had been rescued after more than four minutes under water, he discovered that 11 had survived without brain damage, despite up to 15 minutes of submersion.

Dr. Nemiroff theorized that cold water could save lives as well as end them. While he knew that the four-minute limit for submersion without brain damage undoubtedly held true in warm water (above 70°F), he saw that cold water — the colder the better — could cause a lifesaving reaction. He found that immersing a person's face in icy water triggers a reflex that slows the heartbeat and constricts the peripheral arteries so that oxygen-carrying blood is shunted away from the extremities and carried instead to the heart, lungs and brain. Skin, muscles and gut can survive without circulation for more than an hour.

This reaction, called the mammalian diving reflex, had already been identified in the 1930's in seals, whales and other air-breathing aquatic mammals who, if they must, can stay under water for up to 30 minutes. Humans, it turns out, are also born with an ability to tolerate periods of low oxygen, which helps them survive birth. This reflex, activated by the shock of cold water, is strongest in infants and children, statistically the most frequent drowning victims, but it diminishes with age.

Dr. Nemiroff cites the case of an Ann Arbor 2-year-old who had been missing from his lakeside home for nearly 20 minutes before he was found floating face down in the icy water. His body was blue and he gave every sign of being dead. Refusing to believe it, his mother began mouth-to-mouth resuscitation and chest massage and kept it up throughout the ambulance ride to the hospital. The next morning the baby was sent home, bright and cheerful.

People who are fished out of cold water and seem to be dead — cold, blue, with fixed, dilated pupils and no pulse — may not be. "We have studied nearly 100 cases over the past two years," Dr. Nemiroff said recently, "and we are very optimistic about full recovery of these patients, particularly if they were in cold water and are given immediate, aggressive treatment. The ones who did poorly were the ones who got only mouth-to-mouth resuscitation without chest compression or the other way round. Unfortunately, that happens with some regularity.

"It's not unusual for a parent to see a kid at the bottom of a swimming pool and call the ambulance and wait for professional help to rescue the child," he continued. "In that case, the outcome is usually fatal. But we believe that with immediate resuscitation efforts, 75 to 85 percent of infant drowning victims can be revived without brain damage. I'd certainly take the chance if it were my child."

Last January, Dr. Nemiroff joined Dr. Hayward at a two-day conference on cold-water survival at the University of Rhode Island that was sponsored by the Rhode Island Boating Council. The purpose was to reduce cold-water deaths by acquainting water-safety instructors with new information on drowning causes, hypothermia treatment and in-water survival techniques and equipment.

With the doctors were Lt. Cmdr. Smith of the Coast Guard's Boating Safety Branch in St. Louis, Mo., Comdr. Alan Steinman, a specialist in emergency and aviation medicine for the Coast Guard in Washington, D.C., and Frank Pia, a New York lifeguard who has written several articles and produced two films on drowning.

The first day, the five instructors conducted a seven-hour demonstration class for 78 selected conference participants: certified instructors in water-safety or first-aid programs. Then, the next day, in the "each-one-teach-one" tradition, these 78 men and women demonstrated what they had learned to 100 other fishermen, firemen, pleasure boaters and paramedics from across the country.

"There is a lot of myth," Dr. Hayward told them, "about how long you can last in cold water. It is actually much longer than people think. I have been in 50°F water for close to an hour and was only a third of the way to death." He explained that cooling proceeds at a fairly linear rate, making it possible to predict survival time in water ranging from 32 to 60°F. "Your life expectancy," he said, "depends on three variables besides the water temperature: who you are, how you behave and w[illegible] you are wearing." In 50[illegible]gree water, those variables can make the difference between living one hour and nine.

Sex, age, size and body type are all crucial factors, Dr. Hayward said. A really fat person might last five to six hours in water that would freeze a truly skinny person in one to two hours. The bigger your build, the better your chances; even though women are apt to have more body fat than men, their smaller size works against them, as it does for children.

Sobriety also matters; many drowning deaths are associated with alcohol consumption. Originally, Dr. Hayward said, it was believed that alcohol in the blood hastened in-water death by speeding the body's cooling rate. But his latest research has shown that this happens only if the person has drunk enough to reach the legal impairment level. Still, he emphasized, booze a[illegible] water do not mix: "For [illegible] thing, it makes you more likely to fall into the water in the first place, and once you are in it, alcohol impairs judgment and coordination."

In-water behavior can also determine survival rates. Swimming and thrashing around in panic hasten hypothermia. A swimmer produces — and loses — almost three times as much heat as someone who remains still. Though the swimmer may feel better temporarily, he is defeating his "cold reflex," the physiological reaction that shuts down circulation to the outside of the body in order to save it for the core tissues. A swimmer cools 35 percent faster than someone holding still in cold water. Dr. Hayward's tests have shown that in 50-degree water, the greatest distance an average swimmer can cover before he succumbs to hypothermia is 0.85 miles. His advice, then, is that unless the distance to shore is less than that or the water considerably warmer than 50°F, it is better to stay put and hope for rescue.

At the conference, Dr. Hayward tried to show the participants how to slow heat loss. Heat escapes quickly from the chest cavity because there is little fat or muscle along the sides of the thorax. The groin area also loses heat quickly because it has large blood and lymph vessels near the surface. To help protect these areas, Dr. Hayward and his researchers developed a posture they call HELP (Heat Escape Lessening Posture). It is like the fetal position: upper arms pressed against the edges of the body's ventral surface — or just to the front of the sides — thighs pressed tightly together, knees drawn up to close off the groin region. Holding still in this position can increase predicted survival time by close to 50 percent, Dr. Hayward said.

But there's a catch: One must wear a life jacket or other flotation device to maintain that position in water. Like the Coast Guard, Dr. Hayward believes there is no excuse for not wearing a flotation jacket around open water. Without one, a person faces a much more immediate danger than hypothermia — death by drowning.

Without a flotation device, a non-swimmer is advised to use one of two techniques to keep from drowning, even though both will speed his cooling rate. The first, treading water, makes the body chill 34 percent faster than holding still does. The other technique, advocated by most life-saving organizations, is called drownproofing and involves floating limply in a semi-vertical position with the face in the water, lungs filled with air and arms extended. Every 10 to 15 seconds the head is raised to expel air and take in another lungful.

"We know it's a wonderful technique in warm water," Dr. Hayward said. "It can keep a non-swimmer from drowning for hours. Unhappily, we found that in cold water it causes the fastest cooling rate we had ever measured." Because the head is a major heat-loss area, keeping it submerged speeds the body's cooling rate by 82 percent in 50-degree water.

The doctor and his University of Victoria team have also investigated the effect of clothing and flotation devices on survival time. They found heavy clothing a measurable help in delaying hypothermia and recommend that people in cold water stay clothed. Kapok life jackets and loose-fitting foam vests do not retain heat, whereas tight-fitting foam vests and flotation jackets with foam insulation can extend predicted survival time by 50 to 75 percent.

After their tests, the team designed and patented the UVic Thermofloat Jacket, a device that converts to a short wetsuit with hood to protect all the major heat-loss areas. These jackets, Dr. Hayward says, can more than double survival time, although they are not as effective as the cumbersome full-body suits, designed primarily for military and commercial use, that can keep a person in cold water alive 3 to 10 times longer than a person with no protection.

Finally, there are post-rescue problems. In many cases, people who are rescued from the cold coastal waters die of "afterdrop" within 24 hours of being rewarmed. "What we found was that you can actually make people colder if you don't rewarm them correctly," says Commander Steinman of the Coast Guard.

Treating a rescued person is tricky; as soon as skin temperature is restored to normal, the patient feels fine. The message, "I am cold" doesn't go to the brain unless the skin is chilled. Nevertheless, core temperature continues to drop, even out of water, as increased circulation drives cold, stagnant blood from the peripheral tissues to the inner body. If the body is rewarmed from the outside in, rather than from the inside out, it can cause the fatal afterdrop.

After hearing of Dr. Hayward's work, Commander Steinman flew to British Columbia to discuss Coast Guard post-rescue procedures on boats or helicopters where medical facilities are limited. "For starters," Commander Steinman said, "we needed to know how to keep the core temperature from declining by itself while we were getting the victim to a hospital." The following year, the U.S. Coast Guard and the University of Victoria collaborated on a study of rewarming methods.

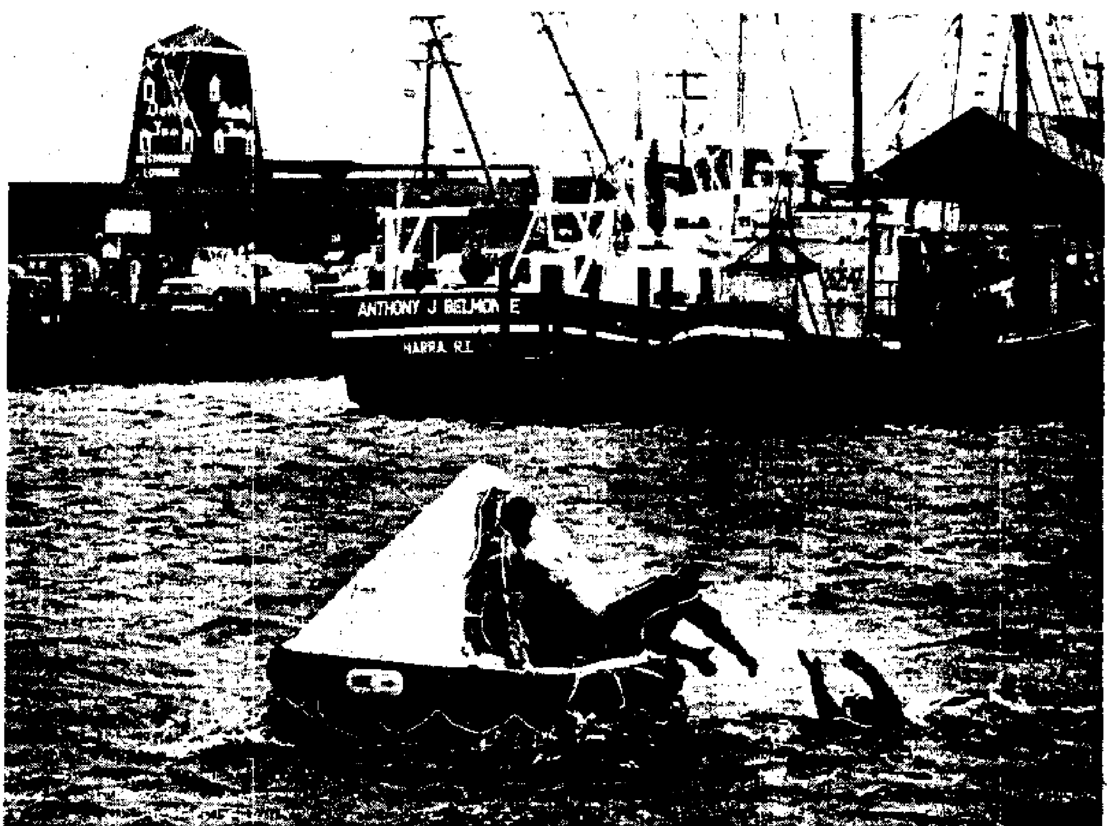
They compared five techniques for warming the body from the inside out and found that inhalation of moist, warm air caused the least amount of afterdrop in mild hypothermia, a method now routinely used in hospitals. As an aid to emergency treatment, Dr. Hayward has also designed a portable oxygen unit for use in the field, and this is currently being tested.

Lacking warmed oxygen, the doctors advise using any gentle method — warm, moist cloths or blankets, hot drinks (excluding alcohol), hot-water bottles, hot sitz baths, even the rescuer's own body heat — that will warm the trunk and inner organs in preference to the extremities.

As research continues, it is clear that conferences like the University of Rhode Island workshop fill real needs. "In the 10 years I've been here, I have never seen people so eager for information as this group was," said Neil Ross, specialist for marine recreation in the University's Marine Advisory Service. Since the conference, he has learned that the water-safety professionals and rescue workers who participated have spread the word in their home states through the Red Cross, schools, Y.M.C.A.'s, fire departments, commercial fishermen's organizations and the boating industry. For its part, the University of Rhode Island will host a second training session next January in conjunction with an international conference on hypothermia research.

"So much knowledge has been gained about cold-water survival in the past five years," says Dr. Hayward, "that naturally we are anxious to see it being used by the public." ■

The New York Times Magazine/June 10, 1979



—Journal-Bulletin Photos by RICHARD BENJAMIN

RAFT OF LIFE: Two men urge a third to the raft during cold water survival demonstration in Galilee. All are wearing survival suits. Below, a drenched dummy lies at poolside while class members gather in the background for more instruction.

10 swim at Pt. Judith and emerge warm, dry

NARRAGANSETT — Ten volunteers dressed in bright red one-piece rubberized suits swam around in the 35-degree water of the Point Judith Harbor of Refuge yesterday.

Four of them spent half an hour demonstrating dye markers, smoke bombs and red flares.

When they emerged from the water, however, they were as dry as when they started and far warmer than the spectators who braved the chill wind to watch the demonstration.

The swimmers were wearing suits equipped with hoods that fitted tightly around their heads. The suits contained foam flotation material to keep the wearers afloat. When fully zipped up, the suits were watertight and insulated their wearers against the cold water.

They were part of the Northeast Regional Conference on cold water survival and hypothermia, which concluded yesterday.

* * *

FISHERMEN, police and firemen were among approximately 180 men and women who underwent the cold-water survival training and received Rhode Island Boating Council certificates as either instructor-trainers or instructors in cold-water survival techniques.

Seventy people selected to be instructor-trainers took 7½ hours of training Saturday at URI's Tootell Physical Education Center. Yesterday those same people helped train the others in a series of 12 half-hour sessions in the Cabana Club area and around the pool at the Dutch Inn, Galilee.

By the time the conference ended they had added a lot of new words to their vocabularies. They learned about hypothermia, the lowering of the core temperature of the body in prolonged exposure to cold air or cold water, and the Mammalian diving reflex, an instinctive reaction in which the body stores blood in the vital organs. It has enabled some people to survive up to 30 minutes under water without permanent brain damage.

They also knew what was meant by H.E.L.P. (heat escape lessening posture) and huddling (another way of lessening heat loss). Most of them already knew about PFDs (personal flotation devices) and CPR (cardio-pulmonary resuscitation).

* * *

IT WILL BE some time before the conference is fully evaluated. But even while it was under way Saturday, four leading members of the Rhode Island Boating Council, which sponsored the conference, and the five leading experts in the world on drowning, cold-water survival and hypothermia treatment, who had lent their expertise to the two-day gathering, had met at the Dutch Inn here and agreed it should be repeated on a larger scale.

"The experts have agreed to return next winter at a date still unspecified for an expanded program which will probably include an international conference on hypothermia," said Neil W. Ross of the University of Rhode Island Marine Advisory Service, who is chairman of the Rhode Island Boating Council.

Ross said there is also a possibility the Rhode Island Council will run additional cold-water survival programs later this winter at the Dutch Inn for special-interest groups.

"We've been asked to try to organize something for commercial fishing groups and perhaps something could be done later for police and firemen," Ross said.

* * *

WHEN THE HORN sounded at 5 yesterday afternoon, ending the six-hour program, the participants were asked to fill out questionnaires, evaluating the speakers and the program and making suggestions for improving it.

The Rhode Island Boating Council had no reason to expect other than a very favorable response.

"People have been asking us 'When are you going to do it again?' " said Ross. "Nobody said: 'Are you going to do it again?' "

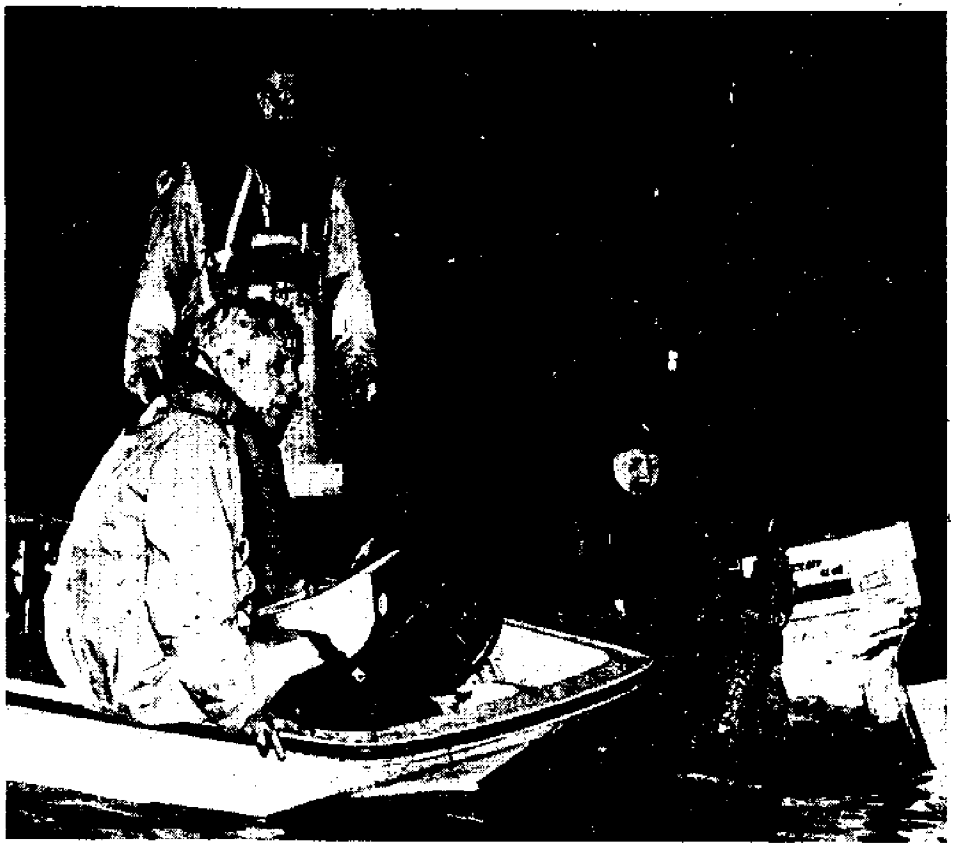
Joining Ross in organizing the conference were Edward Bliven from the Division of Coastal Resources, Rhode Island Department of Environmental Management; Manuel Point Jr. of the Rhode Island Canoeing Association, and Harold Anderson from the Providence Chapter of the American Red Cross. Bliven served as chairman.

The five experts who contributed material and did the initial training were Dr. John Hayward from the Department of Biology at the University of Victoria, British Columbia; Dr. Alan Steinman of Washington, D.C., who holds the rank of full commander in the U.S. Coast Guard; Lt. Cmdr. David Smith from the Boating Safety Division, Second Coast Guard District in St. Louis; Frank Pia of Larchmont, N.Y., instructor-trainer for the Red Cross and head life guard at Orchard Beach, N.Y.; and Dr. Martin J. Nemiroff from the pulmonary division at the University of Michigan Hospital in Ann Arbor, Mich.

Most of the trainees had come from the six New England states.

Members of the Civil Air Patrol, the Air Rescue Service and the Rhode Island Civil Defense Service also attended.

March 10, 1979 Providence Journal, R.I.



RESCUE ATTEMPT: *Art Lussier, seated above, and Bill Clark try to help diver Bill Day spot a man missing and feared drowned after a two-man kayak went over the waterfall at Potter Hill in Hopkinton last night. Rescuers test the current with a cushion, right.*

Man saved, another is missing as kayak tips

By FRITZ KOCH
Journal-Bulletin Staff Writer

HOPKINTON — One man is missing and feared drowned and another was pulled from the fast-moving Pawcatuck River in a daring rescue last night after their two-man kayak went over a four-foot waterfall at Potter Hill and capsized about 5:30 p.m.

Alan N. Brunelle, 21 of 7 Palmer St., Ashaway, a University of Rhode Island student, was rescued. He was taken to Westerly Hospital, where he was treated for exposure and water inhalation.

A 26-year-old Maine man, whose identity was withheld until his relatives are notified, was missing.

The search for the missing man was called off shortly before 9 p.m. because the treacherous current below the falls made the operation "too risky" in darkness, Ashaway Fire Chief Frank Sposato said. It was to resume at 8:30 this morning.

• • •

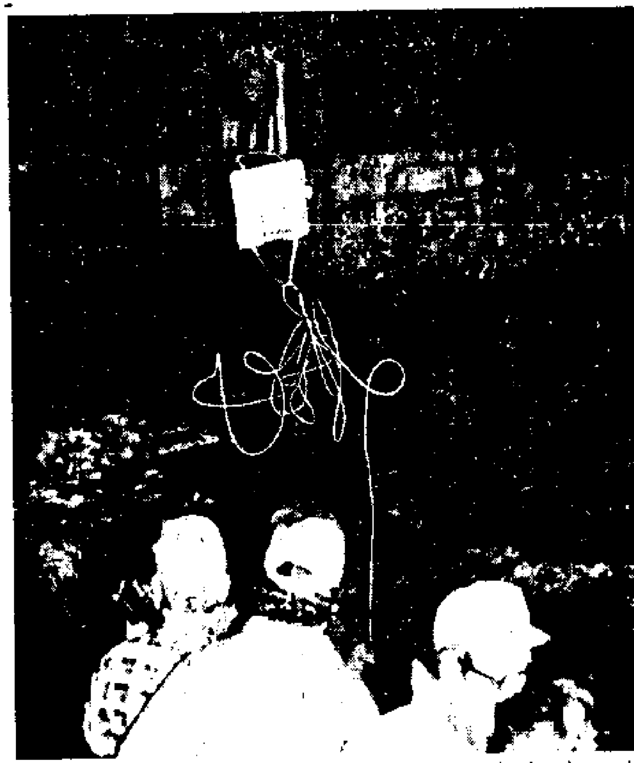
BRUNELLE WAS PULLED from the frigid waters beneath the falls by Earl Clark, a 27-year-old unemployed Vietnam veteran, who lives at 3 Laurel St., several hundred yards from the falls. Police said Clark "risked his own life" to save Brunelle.

Clark was working on his motorcycle in the garage behind his home when his wife ran out and told him someone was in the river, yelling for help. Fully clothed, Clark dived into the river and swam 40 feet to Brunelle, who was bobbing up and down. "I didn't even get my wallet out of my pocket," Clark said last night.

"He looked at me and his eyes rolled back," Clark said, in describing how he grasped Brunelle in the icy waters and headed back to shore. The river at that point is eight feet deep and about 80 feet wide.

While Clark pulled Brunelle to safety, Roger Parteio, an Ashaway firefighter who lives nearby and had been alerted to the danger by a newspaper boy, called a rescue vehicle.

"I didn't see hide nor hair of his partner," Clark said.



The missing man also was thrown from the kayak. A Westerly firefighter said Brunelle told him that the last time he saw his companion was when his friend struggled to reach a life jacket that floated nearby. Clark said Brunelle was wearing a life jacket.

"The river is very bad at that point," Sposato said. He said the recent heavy rains have made it deeper, swifter-moving and more dangerous. "Even the grappling hooks were floating," he said. He estimated the speed of the current at more than 10 miles an hour. "It's boiling," he said. "It looked like a little Niagara Falls."

• • •

POLICE SAID the two men apparently were aware that the falls were ahead of them as they headed downstream from Bradford's landing, where they entered the river, but thought that they could safely cross the falls. There are no markers on the river to indicate to boaters that the falls are ahead, Sposato said.

The two men had gone about three miles when their kayak capsized. Police said Brunelle indicated that he and his companion had limited experience in the kayak, which was made of fiberglass.

The falls are at the site of the old Potter Hill Mill, which was destroyed by fire two years ago. They are visible from River Street and are near the Westerly town line.

Clark, who was contacted at the Shamrock Cafe in Westerly last night after the rescue, said he did not think about much before he dived into the icy waters. "Three years in the Army and a couple of years in the Boy Scouts. it's a natural instinct to save your fellow man," he said.

SUMMARY OF COLD WATER SURVIVAL COURSES

Robert Stuart Pratt
Marine Biologist
Maine Marine Advisory Service
Sea Grant

The Maine Marine Advisory Service developed and carried out courses in cold water survival during the winter and spring of 1979. Twenty-five lectures were offered to over 1700 people from January 12 to April 25. The course included a one and one-half hour lecture on the survival situations most often found in Maine's cold water. Information on various products, techniques, and survival methods was included. A slide show produced by the University of California on hypothermia was used in conjunction with a film on the survival suits. An additional two hours were used at poolside and/or dockside to demonstrate the survival suits, rafts, and other flotation devices. The students were encouraged to don the suits and practice floating as well as entering the raft.

A survival race was developed called "The Great Survival Gear Race" to promote survival training. Before an audience of over two hundred and fifty people, six teams of six competed for donated prizes at the Fourth Maine Fishermen's Forum. The race was such a success that it will become an annual event with out-of-state teams competing.

A preliminary course has been developed and tested for EMTs, ambulance attendants, and SCUBA divers. Lectures appeared to generate positive feedback. Therefore, the program will be improved and presented.

A test of Project ALIVE was conducted with Central Maine Power's Environmental teams in Belfast. Man overboard drills were conducted, survival suits were donned and tested, and an inspection of gear was carried out. CMP felt that the knowledge and experience was a valuable lesson for their crews.

The program conducted at Brunswick Naval Air Station had a dramatic impact. Safety Officer, Lt. Cmdr. James Sinz, is pushing to cancel orders for 5,000 QD-1 suits and replacing them with the less expensive, faster donning, and warmer survival suits.

Benefits from the Program

1. Maine Maritime Academy plans to include a float coat as part of their uniform.
2. At the Brunswick Naval Air Station there are plans to replace their QD-1 with survival suits.
3. Two survival dealerships were set up.
4. One raft and boat dealership was set up.

Equipment estimated to have been sold or to be purchased in the future as a result of the program:

Suits	5,025
EPIRBS	3
Rafts	?
Boats	4
Jackets	800

The Cold Water Survival Course was taught by a Marine Biologist for Maine's Sea Grant Maine Marine Advisory Service (MAS) and was probably the most successful project of this type ever offered to New England watermen. The program received praise from many fishermen, sailors, and educators.

Maine Commercial Fisheries
September 1979

Survival Training Saves Sidelinger

Larry Sidelinger, of Nobleboro, plans to write a letter this week to Bob Pratt, who conducted a demonstration and lecture on cold water survival techniques a few months ago in Boothbay. The young lobster fisherman wants to thank Pratt for the information he gave him that night. It saved his life.

Early on the morning of July 16, Larry Sidelinger headed his 21-foot fiberglass boat, *Mary S.*, downriver from Damariscotta. Like every morning that week, the fog was thick, and Larry concentrated on searching for the first buoy he would pick up near Glidden Ledges. He wasn't listening to the engine, and didn't notice anything amiss until the boat suddenly slowed down. Then he looked back and saw flames leaping out from the battery box in the stern.

"It looked like the hydraulic hoses and battery were afire." he recalls.

Larry's first thought was to get the three six-gallon cans of gasoline stored in in a small cockpit on the stern deck, out of the way. "For some reason, the cover on one can was loose," he said, "and the gas slopped out when I grabbed it." The spilled gasoline roared up in flames. "I was leaning over, and my face was protected," he said, "but my boots were on fire."

With the fire spreading rapidly, Larry sprinted for the bow and grabbed a life-ring that was hanging there, but "it caught on something that ripped it out of my hands when I went overboard."

He thought of crawling over the bow and trying to find it, but was afraid the gas cans might explode, if they hadn't already. In the excitement, Larry wasn't sure, but he didn't want to be within range, so he started swimming away from the boat.

Now, two or three hundred yards from shore, in water that was about 55°F, Larry began to think about survival. "The first thing they taught us in that class," he said, "was not to panic." He thinks that was the most important lesson.

"I tried to take off my boots, but they wouldn't come off," he said. Cold water survival teaches that, although swimming and struggling to remove cumbersome clothing in the water do produce some body heat, even more heat is lost to the cold water due to the extra blood circulation to the arms, legs, and skin. Larry decided to forget about the boots, but did manage to get his jacket off easily. Then he assumed the H.E.L.P. (Heat Escape Lessening Posture), holding the inner sides of his arms tight against the sides of his chest, and pulling his knees up to close off the groin region, with his head out of the water. This is almost a fetal position, and a good way to conserve body heat while you get your bearings. After a few minutes, he began to swim for shore, alternately swimming and resting in the H.E.L.P. position.

Larry says he remembers being colder than he has ever been before, and when he felt kelp and seaweed around his feet, he knew he was close to shore, but didn't think he was going to make it.

Larry doesn't remember reaching shore, or running up to the road to hail a passing car. That period "is all a blank."

The motorist, South Bristol's mailman, Brooks McFarland, sent for help, and in a short time, volunteer fireman arrived with the fire truck. They found Larry sitting on the banking with his boots beside him, and suffering from hyperventilation as well as hypothermia (literally, "not enough heat").

Getting a hypothermia victim warmed up again is tricky. Body temperature may already be dangerously low, near the point at which death occurs. It is important to get the trunk warmed up first, without allowing cold, stagnant blood from the arms and legs to return to the core of the body and cool it more. Often, the quickest way may be for the rescuer to remove his own clothing and transfer heat from his body to that of the victim, skin to skin.

Luckily, Larry's rescuers had had hypothermia training. "They got my wet clothes off, and got some hot coffee into me," Larry said. "That's when I start remembering again."

One of the rescuers remembered that Larry's father-in-law lived nearby, and after Larry was on his way to Miles Memorial Hospital, stopped at the house to tell him of the accident. A call to Larry's wife, Mary, sent her flying to meet him at the hospital.

"After a few hours in the hospital," Larry continued, "I was allowed to go home, but it was two or three days before I could go back to work."

There wasn't much left of Larry's boat. Two aquaculturists, cleaning oysters a half-mile up the river, had spotted the burning boat and put the fire out with their pump. The charred hull was later towed to Waldoboro.

Larry hauled his traps by hand from a skiff for a time, then purchased the 27-foot wooden lobsterboat *Moonshine*, from David Dean of South Bristol. One of the first things he plans to put on it is a survival suit, like those that were demonstrated at the same lecture where he learned the cold water survival techniques that saved his life. "This time," he said, "I was in the middle of the river, and was only in the water about twenty or thirty minutes." He looks at his two-and-a-half year old son, Bryan, and at baby Rachel, crawling towards him across the floor. "If you were out in the ocean and had a survival suit, you could last for a couple of days." A.T.L.

Sept 19, 1979

Dear Bob,

I'm sure that by now you've probably read about my boat accident on July 16. I would like to take a minute to express my personal thanks to you for making me aware of your Cold Water Survival demonstration at the Boothbay YMCA last winter.

After I abandoned ship, I remembered one of the most important things that you said - "Don't panic!" I took my time swimming to shore to conserve energy, and I also used the "curled up" position to conserve my body heat when I was resting.

Had it not been for your demonstration, I wouldn't have been aware of these survival tips. In my opinion, it saved my life.

Thanks again, Bob!

Sincerely,
Larry Sidelinger & family

P.S. I also plan to buy one of the Cold Water Survival suits that you demonstrated in the very near future!

JOHNSTON FIRE DEPARTMENT
"WATER & ICE RESCUE"

ATTENTION: Engine 6 with the board, rescue 4 with the board, engine 5 with the boat, respond to OAK SWAMP, at the GATE HOUSE, report of a child thru the ICE.

SERIOUS BUSINESS: MAKE HASTE SLOWLY: THIS IS A TEAM OPERATION:

EQUIPMENT: Board, picks, suit, line reel:

TALK over strategy on way to call, who will carry the board? Who will carry the line reel? Who will suit up for the rescue? The rescuer should dress on the way to the call, when possible, he should not carry the board or the line reel, he should save his strength for the rescue. At water or ice's edge the reel man must snap the line clip to the board. He must carefully pay the line out, keeping it loose and free, and constantly watching that there is line enough to reach the victim. The reel man also must be most attentive to every move the rescuer on the board makes.

THE RESCUER can propell himself with his hands, dog paddle style, if in water or with the picks, if on ice. Now he must approach the victim carefully. If the victim is conscious the rescuer need only help him to the board, if the victim is unconscious the rescuer should position the victim so his head is out of water and that he can keep an open air way. The reel man must now slowly and steadily pull the board back to shore. AFTER the rescuer on the board waves an arm as a signal to be pulled in.

While this is going on the back up board and crew have been in a standby position, ready to assist the first board only if need be. Also on the beach preparation for follow up treatment is being readied, be it for shock, exposure, or CPR.

POINTS TO PONDER

It is extremely important to have all your equipment, otherwise your safety and your success are in jeopardy. The surfboard was designed for a fast entry and exit in a water and ice rescue, it is built rugged but handle it with care. The survival suit will keep you warm, dry, and bouyant. Should the suit tear and fill with water, it will still be bouyant. The suit's bouyancy come's from the material not from trapped air. The suit comes in one size, and in one piece. When the wearer is in the water, the pressure of the water will fit the suit around the wearer. Also there is a life ring that can be installed on the suit, if one cares to have it on it will add more buoyancy, but it must be filled with air. While on the board position yourself to the rear of the board on the way out to the victim, to give the board an up angle on the front to be able to climb onto ice or iceflows. The same for the return trip only position yourself and the victim to the front of the board to give the rear of the board an up angle, to be able to get on top of the ice emergency with one board to be in the standby position and to enter the water or ice only if need be. The followup treatment for the victim is very important. DO NOT lose a victim on the beach after you saved him from his first peril. DO NOT give up easily; keep working on your victim, many people have come around after long period's of time in the water.

"PLEASE BE CAREFUL YOU ARE NOT EASILY REPLACED"

Pvt. Vinny Monti
Johnston, Rhode Island

EMERGENCIES

In time of emergency, a good marine band, VHF-FM two-way radio is worth every penny of investment. (See page 4 for emergency frequency information.) But if you don't own a radio, there are several accepted methods for seeking help such as shooting off emergency flares or blowing rapid blasts of horn or whistle. Another method is to stand in the bow of the boat, stretch your arms out to the sides and raise and lower them as if flapping. (Don't just wave; you may only get a friendly wave in return.)

- *Engine Breakdown* - One of the most common emergencies is engine failure. Most breakdowns result from lack of proper preventive maintenance. Attempt to make repairs yourself or seek assistance from craft around you. After exhausting these possibilities, signal for help.
- *Boat Sinking* - If your boat swamps or springs a leak, in most cases it will still foat, so stay with it. (You should know your boat's flotation capabilities before venturing out; check with the manufacturer or dealer.) First, find out where the water is coming from. Attempt to plug leaks with anything handy—a towel, shirt or cushion—and begin to pump or bail. If this fails, signal for help. Most boats today have built-in flotation so staying with it makes sense. You will be easier to spot by search teams and will be able to keep more of your body out of the cold water.
- *Hypothermia* (exposure) is an ever-present danger on Lake Superior. It is a lowering of the body's core temperature caused by immersion in cold water (less than 70° F) or, out of the water, by a combination of wet, cold and windy weather. If the core temperature drops more than 20° F, death will soon follow.

Except for shallow bays and beaches, the water temperature in the lake seldom reaches 55° F (13° C), even during the hottest summer weather. Should you fall in, even at this temperature, your survival time without a PFD would, on the average, be less than two hours. There are certain steps you can take to increase survival time, however.

1. *Wear* a PFD when you are on the lake. It cannot be overemphasized that wearing a PFD will give you a better chance of survival after an accident. (PFD's are now designed to be practical and stylish, some as fishing vests and full-sleeved coats.) If you do fall in, they will not only float you, but will retain body heat, particularly the vest and full-sleeved models using vinyl foam for flotation.
2. If you do enter the water, try to climb back in or on top of your craft. The more of your body you can get out of the water the better off you are as water takes heat away from the body 25 times faster than air at the same temperature. In addition you will be easier to spot by anyone searching for you.
3. If you can't climb back in and you are wearing a PFD, curl your body by tucking your knees and keeping your arms closer to your sides. This will decrease loss from the three highest heat loss areas of the body, the head, ribcage and groin, and double your survival time.
4. Swimming is generally not recommended unless you are a mile or less from shore and no other help is available. *The average swimmer wearing a PFD is capable of swimming no more than a mile in 50° F water before succumbing to hypothermia.*
5. If you rescue someone who has been in the water for any length of time, here are the important points to remember:
   - Get the victim out of the wind and rain. If the victim is in the water, use care in rescue to avoid being pulled in yourself.
   - Replace wet clothing with dry.
   - If the victim is conscious, give hot, sweet drinks. *Under no circumstances should alcohol be used, since it speeds up the heat loss of the body.*
   - If semi-conscious or worse, try to keep the victim awake. If there is difficulty in breathing, insure an open air passage. Administer mouth-to-mouth resuscitation if breathing stops altogether.
   - Rewarm the victim by the best possible method, utilizing body-to-body contact in a sleeping bag, a heated room or, if possible, use a hot (105°-110° F) bath, leaving the limbs out.
   - Seek immediate medical attention.

Storm - If a storm hits and you are unable to reach shore, some emergency procedures to remember are:

- Put on your PFD.
- Head for the closest shore, if possible.
- The bow of the boat is designed to take waves, so head into them at an angle. Reduce your speed to keep head way and lessen the pounding on the boat.
- Seat all passengers as low and as close to the centerline of the boat as possible.
- Keep the boat free from water by bailing or using a bilge pump.
- If your motor fails, trail a sea anchor on a line from the bow to keep it headed into the waves. A bucket or a shirt with neck and sleeves knotted together will do in an emergency.

Rescue - Use simple rescue techniques to avoid endangering yourself. Often a rope, PFD, oar or the boat itself (be careful of the propeller) can be used to easily rescue someone who has fallen overboard. *Only as a last resort should you enter the water to retrieve a victim* and then only with the aid of a PFD.

Fire - First put on your PFD's if you don't have them on already. Keep the fire downwind. If the fire is aft (to the rear), head the boat into the wind. If the fire is forward, put the stern or back of the boat into the wind. This keeps the fire from spreading. Act promptly to extinguish the flames. Aim the extinguisher at the base of the fire, while sweeping back and forth.

Float Plan - This plan for boaters is similar to the flight plan filed by airplane pilots. It need not be formal or lengthy, but should contain such items as name, boat number, whether you have a radio on board, where you're going and when you'll return. It is designed to help the Coast Guard o other search-and-rescue units locate you if you're overdue. Leave the plan with the marina operator, a relative or friend and tell them who to call if and when you are either overdue or an emergency arises.

Published as an information service of the Minnesota Sea Grant Extension Program, University of Minnesota, Duluth

LIVING ABOARD

Coping with Cold

Some chilling facts about off-season boating

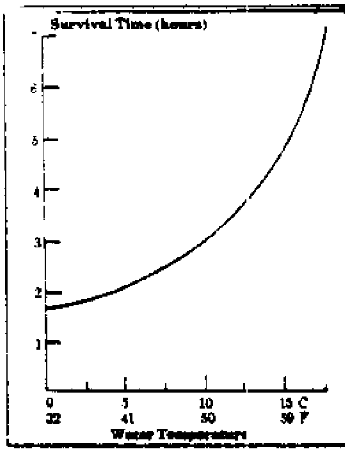
by Bob Armstrong

"Local men missing and presumed drowned"—a too sad, too frequent headline this time of year in northern areas. In spite of diminished boating activity in the off-season, Coast Guard figures show that nearly half of all boating fatalities occur in the colder months between September and May.

Why? The answer is as easy as falling off a boat. This common accident, which can be merely uncomfortable and embarrassing in warm water, takes on a whole new aspect when the water turns cold.

Actually, cold water presents a "good news-bad news" situation. First, the bad news. In addition to the "wet" drownings in which water is inhaled into the lungs, and "dry" drownings where the victim has little or no water in the lungs but suffocates due to blockage of the breathing passage, cold water can kill in two other ways: by shock-induced heart attack, and by hypothermia, or reduction of the body's core temperature. This process starts immediately on entering cold water as the skin and extremities become cooled very rapidly, but it takes 10 to 15 minutes before the internal organs begin to cool. Intense shivering occurs in an attempt to counteract the

Assuming the H.E.L.P. (Heat Escape Lessening Posture) will increase predicted survival time by nearly 50 percent.



Situation	Survival Time (hours)
no flotation	
drownproofing	1.5
treading water	2.0
with flotation	
swimming	2.0
holding still	2.7
H.E.L.P.	4.0
huddling	4.0

Survival time depends largely on two factors: the temperature of the water and the behavior of the victim.

The graph shows predicted survival time for an average adult male in water of different temperatures. The figures are based on holding still in ocean water, wearing a standard PFD. Survival time is increased by extra body fat, decreased by smaller body size. Because of this, women will have a slightly shorter survival time, and children even less.

The table shows the effects of varied behavior on the survival of the same theoretical person in 50° F (10° C) water.

layers. A lightweight shirt and a lightweight sweater are better than one heavy shirt or sweater. Because of the comfort and thermal insulation it provides in addition to buoyancy, a float coat is the ideal outer garment for cold weather boating. Wearing both a float coat and a PFD greatly increases your

large heat loss, unconsciousness begins when the deep body temperature falls to 89.6°F (32°C), and heart failure usually results when the body temperature falls below 86°F (30°C).

Statistics show that two-thirds of all drowning victims cannot swim. According to the American Red Cross, victims usually die 10 feet or less from safety, and Coast Guard studies indicate that less than 7 percent of the people who fell from boats were wearing Personal Flotation Devices (PFDs). Further studies have indicated that actions taken within the first 10 seconds of entry into the water usually determine survival or death. This grim point actually brings us to the good news. You can survive if you are prepared.

Much of what we know about cold water survival comes from research conducted by Dr. John Hayward and his associates at the University of British Columbia. Among the facts revealed by their studies, the most important to those of us on boats relate directly to the use of PFDs.

Researchers found that the more energy you expend, the more rapidly your core temperature drops. For example, a person treading water has a cooling rate 34 percent faster than a person holding still in a life jacket. The "drownproofing" technique of filling the lungs with air and floating face down, lifting the head to breathe every 10 seconds, is useful only in warm water. This activity results in a cooling rate 82 percent faster than holding still in a life jacket and, in studies so far, appears to be the fastest way to die from hypothermia.

In view of these facts, PFDs should be not merely available, but *worn* when boating in cold weather any time you are outside the security of a cabin. If you need further incentive, realise that even trained swimmers find it impossible to don PFDs in the water in 10 seconds.

Another factor in cold water survival is dressing warmly, preferably in

chances of survival.

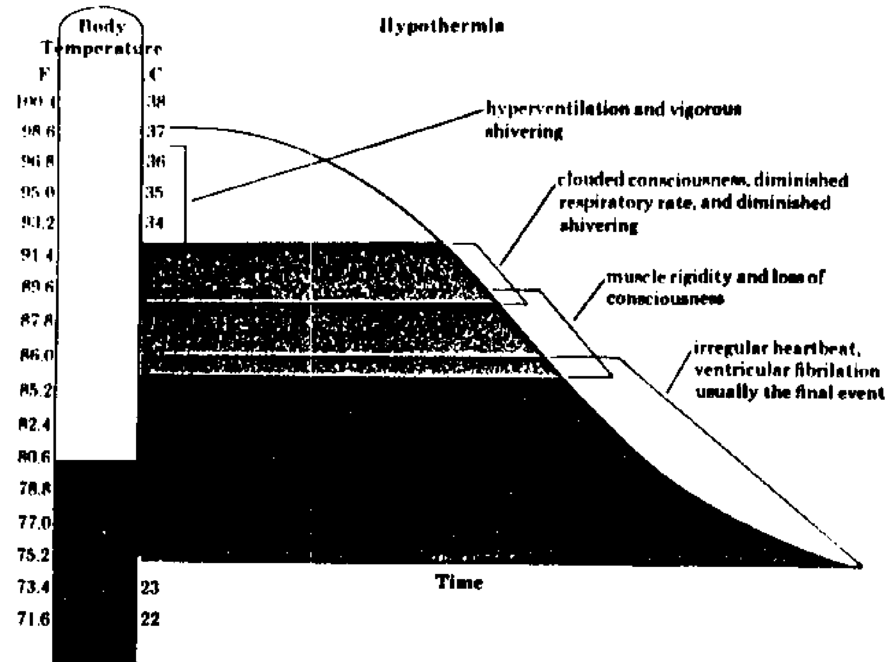
When you fall in

If you do end up in the water, think survival. Keep movement to a minimum and do everything slowly. This will reduce heat loss and aid in the retention of the air trapped inside your clothing, which provides both flotation and insulation.

Resist the urge to warm your hands and feet which will hurt and become numb. By stimulating your extremities, they will feel better as warm blood from your body's core comes to the surface, but this will ultimately mean quicker heat loss, as cold blood returns to the core.

Don't swim unless you're very close to your boat, the shore, or something to cling to. Although the body produces almost three times as much heat when swimming as when holding still, this extra heat is quickly lost because of increased circulation to the arms, legs and skin. Tests have shown that in 50°F (10°C) water, the average person can swim only a little over eight-tenths of a mile before being incapacitated by hypothermia.

Infrared photographs show that heat loss is greatest at the head, neck, sides of the chest and the groin. H.E.L.P. (Heat Escape Lessening Posture) is one technique that delays



Hypotherma is subnormal temperature within the inner body. When the core temperature drops below 86° F (30° C), heart failure is the usual cause of death. However, in cold water, a person may drown because he loses the use of his arms and legs and his consciousness becomes clouded.

body cooling. Hold your arms tightly against your sides, press your thighs together and raise them. This position will increase survival time by nearly 50 percent. If there are others in the water with you, huddle side by side in a circle to help retain body heat. If you can get out of the water, even partially, do so. You may feel colder, but heat loss is actually 30 times faster in water than air, so the less of you in the water, the longer your survival time.

Hyperventilation (over breathing), a common reaction to a sudden plunge in cold water, can lead to uncontrolled inhalation of water or, if prolonged, can lead to unconsciousness and subsequent drowning. Panic magnifies the problem. If you remain calm, steady your breathing, and methodically concentrate on your survival plan, you stand a much better chance of getting out of the water alive.

However, getting out alive is only the beginning. A survivor in a critical hypothermia condition can still suffer a fatal loss of body temperature either from physical exertion or delay in restoring body heat. For this reason, the rescue should be handled to minimize movement and exertion by the victim. Sometimes a suitably clothed rescuer can enter the water to help the survivor get back aboard.

Immediate rewarming is most important. Remove the victim's clothing (as gently as possible to minimize body movement) and apply hot, wet towels to the head, neck, sides and groin. If hot water is not available, a hypothermia victim may be rewarmed by direct body to body contact. The rescuer should remove his clothing also, to provide the greatest heat transfer, then both rescuer and victim should be wrapped in blankets or a sleeping bag to conserve the rescuer's body heat. People who have been hypothermic for long periods may suffer dangerously lowered blood pressure during rewarming, consequently the victim should be kept lying down with the legs slightly elevated and the head slightly lowered.

Research at the University of Michigan Medical Center indicates that, in some cases, people thought dead from drowning, aren't! Dr. Martin Nemiroff, a lung specialist who is also a highly qualified scuba diver, has determined that, if resuscitation is started immediately, people who "drown" in cold water have a chance of survival.

Although most first aid and rescue manuals state that after four to six minutes of submersion it is too late to save a victim, Dr. Nemiroff's studies indicate that this is not necessarily so, and he suggests trying resuscitory efforts on victims who have been submerged for up to an hour. In one case, a victim was under for 38 minutes and survived with no brain damage. In fact, out of 15 case studies of submersion in cold water for more than four minutes, 11 of the victims recovered fully, 2 died later of lung infections, and 2 suffered brain damage because of delayed or mishandled resuscitation.

According to Nemiroff, survival is a result of an automatic response known as the "mammalian diving reflex," cold water, and the rapid and determined action of the rescuers. The reflex slows the heartbeat and constricts the flow of blood to the skin and other orga less likely to suffer from oxygen-loss damage. The remaining oxygen in the blood is directed to the brain and the heart, a process aided by cold water. (Apparently, in water warmer than 70°F, the four- to six-minute limit remains true.) The age of the victim is also a factor; the young have a better chance.

Two very important aspects of the mammalian diving reflex should be noted by rescuers. First, because of the diversion of blood away from the skin and the *extremely* slow heartbeat, a person who has undergone the reflex action has blue skin, dilated pupils, no discernible pulse or heartbeat, and no detectable breathing. In other words, the person appears dead. Second, just as the reflex starts when the victim hits the water, it ceases immediately on coming out. This means that attempts at resuscitation must be started immediately and not stopped until the victim revives or is pronounced dead by a doctor.

As Dr. Nemiroff has said, "If more people will think in terms of trying to revive the victim, rather than in terms of merely recovering the body, it quite probable many more lives will be saved." All victims, even those in near-drowning cases, should be taken to a hospital immediately. A sizable number of near drownings have eventually resulted in fatalities from lung problems which could have been prevented had they been diagnosed and treated promptly.

The key to cold water survival is preparation. Take extra precautions on deck, wear warm clothing and a PFD. If the worst should happen, allow your body to take care of itself. Stay calm, don't expend unnecessary energy, protect your core temperature and, armed with the encouraging knowledge that you can survive under much worse conditions than previously thought possible, don't give up.

CPR Saves Lives

Cardio Pulmonary Resuscitation (CPR), a combination of mouth-to-mouth artificial respiration and external heart massage, has been instrumental in saving countless lives. If you don't already know this technique, the time you spend learning it could be repaid many time over. Contact your local American Red Cross or Heart Association chapters, or your hospital for information on CPR classes in your area.

IF YOU'RE DROWNING...
Here are brand-new ways to save your life!

Startling discoveries by experts indicate about a third of the country's 'drowning' victims didn't drown, and that many such victims declared dead initially are not!

by Richard F. Dempewolff

Hunters and fishermen falling overboard from boats are prime hypothermia victims. Demonstration (right) shows how waders will float a fisherman who lies still.

Near Jackson, Mich., last winter, an 18-year-old college student driving alone "lost it," went sideways off the road and plunged through the ice of a deep pond. The rolling car eliminated any hope that air might be trapped in the passenger compartment. The youth struggled, took on water and lost consciousness.

Luckily a following driver spotted the accident and alerted the authorities. It was 38 minutes later, however, before rescuers pulled the victim from the water. There was no apparent pulse; no signs of life. He was declared "dead at the scene."

While the body was being loaded into the ambulance, however, the "dead" man gasped. Startled rescuers immediately began revival efforts. At the University of Michigan Hospital in Ann Arbor, Dr. Martin J. Nemiroff and a team of colleagues worked over the boy for two hours. After 13 more hours of respiratory support, the student "woke up." He instantly recognized his mother, who was at his bedside.

Brain-damage protection

Attendant doctors, who had expected brain damage in anyone deprived of oxygen for more than four minutes, were even more surprised when the same lad picked up his college career and completed it with A grades.

The apparently "unusual" case, it

turns out, isn't so unusual at all. Today, after several years of scientific investigation prompted and encouraged by the U.S. Coast Guard and the Michigan Sea Grant Program, investigators know that sudden contact of the head and face with "cold" water (anything below 70° F. is classified as "cold" by the Coast Guard) may touch off a primitive response in humans known as the "mammalian diving reflex."

The frigid water triggers complex physiological responses that shut down the blood circulation to most parts of the body except heart, lungs and brain. Though the blood contains only a limited amount of oxygen, it can be enough, investigators have learned, to sustain life and prevent damage to brain tissue for considerable periods of time, once the body's internal temperature has dropped. A cooled-down brain needs less oxygen than one at normal temperature.

Even whales do it

The latter phenomenon has long been known to researchers as the one that permits deep-diving mammals like whales, porpoises and seals to remain active at frigid depths for long periods.

In humans, unhappily, the phenomenon is not quite that convenient—despite the unique life-extending time it may provide in rare cases.

Hypothermia a threat

"Hypothermia," the medical term for dropping the body's internal temperature below its normal 98.6° F., can produce a number of disastrous results. While it may take 10 to 15 minutes before the "core" temperature starts to drop, surface

HELP position can extend survival time.

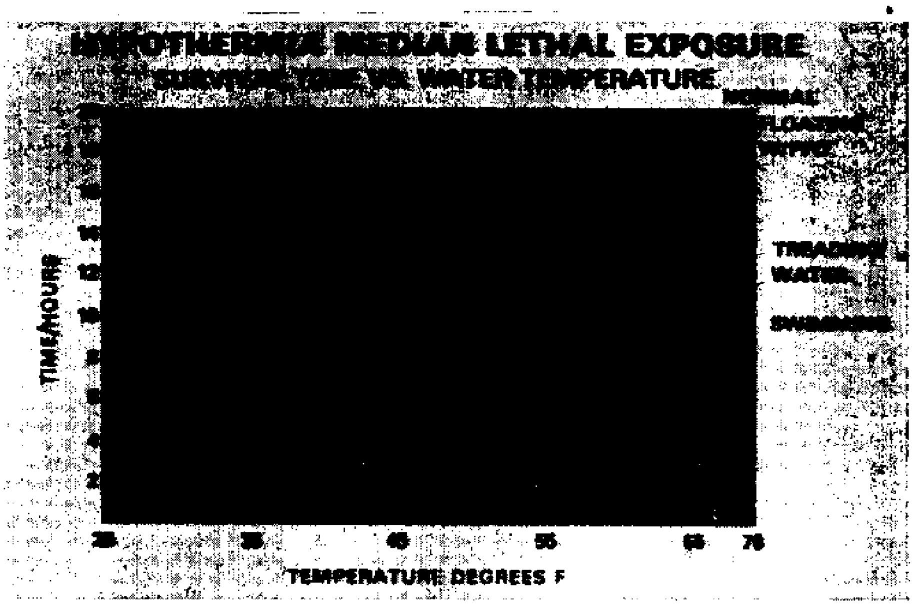
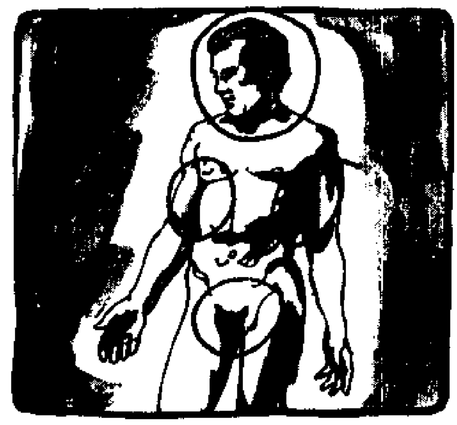


Chart indicates survival time lost in cold water through swimming and other exertion.



Marked areas lose body heat to cold water.

Don't gun it while standing near transom.

Improperly worn life vests lift out of water, wedge noses, lose buoyancy value.

Foam belt pad protects thorax from cold, keeps head high, is worn under clothing.

New hunting jacket PFD insulates body, floats. Hood warms the vulnerable head.

Ski belt pads are not approved as PFDs since they provide too little buoyancy.

tissues cool quickly. A victim may experience labored breathing and stiffness of limbs and hands.

As core temperature drops to 95° there will be violent shivering; at 90° to 95°, mental facilities cloud; at 86° to 90° there's muscular rigidity and loss of consciousness. Below 86° comes diminished respiration and possible heart failure. Below 80°, respiration becomes almost undetectable and death is imminent.

Investigators now believe that something like a third of all the boating drownings reported in one recent year according to best available estimates, probably were not drownings at all but deaths due to hypothermia. Even more tragic, they suspect that in some 20 to 30 percent of these cases, the victim probably was not dead when found, even though there was no discernible pulse, no apparent breathing, eyes were dilated, color was bluish and rigidity had set in—all usual signs of death in familiar warm-water drownings.

Threat to hunters

For the past few years, Lt. Cmdr. David S. Smith, state liaison officer for the U.S. Coast Guard's Second District headquarters in St. Louis, has been traveling the country spreading a new gospel about these discoveries and what people can and should do about them. Recently, he pointed out to *Popular Mechanics* that the primary cause of deaths in autumn hunting accidents is not gunshot wounds, but "drowning," and that many of those so-called drownings are death from hypothermia.

"Some victims don't even have water in their lungs," he reveals. "We lose all kinds of them every year. They make a blind out of a 14-foot boat, stand up to shoot, lose their balance and go over the side. Water in many lakes seldom gets above 60°, even in summer. During spring and fall floods it may get down to 40°. "Worse, those guys usually are hypothermic to start with from sitting there on a cold morning waiting for the ducks. On top of it, they've been drinking to keep warm. The birds come over, the nimrods stand up, stiff and wobbly, fire, and over they go. The cold water hits them and that's it."

Another favorite gaffe, Smith points out, is to reach over with one hand, while standing, goose the outboard throttle, and get pitched over the transom when the boat surges ahead.

Actually, it isn't even necessary to be *in* the water to become lethally hypothermic. "Just last spring," Dave Smith recalls, "we had a young canoeing ace who spilled on a practice run. He was wearing a T-shirt and jeans, and was in the water 10 minutes before we fished him out and put him back in the canoe. He paddled a bit, then he passed out and fell backward. On the beach we checked his pulse and finally picked up a heartbeat—once every eight seconds. We rushed him to the hospital where they treated him for hypothermia and brought him around."

How do you protect yourself in

(Please turn to page 130)

What about 'drownproofing'?

The principles of a procedure known as drownproofing undoubtedly have saved many lives in shallow, sun-warmed lakes and pools where water temperature climbs above 72° F. in summertime. The technique involves floating almost motionlessly for long periods, relying on the natural buoyancy of the body and its tendency to hang in a semi-vertical position in water, head just breaking the surface. Potential drowning victims tend to thrash around in futile efforts to "climb on top" of the water, but the drownproofing concept teaches them to stay alive through maximum conservation of energy.

Instruction in the technique usually begins at poolside, practicing the correct position—head forward, arms down, legs together. With a friend to help at the pool's shallow end (top), the student kneels on the bottom and tilts head back to bring nose and mouth above surface to inhale fresh air, then tilts head forward to exhale. Final step (center) finds student hanging suspended (arms and legs positioned as in the bottom photo) in deep water by herself—nose and mouth above the surface where they can take air as needed—without need for exertion. At that point, the student has been "drownproofed."

In water below 72° F., however, forget drownproofing, says the U.S. Coast Guard—unless you're caught with only bathing attire and no flotation gear. In cold water, the greatest body heat loss is from the head and neck. Since drownproofing requires immersion of those areas, the onset of hypothermia, followed by death, can be brought about with distressing swiftness.

If you are unfortunate enough to go overboard without attire containing some insulative or buoyant potential, then drownproofing, treading water or swimming may be your only chance.

cold water? For boatmen, the Coast Guard emphasizes "personal flotation devices" (now the preferred term for lifejacket). "And you don't just carry them along," says Dave Smith. "You *wear* them." In tests, Smith has found that even experts sometimes take 10 minutes trying to climb into a lifejacket in the water.

The commander and his crew have been running tests on a new family of PFDs, scientifically designed for flotation and warmth in cold water. "The medical people," he says, "have found several body areas extremely vulnerable to the cold—head, sides of thorax and the groin (diagram, page 77).

Insulation vital

One new PFD is an insulated, hooded hunting jacket with built-in flotation. A strap goes around the crotch so it can't ride up. Other new devices are foam plastic pads laced in place beneath outer garments. Both types will keep a man's head well above water; the hooded jacket protects it from weather.

Though not as insulative, approved life vests are even a help in an emergency. "Unfortunately," Smith observes, "most people don't know how to put them on properly. In tests, even Coast Guard personnel didn't know kids' from adults' sizes, and one Academy instructor tried to put on an approved vest inside out."

Actually, ordinary woolen clothing will provide flotation if the person in the water doesn't panic and force the air from the fibers, Smith says. And despite what you may have heard, a fisherman's chest waders will pop his feet up and float him if he doesn't thrash.

Cold water dos and don'ts

DO:

1. **Wear a float coat,** a PFD or several layers of clothing when you're hunting or fishing in a boat. When the water temperature is 50° F., a clothed person can survive an average of three hours in a PFD.
2. **Try to keep lungs filled with air** to maintain buoyancy.
3. **Use minimum movement** to prevent the escape of trapped air in your clothing. An average person who is treading water or swimming in a PFD will lose body heat about 35 percent faster than he would when holding still.
4. **Take advantage of floating objects,** such as boats, paddles and so forth for added buoyancy.
5. **Maintain HELP (Heat Escape Lessening Posture**—see diagram on page 77) until help arrives. If two or more people are in the water, huddle.

DO NOT:

1. **Panic.** Most victims are conscious when they enter the water; most drownings happen only 10 feet away from safety; action taken in the first 10 seconds can mean survival or death.
2. **Struggle.** You'll squeeze out air trapped in your clothing. Ingesting of cold water may constrict the breathing passages and induce "dry drowning."
3. **Swim for land that's over a mile away.**
4. **Remove clothing.**
5. **Use so-called "drownproofing" techniques** in water that's colder than 72° F.

FURTHER INFORMATION

On hypothermia: Dr. John Hayward, Dept. of Biology, University of British Columbia, Victoria, B.C.
On resuscitation in hypothermia: Dr. Martin J. Nemiroff, Pulmonary Div., University of Michigan Hospital, Ann Arbor, Mich. 48104.
Slide lectures: Second Coast Guard District, 1430 Olive, St. Louis, Mo. 63103, attention of Lt. Cmdr. D.S. Smith.

HYPOTHERMIA BY EXPOSURE TO COLD

Every person in a canoeing group has responsibilities to himself and to others. However, in outdoor travel away from civilization, a person's first responsibility and obligation is to his body--its warmth, its energy, and its protection.

Strange as it may seem, canoeists can perish in a very short period of time (as little as 6 hours) from the effects of hypothermia (reduction of normal temperature of the vital organs). Hypothermia can be brought about by strenuous muscle activity (which drains energy) in windy, cold environments. It is for this reason that canoeists should have a knowledge of hypothermia.

Characteristics and Effects

Cold kills in two distinct steps:
(1) Exhaustion and exposure to cold
(2) Serious hypothermic effects

The moment your body begins to lose heat faster than it produces it, you are undergoing hypothermia from exposure to cold. In step (1) two things happen: (a) You voluntarily exercise to stay warm and (b) your body makes involuntary adjustments to preserve normal temperature in the vital organs. Either response drains your energy reserves, contributing to exhaustion. The only way to stop the drain is to reduce the degree of exposure to the cold environment.

Step (2), serious hypothermic effects, will result if exposure to cold continues until your energy reserves are exhausted. Once cold reaches the brain, its effects deprive you of judgment and reasoning power. *You will not realize this is happening.* You will lose control of your hands. With this onset of advanced hypothermic symptoms, your internal temperature is sliding downward. Without treatment, this slide leads to stupor, collapse, and, finally, death.

Most outdoorsmen simply cannot believe that air temperatures between 30 and 50 degrees can be dangerous. (Most hypothermia cases develop between these temperatures.) Low air temperatures combined with wind can create a chill factor that is unbearable.

If clothing becomes wet because of perspiration, rain, or mist, the chill factors shown on the chart that follows will have rapid and fatal results.

WIND-CHILL FACTOR (INDEX)

DEGREES FAHRENHEIT DRY-BULB TEMPERATURE	CALM	5*	10	15	20	25	30	35	40
	EQUIVALENT DEGREES								
35	35	33	21	16	12	7	5	3	1
30	30	27	16	11	3	0	−2	−4	−4
25	25	21	9	1	−4	−7	−11	−15	−15
20	20	16	2	−6	−9	−15	−18	−20	−22
15	15	12	−2	−11	−17	−22	−26	−27	−29
10	10	7	−9	−18	−24	−29	−33	−35	−36
5	5	1	−15	−25	−32	−37	−41	−43	−45
0°	0	−6	−22	−33	−40	−45	−49	−52	−54
5	−5	−11	−27	−40	−46	−52	−56	−60	−62
−10	−10	−15	−31	−45	−52	−58	−63	−67	−69
−15	−15	−20	−38	−51	−60	−67	−70	−72	−76
−20	−20	−26	−45	−60	−68	−75	−78	−83	−87
−25	−25	−31	−52	−65	−76	−83	−87	−90	−94
−30	−30	−35	−56	−70	−81	−89	−94	−98	−101

COLD
VERY COLD
BITTER COLD
EXTREME COLD

* MPH

Prevention

Your *first* line of defense against hypothermia is to avoid exposure to cold. Do this by staying dry and avoiding the wind. Wet clothes lose about 90 percent of their insulating value. Wet clothes can extract heat from your body 240 times as fast as dry clothes. Wind drives cold air under and through clothing and it refrigerates wet clothes by evaporating moisture from the surface. Use your clothes properly before a hazard presents itself. Put on rain gear *before* you get wet. Put on wool clothes *before* you start shivering. Wool is warm even when wet.

A great deal of body heat is lost through the head and neck areas. Therefore, it is essential to protect these areas from the cold. A woolen hat or knit cap will help to preserve body heat. Also, when extreme cold is encountered, a woolen scarf around the head and neck will not only retard heat loss but will also trap heat from exhaled air and will prewarm air being inhaled.

If you cannot stay dry and warm under existing conditions, using the clothes you have with you, *terminate* exposure. This is your *second* line of defense. Get out of wind or rain; go ashore and build a fire. Concentrate on making your camp as secure as possible, *regardless* of how temporary. Your canoe, when inverted on land, can provide some shelter. Never ignore shivering. If it is persistent or violent, you are on the verge of hypothermia. Make camp.

Making camp while you still have a reserve of energy will forestall exhaustion. Allow for the fact that exposure to cold greatly reduces your normal endurance.

Recognition and Treatment

It is wise to appoint a person to watch each member of your group for early signs of hypothermia. Make the best-protected member of your party responsible for calling a halt before the least-protected member becomes exhausted or begins to show symptoms of hypothermia.

Your *third* line of defense is the ability to *detect* hypothermia. If your party is exposed to wind, cold, and wet, *think hypothermia.* Watch yourself and others for the following symptoms:

- Uncontrollable shivering
- Vague, slow, slurred speech
- Memory lapses, incoherence
- Immobile, fumbling hands
- Frequent stumbling
- Drowsiness
- Apparent exhaustion; inability to get up after a rest

The *fourth* and last line of defense is the *treatment* of hypothermia. The victim may deny he is in trouble. Believe the symptoms, not the victim. Even mild symptoms demand immediate, drastic treatment. Get the victim out of the cold-producing environment. Strip off *all* his wet clothes and get him into a warm sleeping bag. However, if he is semiconscious or worse, try to keep him awake and give him warm drinks if he is able to swallow. An accepted and proven practice in survival, when the victim's life is in danger, is to have him stripped and put into a sleeping bag with another person (also stripped). If you have a double bag, put the victim between *two* "warmth" donors. Skin-to-skin contact is the most effective treatment.

CAUTION. Do not administer alcoholic beverages to a victim of exposure to cold, exhaustion, or hypothermia. Alcohol seriously hinders the ability of the human body to function properly in regulating the blood flow to conserve body heat in the vital organs (the body core temperature). The result could be a worsened condition of the victim.

A serious phenomenon associated with the rescue and treatment of hypothermia victims is *after-drop*. The extremities of hypothermic victims are frequently at or near the temperature of the surroundings. If the cold, stagnated blood within the extremities is allowed to flow too quickly back into the rest of the body, the result will be a further lowering of the core temperature. This could lower the temperature beyond the critical point and result in the victim's death.

The period immediately after rescue is most crucial, and rescuers must know how to treat hypothermic victims for prevention of after-drop. It is essential to apply warmth to the victim's body while keeping his extremities relatively cool. This warmth can take the form of a warm, sweet, nonalcoholic drink (given only if the victim can swallow), or warmth can be applied by using any of the methods mentioned earlier. Therefore, if a victim's body is warmed first, after-drop can be averted. In any case, watch for any depression of the victim's vital functions and treat him accordingly. All victims of hypothermia should be transported to medical attention as soon as possible.

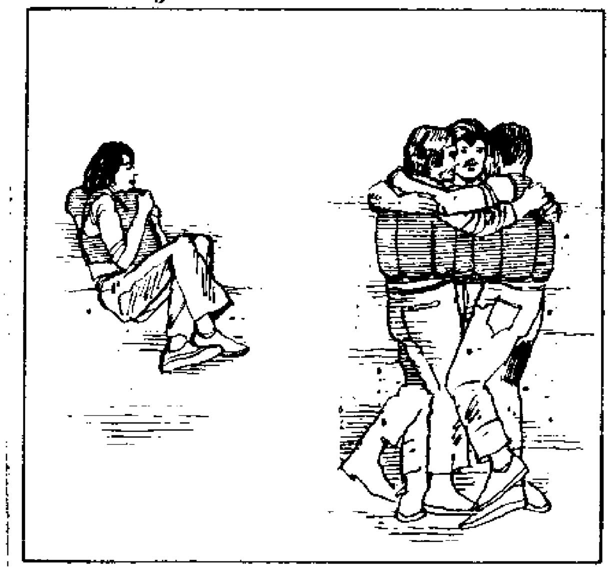
IMMERSION HYPOTHERMIA

With the exception of immersion in waters warmer than from 70° to 75°, the main threat to life during *prolonged* immersion is cold or cold combined with the possibility of drowning. You can greatly reduce the latter threat by putting on a lifejacket.

The rate at which a person is affected by hypothermia varies from individual to individual. It has been shown that thin or slight persons show signs of hypothermia more rapidly than obese or robust persons. The one factor that is foremost is the environment: cold water. Unlike the effects described in the previous section, dealing with exposure to cold, immersion in cold water is an instantaneous reduction of temperature at the surface of the body rather than a gradual reduction.

Immediately after you enter cold water, it will be difficult for you to breathe normally. You should float quietly in a lifejacket or by clinging to a floating object. The discomfort should decrease. If you are not wearing a lifejacket, try to get one and put it on.

If there is no adequate floating object to cling to, inflate your outer jacket by trapping air inside it to provide a means of support with minimum activity. Effective positions to assume (while waiting for rescue) to conserve body heat and energy are shown in the following illustrations.



The above positions do not apply in swift river currents. See "Capsize Rescue" in chapter 7 for correct procedure.

If you fall into cold water, do not attempt to swim unless it is absolutely practical or necessary to do so—for example, if you are being carried by current toward danger, such as a waterfall or a dam, or if the distance to shore or safety is short. Even skilled swimmers are liable to drown suddenly if they attempt to swim any distance in very cold water, and few swimmers can cover as much as 200 yards in water near the freezing point. While floating in a lifejacket and waiting for rescue in cold water, do not exercise in the water in an attempt to keep warm. Exercising will actually have the reverse effect.

REPRINTED FROM

CANOEING

AMERICAN NATIONAL RED CROSS

Body-temperature drop is cited in woman's underwater survival

By GREGG KRUPA
Journal-Bulletin Staff Writer

HOPKINTON — An expert on cold-water survival and a registered nurse said yesterday that a Hopkinton woman who was rescued by Hope Valley firemen and passersby from the icy waters of Surface Brook Saturday may have survived because her body temperature was lowered by almost 20 degrees.

Reports by the state police and firemen indicate that Jo Ann Thibodeau, 22, was underwater in an overturned car for at least 10 to 15 minutes after it crashed through a guardrail on the Canonchet Brook Bridge. Miss Thibodeau was listed in stable and satisfactory condition last night in Westerly Hospital. She was transferred from the intensive care unit at the hospital yesterday.

A state police spokesman had speculated earlier that Miss Thibodeau survived because an air pocket formed in the overturned car, which rested in five feet of water.

But Dr. Martin J. Nemiroff of the pulmonary division at University Hospital in Ann Arbor, Mich., and Andrea Sellins, night nurse supervisor at Westerly Hospital, both said the woman may well have been saved because her body temperature was lowered drastically in the cold water.

Dr. Nemiroff, an expert on survival in frigid conditions, who spoke at the University of Rhode Island last month on the topic, called this ability of the body "hypothermia."

"It's very definitely possible that the young woman was saved because her body was so cold," said Dr. Nemiroff, who is an assistant professor of internal medicine at the University of Michigan. "How long a person can survive without breathing in extremely cold conditions depends on how young the person is.

"I know of a case in Jackson, Mich., when an 18 year-old boy survived for 38 minutes while he was totally submerged," Dr. Nemiroff said.

* * *

MRS. SELLINS said Miss Thibodeau's body temperature was 79 degrees when she arrived at Westerly Hospital. Miss Thibodeau was revived when Hope Valley fireman Robert Stanley Sr. administered mouth-to-mouth resuscitation.

"When people go into very cold water their body temperature drops and they need less oxygen for survival," Mrs. Sellins explained.

Dr. Nemiroff said Miss Thibodeau probably also benefited from a phenomenon called the "mammalian diving reflex." Nemiroff said the reflex is common among all air-breathing aquatic mammals and has been inherited by human beings. The reflex slows down the breathing and diverts oxygen-carrying blood from the extremities to the vital organs, including the brain, helping it survive long periods under water without permanent damage.

Harold Anderson, director of safety services for the Providence chapter of the American Red Cross, said the agency is working with Dr. Nemiroff to help prove his theories, which are currently being given close scrutiny by the medical community.

"We have instructed all of our local chapters to send Dr. Nemiroff all cases of survival under prolonged, extremely cold conditions," said Anderson.

"Many people who would have been given up for dead a few years ago are being saved because of an increased awareness of the possibilities of survival in very cold conditions," he said.

Anderson said that even if there are no visible signs of life, the rescuer should give the victim "the benefit of the doubt. . . no matter how long it appears they have been under water."

Anderson said that proper first aid, after removing the person from the water, is to try to warm the body's core — the torso and hip area — as soon as possible and then get the victim to the hospital.

Four passersby, David Moore, John Bowen, William Ross and Edward Nash, all of Hopkinton, Hope Valley Fire Chief Frederick Stanley and Deputy Chief Thomas Rekowski, along with state policemen from the Hope Valley barracks, were credited with assisting in the rescue.

Providence Journal 2/13/79

Canoe with two brothers overturns; one drowns

By PETER MANCUSI
Journal-Bulletin Staff Writer

WESTPORT, Mass.— An 18-year-old college student drowned yesterday in South Watuppa Pond as he was trying to swim to shore with his brother after their canoe overturned in rough water about 200 feet from shore.

The body of Paul Hallahan, a freshman at Boston State College, was found by rescue units at 6:30 p.m. a few feet from the spot where the canoe overturned. His brother, David, 25, who managed to reach shore, was uninjured.

David, a student at Southeastern Massachusetts University, told police Paul was visiting him for the day. They decided to spend the afternoon on the pond and, shortly after 3 p.m., set out in the 11-foot canoe from the Fall River Rod and Gun Club, not far from David's rented house at 17 Plymouth Blvd. Another brother, John, who also lives at the house, stayed behind.

"The water was pretty choppy and they thought they had better turn around a while after they got out there," said Westport Police Sgt. Alfred Candeias. "When they started heading for the shore, though, they went right over."

The brothers were able to grasp the bottom of the capsized canoe, but after several minutes in the 40-degree water, and with no help in sight, they decided to swim for shore. David, a weak swimmer, started out first. He told police he thought his brother, who was a strong swimmer, was right behind him.

Tired and cold, David turned around for the first time when he reached shore, but there was no sign of Paul. He ran to his house, told his brother to call police, and then passed out from exhaustion, according to Candeias.

Rescue crews using emergency boats from the Fall River and Westport Fire Departments were aided in the search by several of David's neighbors.

Besides his parents, Mrs. and Mrs. David Hallahan of 11 Celia Road, West Roxbury, and brothers David and John, Paul leaves two other brothers and four sisters. His body was taken last night to the Potter Funeral Home in Westport.

he Evening Bulletin, Friday, March 30, 1979

Providence Journal February 1979

Hypothermia poses danger

On the slopes

By MIKE SZOSTAK

Nobody has to tell skiers to bundle up when the temperature plummets to zero or below, but sometimes skiers forget it is just as important to dress warmly when it is in the 20s or 30s.

There are several reasons. Most obvious is that the temperature at the summit of a mountain generally is colder than at the base. On a recent visit to Gunstock, it was about 25 degrees at the bottom, 8 at the top.

Then, there is frostbite. Ears, necks, faces and hands unprotected from cold temperatures and bitter winds can be affected.

Mild cases, which can be spotted as small, white patches, usually on the nose, cheeks or earlobes, can be treated simply by placing a hand over the area to warm it. Never rub the area, especially with snow.

In cases in which more than just the surface tissue is frozen, hospital care should be considered.

The most serious threat cold poses is hypothermia, the body's inability to maintain warmth. Hypothermia can be fatal, but it can be avoided by precautions that are more common-sense than anything else.

* * *

● WEAR A HAT, even if the temperature is above freezing, for it does not have to be Arctic-like for hypothermia to occur. The hat does more than keep hair in place and ears warm. It keeps body heat in the body, where it belongs on a mountain slope. Surprisingly, as much as 75 percent of the body's heat loss can be because of an uncovered head.

● Wear adequate clothing. Jeans, though inexpensive compared to ski wear, provide almost no protection against cold and moisture. Neither do cotton shirts. Wool, though bulky, is warm, even when wet. Nylon and other similar material will help keep out wind.

● Dress in layers. Instead of wearing one heavy sweater beneath your parka, wear a couple of lighter garments. The layers trap body heat and help in the regulation of body temperature. And layers can be shed one at a time. Wet or windy days require layers to compensate for those factors.

* * *

THE SYMPTOMS of hypothermia are easily recognized — uncontrollable shivering, clumsiness, loss of rational judgement. The victim cannot recognize these symptoms in himself, another reason why it is important for skiers not to ski alone and for everyone to be familiar with the symptoms.

Immediate treatment is vital because the victim can become unconscious and die within a few hours. A hypothermia victim should be found shelter, have wet clothing replaced with dry clothing and given warm fluids. Alcohol and cigarettes should be avoided. They hinder the body's fight to regain warmth.

Since this is a vacation week, many skiers will be out there for the first or second time this season, so it is important to be aware of the possibility of hypothermia.

The Evening Bulletin, Monday, December 24, 1979

Boy, 11, survives an icy grave with 'heart that wants to live'

United Press International

CHIPPEWA FALLS, Wis. — At first doctors thought Darven Miller was dead. He had been under the freezing water of Duncan Creek for 30 minutes, his skin had turned a deep blue and his body temperature was 82 degrees.

But the 11-year-old boy with the heart "that wants to live" will be home for Christmas in good physical and mental condition.

Miller broke through the ice of Duncan Creek Dec. 13. The Chippewa Falls Fire Department recovered his body an hour later. He had been under water for 30 minutes.

His lungs full of water, Miller was taken to St. Joseph's Hospital in Chippewa Falls. His pupils were dilated. He was not breathing. His heartbeat was very low and erratic. His body temperature was 87 degrees and fell to 82.

* * *

"WHEN HE came in, he was, by clinical evaluation, dead," Dr. Bruno Rahn said. He said Miller was given shots of adrenalin and an electric shock to revive his heart, but he was very cold. His body remained a deep blue color.

"I told the staff, if there's any chance to do some good, we're going to have to get some heat back into his body," Rahn said.

The staff wrapped the boy's body in a heating wrap that circulated water heated to 105 degrees around his body, gave him more injections and two more jolts of electricity.

The monitor showed an erratic bleep, and one hour and 10 minutes after Miller had been brought to the hospital, his cardiopulmonary system began working.

"First, when he starts to get a heartbeat back, you say, 'Oh my God, he's been dead 20 minutes. What if he survives?'" Rahn said. "You can't play God. Here's a heart that wants to live, so you support it."

Then the boy's pupils responded to light, Rahn said.

* * *

"WE HAD another branch put back on the tree, so you're now supporting something of a nervous system; you're now supporting circulation, too, so again you can't quit," Rahn said.

"We got nothing then except a little bleep as we kept working," he said. "And I think it was the godsend that kept us from facing the ultimate decision: 'Are we saving a vegetable or what are we doing?'"

The boy was reported in stable condition. He has a normal diet and his mental condition was reported good.

His hands remained swollen and unable to grasp objects, but his personal physician, Dr. Romeo Sangalang, predicted the boy would make a full recovery.

Two brothers drown in pond

MIDDLETOWN, Conn. (AP) — An 11-year-old boy who was revived after falling through ice and spending more than an hour at the bottom of a pond died yesterday.

Benjamin Johnstone, who was pulled from a 100-foot wide pond in Durham late Saturday afternoon, died shortly before 1 a.m., authorities said.

His brother, Joel Johnstone, 8, who also fell into the pond, was pronounced dead at Middlesex Memorial Hospital in Middletown about 7 p.m. Saturday after doctors worked three hours attempting to restart his heart.

A third boy who also fell through the ice had managed to pull himself out of the water. He told officials what happened after he was found, wet and dazed, on Main Street in the south-central Connecticut town. Officials estimated the boys fell into the pond about 2:30 p.m.

The nearly freezing temperature of the water in the 100-foot wide pond apparently put the boys in shock and kept the older one alive, said George Planeta, chief of Durham's volunteer fire company.

The boys must have been at the pond bottom for more than an hour, Planeta said, because rescue workers spotted no sign of them for an hour after arriving at the scene.

Providence Journal
January 14 1980

Hunting mishap capsizes canoe; 2 deaths result

PORT ANGELES, Wash. (AP) — Three duck hunters in a canoe all fired at the same time and the recoil capsized the boat, sending two of the men to their deaths, the survivor says.

Richard Leighton said after the accident Saturday that he used duck decoys for flotation on Lake Aldwell, eight miles west of Port Angeles. He said he swam ashore and hiked to a lodge on the lake.

Leighton, 22, is a petty officer at the Coast Guard air station at Port Angeles. He called the air station directly and the first rescue helicopter arrived in eight minutes, said Coast Guard spokesman Lt. Philip Johnson.

The helicopters airlifted the two hunters to a Port Angeles hospital, Johnson said. They died later in the afternoon after emergency treatment for hypothermia — loss of body heat or exposure. Johnson said they had been in the water about an hour.

He identified the dead as Coast Guard Petty Officer Michael D. Bultena, 31, of Sioux Falls, S.D., stationed at the Coast Guard air station in Port Angeles, and Lynn B. Rhodes, 22, of Port Angeles.

Leighton was treated and released from Olympic Memorial Hospital in Port Angeles, a nursing supervisor said Saturday.

The Evening Bulletin, Monday, December 24, 1979

BOSTON SUNDAY GLOBE March 25, 1979

The water was so cold it helped save her life

By Robert Cooke
Globe Staff

Cold, cold icy water, the doctors say, was the important thing in saving Libby's life.

And Libby, 24, now alive, well and smiling, is going home Tuesday from St. Elizabeth's Hospital here in Brighton. She survived, trapped in the back seat of a sunken car in Boston's Charles River, for almost half an hour underwater.

"My friends are treating it as some sort of religious experience," Libby said during an interview yesterday in her hospital room. "But it's too easy to chalk it up to that. There was a lot of work involved by a lot of people."

Libby, known more formally as Elizabeth Margolis, resident of Beacon Hill, a technical editor at the Stone & Webster engineering firm, was riding with Leslie Cook, also 24, when Cook's 1973 Mercury Comet swerved off Memorial drive in Cambridge, hit a tree, then plunged into the Charles River.

A motorist who saw the post-midnight accident alerted Harvard University police, and security officer Peter O'Hare quickly stripped and jumped into the frigid waters to attempt a rescue. On his second dive, O'Hare said, he was finally able to wrench a door open and pull Cook out. A resuscitation attempt began immediately, but it failed.

Some 25 minutes later, when the car was pulled from the river by a wrecker truck, Libby's unconscious form was found in the car too.

"I was on the floor in the back seat, and I had been underwater for 25 minutes," she said.

When Libby was brought in to the emergency room at St. Elizabeth's, said Dr. Richard Herman, "she was essentially without pulses, without respiration, and she was very, very cold, down to 84 degrees.

"Essentially," he explained, "she was in suspended animation. Her heart showed very little electrical activity, almost a flat line on the electrocardiogram."

Herman, a medical resident at St. Elizabeth's working in the intensive care unit, added that "we had to get her warm," so warming fluids were pumped through her body cavities, into her stomach and intestines. By 8 a.m. her temperature was up to 98.

"It was definitely important that she was hypothermic (very cold)," Herman said. "She was so cold that it kept her heart and brain alive."

'My friends are treating it as some sort of religious experience. But it's too easy to chalk it up to that. There was a lot of work involved by a lot of people.'

He added, too, that there's a medical expression: "No one is dead until they're both warm and dead."

Her attending physician, Dr. Kenneth F. MacDonnell, director of the hospital's pulmonary department, and associate professor of medicine at Tufts University, also said it was important for her survival that resuscitation efforts began immediately at the scene of the accident, and continued.

"People should know that if they see someone who's submerged, especially in cold water, it's important that resuscitation be continuous and vigorous. It should not be stopped. If the body temperature is low, then they shouldn't give up on anyone."

Libby's father, Emmanuel Margolis of Westport, Conn., said he was notified of the accident by Dr. Herman "at about 2:15 a.m. He was very sober, and somewhat pessimistic, but not totally without hope but he said he couldn't promise me anything."

Margolis said he called Libby's mother, Edith Woodard in New Haven, Conn., and she headed immediately for Boston.

"At that time," Margolis said, "we had no idea whether we were going up there just to collect the body. It was a long trip up here, but I don't remember it."

Margolis said his daughter "was in a total coma for 1½ to two days. When she started opening her eyes there was a little flicker of recognition. Starting that third day, nice things began to happen and we could begin to hope. Until then, she was just fighting for life, and we assumed there would be permanent damage of some kind."

"I fooled you," Libby replied laughing.

SURVIVOR, Page 39

The water was so cold

★SURVIVOR
Continued from Page 25

She had been listed in critical condition in the intensive care unit for days, and she was on the breathing assist machine for at least 10 days, but now, Libby said, "the only bad part is the fact that Leslie (Cook) is dead. Other than that, everything now is very positive."

Dr. Herman noted that Cook, who was driving, may have suffered numerous injuries in the March 12 accident, in addition to being submerged and drowned.

"We had gone to a country-western music festival in Nashua, N.H., and we were driving back when the accident happened on Memorial drive," she explained. "But I don't know many of the details of the accident."

She said she was in the back seat, probably asleep, because I had to be at work the next day."

Libby added that the Harvard security guard who pulled Cook from the sunken car "came in to see me" a few days ago, and "he's a super guy. He looks like the Angel Gabriel with his white hair."

As it turned out, the doctor who was instrumental in pulling her through, Herman, was already an acquaintance from last summer.

"I didn't recognize her when I was working on her" in the intensive care unit, Herman said. "Her name was Elizabeth, but I knew her as Libby."

Later in the morning, about 10 a.m., a friend called asking Herman for some inside information on her condition.

"I kind of freaked out" when he learned who she was, Herman said. "But I went back in and looked at her and, yep, that's Libby."

SURVIVAL IN WINTER

CAMERON C. BANGS, M.D.

The human body normally functions within a very narrow temperature range of 97° to 99°F (Normal 98.6°). It maintains this temperature range through a very delicate balance of heat production and heat loss. Heat is produced by the metabolism of food which is influenced by metabolic rate and muscular work. Heat loss occurs through a carefully regulated system which includes respiration, circulation and perspiration.

Heat loss from the body is controlled by many environmental factors. These include (1) rate of sweat evaporation influenced by humidity and air movement. (2) Convection or air movement which carried the insulating envelopment of warm air from the body. (3) Radiation which is the direct transfer of heat through the atmosphere and (4) conduction which is the transfer of heat by direct contact or touching.

Under normal circumstances heat is lost from the body at the same rate it is produced and we stay in balance at a normal temperature. When exposed to a cold environment and heat loss is increased the body produces more heat and we again remain in balance. If the exposure is prolonged and severe, the body may be unable to keep up the accelerated production and heat loss will exceed heat production. This causes the body temperature to drop below normal, a condition called *hypothermia.*

Under these circumstances the body does not function normally. If the body temperature drops to very low levels, for example less than 95°F, the mind and muscles function poorly. Soon the heat production decreases and temperature drops at an accelerated rate resulting in death from cardiac stoppage or ventricular fibrillation.

Under extreme situations it is important to conserve every possible calorie of heat. The essence of winter survival is understanding the mechanisms of caloric loss and avoiding them.

Saturday

On Saturday morning November 3, 1973, Scott (28) and Diane (31) McIntire and their 4½ month old daughter Emily left metropolitan Portland, Oregon for a days outing at the Bagby Hot Springs. Before leaving they had called a friend to ask directions, thus notifying someone of their plans.

Into their 1966 Chevy wagon they loaded a wool blanket and a hand made baby blanket, a lunch of 2 pastrami sandwiches and a thermos of hot chocolate. Emily had been breast fed since birth so lunch for her was no logistic problem. As both Scott and Diane worked for an advertising firm, photography was a way of life for them and they therefore included a camera. Thus equipped they drove the 25 miles to Bagby Hot Springs, talking and thinking about the 137° hot natural bath waiting for them.

One of the hazards in the mountainous Northwest is the failure to realize that violent weather conditions can occur without warning within a very small radius of a metropolitan center. Because of high altitude, storms are a year around threat. The basic element of survival is preparation.

The experienced outdoorsman in this area won't drive to the Coliseum without their essentials. Waterproof matches and fire starter, compass, maps, whistle, fueled stove, cooking pot, sleeping bag, flares, flashlight, and insulated waterproof ground cloth. In addition, highly recommended are rain clothes, sun screen and insect repellent, water bottle, pocket knife with can opener, and extra warm clothes. These things make up into a small package and should be left in the car or kept packed and ready to go. There is no substitute for preparation.

Scott, Diane and Emily enjoyed the mile and a half hike into the hot springs under overcast skies. There were patches of snow on the ground, but it wasn't snowing. At the springs they lounged in the ancient hand carved hollow logs filled with 137° natural spring water. As they left the springs to return to

DAVID WEINTRAUB

their car, they noted that the weather had cooled and it was now snowing. By the time they reached the parking lot it was snowing heavily and had begun to pile up. At the parking lot they noticed a large converted self contained bus with a propane heater as well as several other cars and campers. When leaving they saw two sets of tire tracks in the snow, one belonging to the Volkswagon of two reliable appearing people they had met on the trail. They ate their sandwiches and started home.

In some cases "there is safety in numbers." Many unfortunate experiences have occurred because someone got separated from the group. By combining resources and equipment several small ill equipped groups can sometimes become one well equipped group. In time of trouble stay together.

Within short order after starting to drive, they began to have trouble with traction and sliding. Scott was frequently forced to get out and push while Diane drove. Scott recalled that he had had a flat tire a few weeks ago and the old spare was still on the back wheel while a good radial tire lay in the car. Because the old tire did most of the slipping he decided to change it. After going through all this effort, the repaired radial was flat and had to be rechanged. This was very disheartening, in addition to getting him wet and tired. After changing the tires, they let some air out of the tires, to increase traction, used the wool blanket for further traction and with Scott pushing. Within one half hour, they skidded into the right hand ditch and were permanently stuck. At this point Scott was dressed in wet levies, waffle stompers with two pair of cotton socks, a Pendleton wool shirt, and a zipper light wool coat. He had single thickness leather gloves and a wool knitted stocking cap. Diane's feet were dressed like her husbands, but she had on woolen pants of medium weight, a woolen sweater, a leather three forths length coat, and a large windbreaker to her knees. She had handmade woolen mittens and a cap similar to Scott's. Emily was in pajamas and new snowsuit with hood which zippered and totally covered her.

Clothing is one of the most important aspects to enjoying and surviving in the outdoors. Ideally, clothing should be worn in layers, using several light garments rather than one heavy one, to allow for versatility. Layering provides more insulation per weight because of the air trapped between layers.

All areas of potential heat loss must be covered, especially the head which is all too frequently forgotten. The scalp and back of the neck carry much heat close to the surface because of the large blood supply here. Hats should be capable of being pulled down over the ears and neck. Hoods offer excellent additional protection from the elements.

Wool deserves special mention because it is the only material that preserves any appreciable insulation when wet. All areas of the body should be covered by at least one layer of wool. Wool retains 40% of its insulating value when wet. Cotton and down may drop to 10% or less of its dry insulating value when wet. Down, in addition to losing insulation value when wet, absorbs large quantities of water making it nearly impossible to dry out of doors. Down does have tremendous insulating qualities for its light weight when dry and therefore makes excellent cold weather clothing. Sleeping bags are usually of down, but must be kept scrupulously dry if they are to remain useful.

At least one layer of stockings must be of wool. Care must be taken that stockings do not constrict the feet and impair circulation. If boots are too tight sometimes removing a

CAMERON BANGS, M.D.

pair of socks will warm the feet. Mittens and gloves must similarly be non-constricting.

The outer layer of clothing must be windproof to diminish the chill factor. Preferably it should also be water repellent.

There they were soaking wet, stuck in the snow at dusk with one quarter tank of gas, a wet wool blanket, a nursing four and one half month old girl, and the hope that someone would notify authorities that they had not returned. They ran the car and heater for about one half hour at a time and were able to dry all the wet things except the wool blanket.

They spent the night in the car, nursing the baby and occasionally starting the engine to warm the heater. By morning the gas tank was down to one eighth.

Sunday

At 8:00 a.m. by the car clock, they discussed the dilemma and made their decision. The snow was knee deep but passable; the weather, snowing hard but with little wind and "not too cold." They thought they were five miles from the Ripple Brook ranger station and they felt sure help was on the way. For these reasons they elected to walk out. They nursed the baby, left a note in their car and then placed the baby in her backpack covered by a large umbrella. They took their camera and diaper bag and left the car.

It is usually the strong swimmers who drown after a boating accident because the weaker ones stay with the boat. Each situation is different and each requires independent judgment and decision. In general the statistics show that staying put in previous shelter offers the best chance of survival.

Continued.

MICHAEL GRUBER

DAVID WEINTRAUB

As they left they noted that all car tire tracks had been covered with snow. Scott usually led and broke trail but they switched leads occasionally. At 10:00 a.m. they found parital shelter next to a tree and stopped to nurse Emily. The nursing was accomplished by sliding Emily under the outer garments without much exposure of Diane to the elements. During the nursing Diane became thirsty and ate large quantities of snow. She felt that this was necessary to keep up the production of milk.

Here is probably the crucial point in this heartrending story of a young mother giving her life to her infant daughter. Replacing fluid loss by eating snow and ice costs a large amount of calories. It takes 80 calories to convert 1 Gram of ice at 32°F to 1 Gram of water still at 32°F. In another illustration, it requires about the same amount of heat to convert snow to one ounce of freezing water as to heat an ounce of soup from room temperature to boiling. The heat loss required to melt snow can tip the delicate balance of heat regulation.

If you have a choice, drink cold water from a stream, rather than eat snow. If you have no choice but to replace your fluid loss with snow then in most circumstances you are better off to become dehydrated. You can survive two days or more without water, but you cannot survive at lowered body temperature.

At noon they again stopped to nurse Emily and again at 2:00 p.m. By this time the snow was nearly waist deep and they were beginning to get fatigued. They particularly noted that their upper legs or thighs were aching from constantly stepping into deep snow.

When the threat of having to spend the night in the wilds occurs it is best to build camp early. When one waits until they can go no further, they are usually too fatigued to build a protective camp.

Diane was particularly tired at this point. She had been carrying her camera but now no longer could do so and cast it aside. She later also discarded the diaper bag.

Remember that metal conducts heat much more readily than air or more porous material. In the cold avoid direct contact with any metal. Even when insulated by a boot or mitten the heat losses are increased. Skiers, climbers and hunters often carry metal objects and must use caution.

By midafternoon they came to a small road junction. The right hand road seemed the more likely route and they took it, starting down a long hill. After a while they thought this route was wrong so they returned uphill to the junction and proceedad left. This too seemed wrong and they then returned to the right hand road. They proceeded down the long hill and at the bottom found an impassible snow drift just where the road started uphill. Scott tried unsuccessfully to go around this.

During this long trek of more than two hours, Diane frequently dragged both hands in the waist deep snow. Scott mentioned this to her on several occasions but unfortunately she lost both gloves.

The early symptoms of hypothermia (low body temperature) include stiff uncoordinated muscles which lead to staggering, stumbling and falling. Minor mechanical tasks such as tying knots become difficult and prolonged. *Thinking becomes slow and time seems to drag.* Decision making presents problems and even simple choices seem insurmountable.

As body temperature drops, muscular activity, walking, etc., become more difficult. Decisions not only seem difficult, but are frequently incorrect. These symptoms can be observed in others but even more important can be recognized in yourself. Just as you can recognize the symptoms and changes as you get intoxicated with alcohol, you can recognize the changes of hypothermia. With alcohol intoxication you can take steps to avoid trouble, walk slower, check decisions carefully, avoid certain people. You can do the same thing with early hypothermia. When you recognize slow thinking or lack of coordination in yourself, check each decision carefully and move more cautiously. When you see it in yourself, check others in your party and discuss it with them. Watch their decisions and steps carefully. People have been known to remove their boots, coats or take obvious wrong routes when hypothermic.

Just about dusk on Sunday evening they decided they could go no further and had to camp. To the right of the road there was a logged over area where they found the butt end of a log. They were able to scrape what little snow there was under the log away to bare ground. They lay beneath the log, perpendicular to it and were able to place the umbrella and a sheet of plastic at their heads to keep the wind out. Their feet stuck out into the snow so they placed their four feet into one large plastic bag. The bag extended to their knees so they put the baby blanket from their knees to their waists. They lay on their back with Emily on their belly beneath their outer garments.

The requirements for a shelter are basically three. It must (1) keep you dry, (2) keep you out of the wind, and (3) insulate you from the surrounding snow or ground.

To keep you dry, a shelter must be properly ventilated. One person loses about two pints of water a day through breathing and another two pints from the skin. Without ventilation this water condenses in the shelter and drips down to soak the occupants.

Ventilation must be provided without allowing excessive air movement or wind. Wind removes the protective envelope of warm air around each body and causes greater loss of heat or "wind chill." For example with an actual still air temperature of 30°F and a wind of 10 mph an effective temperature of -30°F is produced.

Insulation from surrounding snow, ice or ground is the most frequently overlooked requirement. Here can be used tree boughs, ropes, wool blankets, back packs (watch the metal), foampads or sleeping bags.

Scott had paper maps with him and matches. He was able to scrape some dry bark from the log and attempted to build a fire. Unfortunately all his matches were wet and unusable.

Matches must be kept dry, preferably in a waterproof container. A less reliable alternative is to carry them in several pockets thus increasing the chance of a dry one. Fire starters or candles help a great deal here. In fire building nothing substitutes for practice and experience. Practice building fires in fireplaces at home with wet wood, wood shavings, bark moss, pitch, etc.

Sunday evening was spent shivering beneath the log. Both were soaking wet to the skin from the waist down. Emily who had been adequately nursed had no change of diapers so her urine soaked down to wet her parents from the waist up. They had been wet since shortly after leaving their car twelve hours earlier.

Water is the killer in cold situations. Water conducts heat away from the body 240 times faster than air. A nude man can survive temperature of 32°F over 24 hours if he remains dry and active but it was found during World War II in the cold North Atlantic that survival is less than 5 minutes in sea water at 32°F.

Survival success in the cold depends on how dry you remain. This is why rain clothes and extra clothes are so important. This is why layered clothing is necessary to prevent excessive perspiration. This is why shelters must be ventilated and why wool is life saving.

Once beneath the log and settled down for the evening, they noted they were still shivering but were able to talk quite freely. They discussed many things at length. They both felt there was a likely chance that they would not make it. They stated that they "loved each other very much" and that they "had a good life together." If they didn't make it, they "had a better two and one half years than most people do in a lifetime." They couldn't understand why this had happened. This was their first unfortunate experience in life and generally, life had been very favorable toward them. They did not feel that they were being punished in any way and had no guilt feelings for any of their previous behavior. Neither of them were extremely religious, although Diane had attended church as a child and still went occasionally. During Sunday evening she did pray occasionally and asked that "the Lord help them." They both concluded that they were there only as a result of a "crazy accident" which was pure happenstance of them being in the wrong place at the wrong time. They felt that there were a few things that they could have done differently which would have made any difference. They wished that the tires on their car had been in better condition and that they had had better first aid equipment. They both discussed the fact that they would probably lose their feet due to frostbite. They had been making plans for redesigning their kitchen at home and Scott planned how they would alter these plans to accommodate them after they lost both feet. Scott similarly made plans as to how he could continue work as an artist without feet. These same thoughts regarding loss of feet were continued during the entire experience.

One of the elements of success in a survival situation is the psychological emotional reaction to it. When one maintains a reasonably calm, realistic, hopefully optimistic attitude, the chances of success are enhanced. With loss of self control comes erroneous hurried decisions, wasted energy and wasted body heat. Lack of will to live or depression is known to decrease metabolic rate and thus heat production.

To stay calm and in control is easier to write about than to practice. Certain guidelines may be helpful: First and foremost is the ability to understand yourself and to recognize

Continued.

DAVID WEINTRAUB


CHARLIE CRIST

when you are not in control. A stern reprimand to yourself, sometimes in a spoken voice may remedy the problem. Secondly comes confidence in yourself that you are capable of meeting the demands. Confidence comes only from experience, preparation, and knowledge. These things must be achieved in advance. Anyone who roams the challenging Northwest should study and practice his techniques at home.

They noted at this time that their feet were quite "club-like" but not at all painful. They became less and less aware of their feet as numbness progressed. Scott took his shoes and one pair of socks off for a few minutes to rub his feet. Diane did not do this. During the night they were able to sleep in stretches of fifteen to twenty minutes. They were quite afraid to sleep for longer periods because of the fear that if you sleep two or three hours you may not be able to rewarm yourself on awakening. The baby awakened frequently during the night and was nursed by the mother. While the mother was nursing, Scott would feed his wife snow. Diane complained of severe stomach cramps made worse by eating snow. Scott also had cramps but to a less degree, since he was eating less snow.

Scientific studies show that most people stop shivering when they drop off to sleep. This lowers the metabolic rate and leads to less heat production. Therefore avoid sleep in a critical situation or at least keep it to a minimum. Cold, hypothermia, and muscular fatigue all lead to desire for more sleep. Sleep also provides temporary escape from discomfort and is therefore sought after by trapped people. Be aware of this and do not remain idle and sleeping for prolonged periods of time.

Medications which produce sleep should be avoided for the same reason. Alcohol is deadly in a cold experience because of its sedating and depressing effect. It causes more blood to go to the skin surface (blushing) and this leads to more heat loss.

Monday

Diane had talked of dying more Monday afternoon than previously and they both became more convinced that they would not survive. Scott seemed to accept the fact that they would not survive and did not become hysterical or panicky about it. He had the feeling that he was expected to survive longer than Diane and would probably do so. He did not feel, however, that he would survive if she did not.

As the evening wore on Diane became more and more delirious. She had periods during which she was lucid and rational, but other periods of delirium.

Scott went to sleep with Emily on his stomach. When he awakened, he noted that Diane was not moving. He grabbed her wrist and thought immediately that she had died. He tried to feel her pulse, but couldn't. He felt below her nose and noted that there was no air moving. He accepted her death as inevitable and felt no sudden grief, remorse or guilt. He did not feel an increase in anxiety or panic at her death but felt "what can I do." He did not have any immediate thoughts as to the future if he and Emily should survive.

He felt that he and Emily would benefit greatly by using Diane's windbreaker and he made an attempt to remove this from her. She way lying on her back and the zipper of the windbreaker had previously been ripped and torn. He tried to get the sleeve off the right shoulder and was able to pull it down approximately six inches; he attempted the left shoulder but found that he was too weak to move the windbreaker at all. At this point, he abondoned the idea of removing the windbreaker. He spent the rest of the night sleeping off and on as he had before.

As body temperature drops to 80°F or lower, the mind sinks into complete delirium. First come short spells of delirium alternating with lucid periods. Soon the delirium becomes constant. When body temperature drops this low, the ability to produce heat is gone. If rescue occurs, the body must be rewarmed by adding heat. Prevention of further heat loss by blankets is not enough. If no other heat is available, the insulating clothing must be removed from the victim and warm rescuers and they should be wrapped together in blankets or sleeping bags. Any means of external heat is valuable, including hot water bottles and hot food, or liquid. Cold food may stimulate metabolism slightly but to no great degree. Placing someone indoors at room temperature (68°F) at this point is ineffective because they cannot produce heat.

Once rewarming has started there is some danger of "rewarming shock." Blood flow to the skin increases rapidly leaving too little for the core. When outside of a hospital, slow rewarming is recommended, currently at 1°F per hour.

Bear in mind that after one has experienced profound hypothermia they may have poor control of body temperature for several years and should be extremely cautious in a cold environment. Once a person has been rewarmed he must be carefully observed to see that temperature does not fall as may occur even in a warm room.

Hypothermia, because of the slowing of both pulse and respiration, may mimick death. Hypothermic deaths should be carefully evaluated before abandoned.

Tuesday morning

His sleep at this point was influenced primarily by Emily's sleeping and waking pattern. She would sleep for an hour or an hour and a half and then wake up crying. He would put snow in his mouth to melt it and then attempt to nurse it into Emily's mouth, either using his curled up tongue or his lips. Initially, she took water quite vigorously and returned to sleep. But as the day wore on, she became less interested in the water and took very little.

Each time he would fill his mouth with snow, he would swallow some himself and then develop severe belly pain followed within minutes by vomiting. Vomitus was small in amount and was a brownish, *coffee ground-like material which he felt was probably blood.*

His activities during this period consisted primarily of sleeping, melting snow to feed Emily and standing to urinate. He found that in order to stand, he had to reach a branch on the log, pull himself up and then lean against the log. He was too weak to stand without support and as time went by he had greater and greater difficulty standing up. His hand motions became incoordinate and at times he had great difficulty undoing his zipper. It also seemed to him that it took a tremendously long time to perform any menial task, such as urinating, or putting snow in his mouth.

During this time, Tuesday morning, he was aware of commercial airliners flying overhead and also of some small planes flying by. He did not at any time think that the small planes were searching for him, since they seemed to by flying directly from one point to another. It was also too overcast to be of much value. He had no real thought about what was going on in the planes but just felt "they are up there and I am down here."

He kept Emily on his own stomach during the day except when he would have to stand to urinate. At this time, he would put her onto Diane. He felt that he and Emily contributed to each others survival. He had definite feelings that her body heat benefited him as much as his benefited her. He felt that he had an obligation to see that she survived and that her "precious life" should be saved. He did not dwell on thoughts of death.

Rescue

At approximately two o'clock Wednesday afternoon he heard a helicopter overhead. He knew immediately that he had been rescued and he felt great relief. He put Emily on Diane and immediately left the snow cave and ran out to wave his hat at the helicopter. The helicopter made several passes and he felt sure they had seen him. He then sat down in the snow and felt very relieved and relaxed. The helicopter was able to land fairly close and three men including a deputy sheriff and two newsmen came to him and asked his name and how he was. He stated immediately that he and his daughter were fine but that his wife had been dead since Monday night. Scott reached into the snow cave by the log and grabbed Emily by the snowsuit and handed her to one of the rescuers. The other two rescuers then assisted him to the helicopter. He took one sip of hot coffee in the helicopter but the belly pain was such that he wanted no more of it.

This entire tragedy took place only twenty three minutes from Oregon City where they landed at Willamette Falls Hospital. This hospital has had much experience in treating cold injuries and is well equipped and carefully trained to do so. They were taken to the emergency room, where core body temperatures of 94°F were recorded on each of them. They both had immediate rapid thaw of all extremities.

Scott's feet were darkened and discolored from frostbite and it appears at present that he will lose part or all of his toes. Emily was alert and hungry but amazingly healthy. She had a severe diaper burn which cleared up in a few days and had no frostbite.

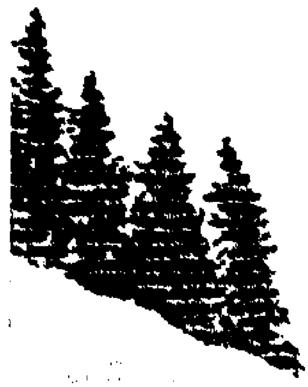
Frostbite should always be rapidly thawed as this leads to less tissue destruction. The extremity is placed in water at 110°F (by thermometer) and left there for over thirty minutes. The water temperature should not be allowed to go below 105°F before it is warmed or replaced. This process is painful but after the first few minutes becomes tolerable.

It is sometimes difficult to recognize frostbite early. Whenever the remote possibility exists, all four extremities should be rapidly thawed. After thawing, the extremities are very delicate and must be protected and not used. It does little harm to walk on frozen feet, but once they are thawed the person must be carried.

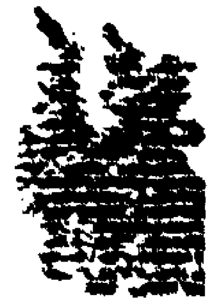
There is no question that Diane died and the others lived because she had to eat snow to nurse her baby. The tremendous amount of heat that she lost doing this exceeded her body's heat production. Diane gave her physical warmth and life to her child. If her story, told here, prevents other such tragic deaths, then she did not die in vain.

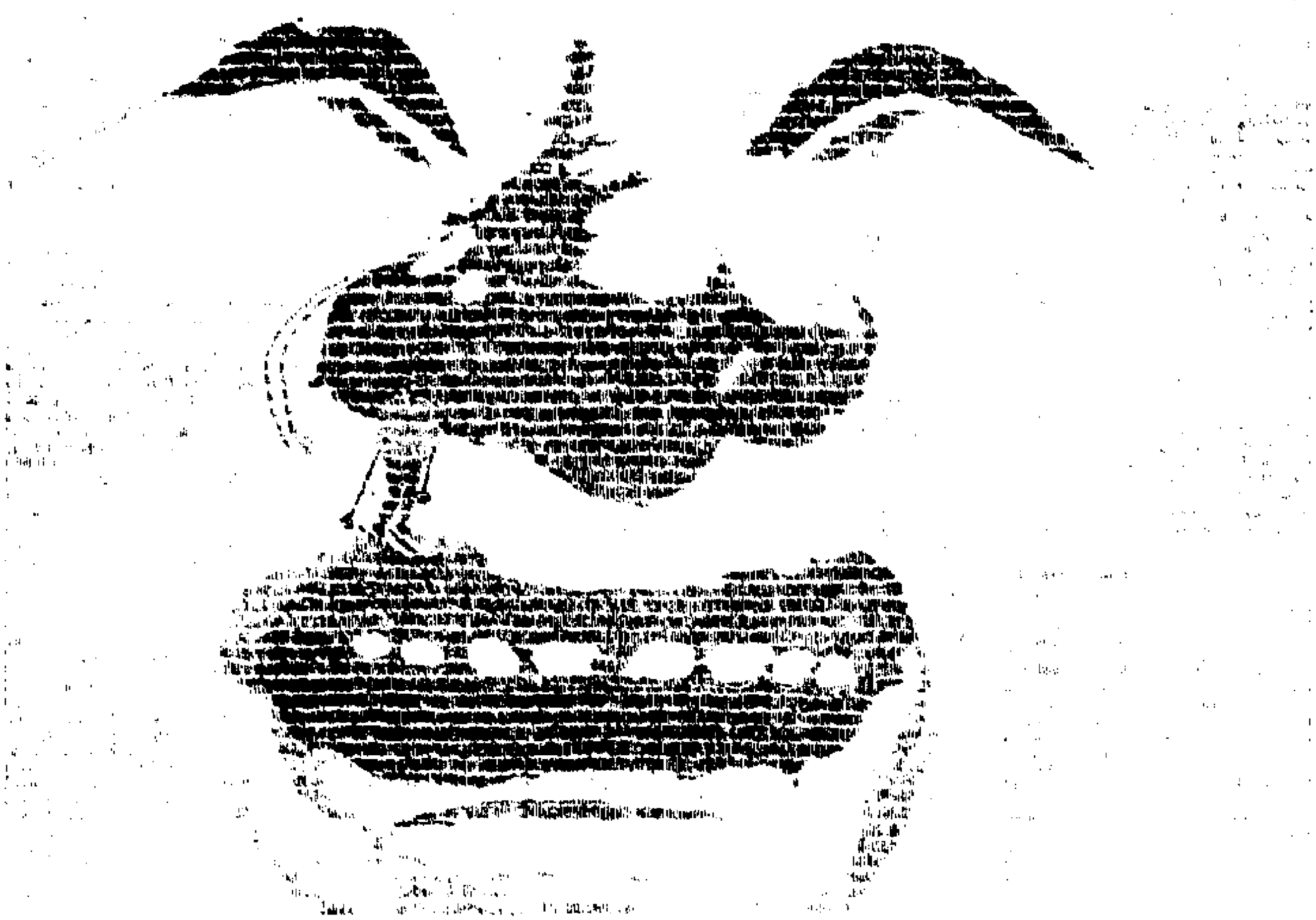
—Cameron Bangs, M.D.
Portland, Oregon

PRICE ZIMMERMAN



Taking the Bite Out of Frostbite and Other Cold-Weather Injuries





By Tina Davis DeLapp

Poorly adapted physiologically to deal with the effects of lowered temperatures, we are dependent on shelter and clothing for protection from the cold. When these are lacking or inadequate, even for short periods of time, cold trauma may result.

Although most commonly seen in arctic and subarctic climates, local cold injuries can occur whenever a causative combination of cold, wet, wind, and altitude exists.

The physiological response of the body to cold is most easily understood by picturing the body as consisting of two major parts: a core in which heat is produced and a shell in which heat is conserved or dissipated, depending on the body's needs at the time. When core temperature is significantly reduced, hypothermia results. When shell tissues (skin, subcutaneous fat, musculoskeletal components, vessels and nerves) are subjected to low temperatures, local trauma may result.

The physiological response of shell tissues to cold is vasoconstric-

TINA DAVIS DELAPP, R.N., M.S., is assistant professor of nursing, University of Alaska, Anchorage.

tion, with a decreased blood flow and a proportionate decrease in oxygen supply to the tissues. The vasoconstriction is caused in part by a direct effect of cold on the blood vessels and in part by a concurrent sympathetic response. The degree of vasoconstriction depends on the duration and severity of exposure and on the susceptibility of the individual(1).

The effects of vasoconstriction are many and varied. The decreased volume of warming blood flowing through the part further reduces the temperature of the tissue. This temperature reduction produces a characteristic muscle weakness and a decrease in local sensation.

Direct damage to the vessel wall from the cold results in plasma fluid leaking into the interstitial spaces. The resulting hemoconcentration, together with the narrowed lumen, promotes the development of small clots. These clots block the smaller vessels. When the blood flow is obstructed, either by clots or by closure of the precapillary sphincters, the arteriovenous shunts open, allowing blood to bypass the part. The cooled tissue thus becomes essentially avascular(1).

Skin is the first tissue to become cooled. Muscles, nerves, and vessels are also highly susceptible. Relatively resistant tissues include connective tissue, tendons, and bone. The parts most frequently subject to cold trauma are the hands, feet, and facial skin, particularly the ears, cheeks, and nose(1).

Chilblain

Seen most commonly on the dorsal surfaces of the hands and feet, chilblain results from intermittent exposure to temperatures in the range of 33° to 60°F., often in a humid environment. Generally, the exposure is fairly short, although it must be long enough to produce the physiological cold response. Cold response varies with the environmental temperature, the degree of humidity, and the individual.

Shortly after vasoconstriction, a brief, intense vasodilation that raises the temperature of the tissue above that of unaffected tissues occurs. Vasospasm produces typical edematous, reddish-blue patches that itch and burn. The itchy, burning sensation becomes more intense with increased warmth(2). Generally, the lesions subside in a few days.

Repeated exposure may result in a chronic condition, in which the characteristic lesions develop as cold weather approaches. The condition goes into remission spontaneously in the spring, when environmental temperatures rise. Although the appearance of the lesions varies with the room temperature and the degree of dependence of the limb, they do not expand at the border or spread to other parts of the body. This condition may occur perennially for several years.

Pathological specimens show intense edema of the papillary dermis, which tends to separate in places from the epidermis. Endothelial proliferation is evident in the small dermal vessels, with the deeper vessels demonstrating a mild vasculitis and perivasculitis(3).

Treatment consists of raising limb temperature. Rewarming can be accomplished by placing the limb in a dependent position in a warm water bath, not to exceed 108°F. Because temperature sensation is decreased in the affected limb, the water temperature must be measured. The warm water is likely to increase the intensity of pruritus and burning, so analgesics may be necessary. In general, the faster the rewarming, the more severe the pain. Vasodilators have been used as a treatment in both acute and chronic cases but with minimal success(3).

Immersion Foot

A second type of nonfreezing injury is immersion foot, a condition produced by prolonged exposure of the extremities (usually the feet) to cold and wetness at temperatures below 50°F. Development of symptoms is associated with immobility and dependency of the lower extremities and with exposure times exceeding 10 to 12 hours.

A variation of immersion foot is trench foot, a condition seen in shipwreck survivors and in soldiers exposed to wet but not freezing cold for long periods, such as in trenches. Tropical immersion foot

SUSCEPTIBILITY FACTORS

Local injuries caused by cold exposure are almost totally preventable, particularly if the numerous factors that predispose the individual to these injuries are attended to.

- Wind markedly increases the rate of heat loss from exposed skin. It literally blows away the thin, insulating layer of boundary air that ordinarily surrounds the body. Boundary air also is absent when the air is still but the body is moving rapidly, as during skiing or when traveling by snow machine. The absence of the insulating layer of boundary air has the effect of lowering the temperature to which the skin is exposed.
- Moisture increases heat loss via conduction. When protective clothing becomes wet from rain, snow, or perspiration, the enclosed parts lose heat at a faster rate than do body parts covered by several layers of warm, dry clothing. Also, wet skin increases the cooling and freezing rate.
- Using alcohol or nicotine in a cold environment increases the likelihood of cold injury by opposite mechanisms. Nicotine use results in peripheral vasoconstriction, decreasing the flow of warming blood to the periphery.

  Alcohol, on the other hand, causes peripheral vasodilation, which increases the rate of heat loss from the skin. Individuals using alcohol may feel quite warm and fail to protect themselves adequately, thus increasing the danger.
- Disease conditions such as peripheral vascular disease, that slow the rate of blood flow to the periphery predispose the individual to cold injuries. Severe generalized dehydration also slows blood flow by increasing the viscosity of the blood. Arteriolar vasoconstriction occurs at high altitudes, even at normal temperature. High altitude is also a predisposing factor because the lowered oxygen tension of the air causes an increased respiratory rate and thus promotes increased fluid loss.
- Excessive washing and shaving increase the possibility of injury to superficial facial tissue by compromising the skin integrity. After-shave lotion further dries the skin and removes oils that partially protect the tissue from cold injury.

occurs in individuals whose extremities are immersed in warm water for long periods. These victims exhibit similar symptoms and pathophysiology and are treated in a manner similar to cold water immersion victims(4).

HOW TO PREVENT COLD INJURY

- Plan activities carefully to minimize time of exposure.
- Always let someone know where you are and when to expect you back.
- When possible, use a buddy system when out in the cold.
- Dress for the weather. Protection is more important than fashion.
- Avoid vigorous washing of the face and shaving the beard until after the day's outing.
- Apply protective cream to the face prior to exposure.
- Wear several layers of loose, warm clothing (rather than a single, fitted layer).
- Use hand protection. Mittens are generally more effective than gloves.
- Carry extra socks. Keep boot liners dry and make sure wet ones are thoroughly dry before using.
- Avoid alcohol and cigarettes.
- Avoid becoming wet with snow, rain, or perspiration.
- Pace yourself to avoid becoming unduly fatigued.
- Pay attention to the messages your body sends. If you note sensation and color changes in the skin, seek shelter.
- If freezing does occur, avoid thawing the part until refreezing is eliminated as a threat.
- Do not use snow, ice, cold water, or excessive heat to thaw frozen tissues.
- Seek medical attention as soon as possible when freezing injury occurs.

Cold water immersion injury develops in three phases. In the first, the prehyperemic or ischemic, vasospastic phase, the extremities are cold, swollen, white or blue, and pulseless. Tactile sensitivity is decreased or absent.

This is followed by the hyperemic (warming) phase, characterized by extremities that are hot, dry, and red with bounding pulses and severe pain. The time it takes for hyperemia to develop depends on the severity of the insult and the individual's susceptibility. This phase may last from 4 to 10 days and in severe cases may result in muscle weakness, atrophy and ulceration, or gangrene of superficial distal areas.

In the last phase, the posthyperemic, or recovery phase, color and pulse gradually return to normal. In severe injuries, some depigmentation may occur, especially if the individual is dark skinned. Hypersensitivity to cold or pain on weight bearing may develop and last for several years.

Although the pathophysiology of immersion foot is poorly understood, it is clear that the vasoconstrictive response to cold results in tissue anoxia and subsequent damage to the vessel wall and nerve. Capillary permeability is thus increased, resulting in edema. Hyperemia may occur as an exaggerated response by compromised neurovascular mechanisms.

After careful rewarming of the affected extremities, treatment is primarily supportive. The individual is kept in bed with the affected feet moderately elevated, and the affected part is kept clean. Phenoxybenzamine hydrochloride (Dibenzyline), an alpha-adrenergic blocking agent, may be used to decrease spasm.

During the hyperemic phase, judicious cooling of the part may be necessary to decrease pain and to lower oxygen requirements of the tissue to prevent gangrene. If gangrene does develop, amputation may be necessary, although this is usually delayed until the full extent of tissue loss is clear(5).

Obviously the best approach to cold injuries is prevention. Nurses working in schools, industry, and private clinics are in a position to provide potential victims with information regarding the danger of immersion and nonfreezing cold.

Frostbite

Frostbite, a freezing cold injury, occurs when tissues are cooled to the point that ice crystals form in superficial or deep structures. Depending on the severity and duration of the freezing and on the efficiency of treatment, varying degrees of tissue loss and function may occur with frostbite injury(6).

In this condition, ice crystals form in the extracellular spaces, causing the extracellular fluid to become hypertonic in relation to intracellular fluid. This results in fluid being pulled from the cell. When approximately one third of the cellular fluid is lost, injury to the cell from dehydration and disruption of enzymatic processes occurs(7).

The clinical manifestations of frostbite injury vary depending upon the severity of the injury. If superficial--involving only the skin and subcutaneous fat--sharp, aching pain is common. The part is white or blanched, and frozen on the surface, but when gently pressed feels soft. After thawing, the part becomes flushed and sometimes deep purple in color.

When frostbite injury involves deeper structures, the part appears white and feels solidly frozen on palpation. After thawing, it may be blue, purple, or black in color. The severity of the injury cannot be assessed prior to thawing.

Large blisters filled with serous fluid generally form within the first 24 to 48 hours after rewarming. These blebs are frequently large enough to restrict motion of the part. If bleb formation does not occur, this usually indicates that adequate circulation is lacking. Tissue loss often results.

The bleb fluid begins to be reabsorbed within 5 to 10 days, often followed by the formation of a hard black eschar layer that also can interfere with mobility. The eschar layer is insensitive and may occur over areas where blebs don't form.

Within a few weeks, a line of demarcation appears. This line marks the point below which tissue is not viable and makes it possible to estimate the extent of probable tissue loss. Above the line of demarcation, the eschar layer separates, revealing the new underlying skin. The shiny, babylike skin is often abnormally tender and sensitive to temperature; abnormal sweating may occur for a time. Within two to three months, however, the appearance becomes normal.

The eschar does not separate

1. White or blanched frozen parts are rewarmed in a whirlpool bath.

2. Blebs develop within 48 hours unless circulation is impaired.

3. Within 10 days, fluid reabsorbs and hard eschar layer forms.

4. In third week, hardening eschar must be slit to free joints.

5. Debridement occurs naturally and because of treatments.

6. Appearance at 6 weeks; gross anatomy, function are preserved.

below the line of demarcation. Rather, deeply injured tissues remain hard, black, and insensitive and eventually undergo autoamputation without surgical intervention(6).

The clinical course and prognosis of frostbite injury vary considerably with clinical management. Experiences over the past 20 years have led to the development of a treatment method that minimizes tissue loss and dysfunction.

Prior to 1955 in Alaska, frostbite was initially treated with a variety of methods, including rubbing with snow, thawing in an ice or snow bath, gradual, spontaneous thawing indoors, and rarely, immersion in warm fluid. This was followed by all types of management, ranging from near total neglect to early surgery, which often resulted in unwarranted tissue loss(6). Treatment today is standardized and results in a more favorable outlook.

Immediate first aid begins with the removal of the client to a sheltered area to prevent refreezing of traumatized tissue. His or her temperature is taken immediately to assess the presence of hypothermia. If the temperature is below 94°F., the treatment of hypothermia receives priority because of its life-threatening effects.

Once there is no chance of refreezing and hypothermia has been treated, the frozen part is rewarmed by immersing it in well-agitated water at 100° to 108°F. A whirlpool bath is ideal for this purpose. For injuries involving the face or ears, warm moist soaks (changed frequently to maintain the desired temperature) are applied(8). The rewarming is continued until the part is completely flushed.

Rewarming is usually a painful process that requires sedatives and analgesics. Further, because the client often is chilled and wet, general rewarming measures are indicated. These include providing dry clothing, adjusting the environmental temperature accordingly, and encouraging the client to drink warm liquids.

Some authorities support the judicious use of a small amount of an alcoholic beverage, which acts as a mild sedative and encourages peripheral vasodilation(1). The use of alcohol, however, should be restricted to clients who are being monitored by medical personnel. Alcohol as a treatment without professional assistance may prove hazardous.

Once the rewarming process is complete, the client is hospitalized and placed in protective isolation. The affected parts are placed on sterile sheets. A bed cradle protects the tissues from the pressure and friction of top covers. No dressings are used, although sterile cotton pledgets may be placed between bleb-swollen digits to minimize friction and thus decrease the likelihood of bleb rupture. If protective isolation is not possible, some physicians apply an anti-infective cream to the part and wrap it loosely in a Kerlix dressing, again using cotton pledgets to separate the digits.

Rupture of the blebs is carefully avoided. Infection is prevented by cleansing the part daily in a warm whirlpool bath between 90° and 98°F. to which a mild disinfectant soap has been added. The whirlpool with its gentle debriding action stimulates circulation and encourages active motion of the part.

If the eschar that forms is so stiff that it prevents movement of the part, it may be gently split on the sides or on the dorsum of the digit. No additional debridement is carried out; this is left to natural progress and to the gentle action of the whirlpool. When the eschar begins to slough, protective isolation is discontinued, although the daily whirlpool baths and active exercise in the bath are continued.

Where tissue loss is inevitable, no debridement is done until spontaneous sloughing of the soft tissues is virtually complete. Any remaining mummified portion may then be surgically removed. This delay, often as long as three to four months, markedly decreases the danger of retraction and infection and reduces the need for later skin grafting and stump revision(6).

Increasingly, arteriography is being used to assess the extent and severity of vasospasm in frostbitten tissues. If arteriograms demonstrate significant vasospasm, a vasodilating agent, such as reserpine, may be injected into the artery. This creates a local medical sympathectomy that avoids the permanent systemic side effects of surgical sympathectomy. Although studies evaluating this treatment are limited in scope and number, those published have demonstrated marked relief from vasospasm and associated symptoms(9).

Anticoagulant therapy has been attempted in an effort to prevent sludging in the microcirculation, but with little demonstrable effect. At least one authority suggests that anticoagulant therapy, combined with platelet antiadhesive drugs, might be successful in preventing damage from intravascular coagulation if instituted early(10).

Basically, rewarming with a warm water bath, followed by protective isolation, daily whirlpools, and avoidance of early surgical intervention remain the cornerstone of management. Once there is no threat of refreezing the part, initial rewarming should never be delayed until the client is transferred to a special treatment center. Rather, therapy should be instituted prior to the transfer, with measures being taken to protect the injured part and to prevent refreezing during transport.

Nursing care during the rewarming phase is concerned primarily with promoting comfort and with observing the client's response to the thawing procedure and to comfort measures.

During the time that the client is in protective isolation, the nurse attempts to prevent complications from immobility and sensory deprivation. Nursing history information should be incorporated into the plan of care, and as much independence as the client's physical and emotional state permits should be encouraged.

Diversional activities, including frequent contacts with friends, family, and nursing staff assume special importance during isolation. Explaining the reasons for isolation and demonstrating the correct procedures for gowning and handwashing often markedly increase the comfort of visitors. Activities such as needlework, puzzles, and model building can be continued in the isolation unit. When the hands are affected, adaptive devices may be used to increase independence.

During isolation, the client is waiting for the extent of tissue loss to become clear. To deal with psychological problems during this time, open communication for the client to express feelings, uncertainties, and fears is essential. Prerequisite to open communication is the establishment of trust between the client and at least one or two members of the nursing staff. This may be enhanced by limiting the number of staff members assigned to the care of the client and by maintaining continuity of care.

If there has been significant tissue loss, the hospital nurse ensures that appropriate referrals for rehabilitation are made, including physical or occupational therapy. Referral to a public health nurse and possibly to vocational rehabilitation services may be necessary.

The prognosis in frostbite injury is highly variable, even if only minimal tissue loss occurs. Late results include hypersensitivity to even mildly cold weather and humidity, increased susceptibility to repeat frostbite injury on subsequent exposure, and pain and paresthesias in the injured area. Phantom limb pain may follow amputation(11). Children may suffer epiphyseal damage that later results in deformities; this is especially common in the fingers(12).

It is likely that a cold acclimatization mechanism does exist. This is defined as an increased metabolic heat production in response to extended periods of intermittent exposure to a frigid environment(11). For some people, the combined effect of increased heat production and better knowledge and use of protective measures increase ability to withstand cold temperatures. Starvation and fatigue may negate the cold acclimatization mechanism by limiting the ability to increase heat production(6).

References

1. Ward, M. Frostbite. *Br.Med.J.* 1:68-69, Jan. 12, 1974.
2. D'Ambrosia, R. D. Cold injuries encountered in a winter resort. *Cutis* 20:385, 387, Sept. 1977.
3. Tring, F. C. Chilblains. *Nurs.Times* 73:1752, Nov. 10, 1977.
4. LaBonve, R. S. Immersion foot in scullery workers. *P.A.J.* 7:31, Spring 1977.
5. Petersdorf, R. F. Disturbances of heat regulation. In *Harrison's Principles of Internal Medicine*, 7th edition edited by M. M. Wintrobe and others. New York, McGraw-Hill Book Co., 1974, p.53.
6. Mills, W. J. Frostbite. A discussion of the problem and a review of an Alaska experience. *Alaska Med* 15: 28-30, Mar. 1973.
7. Dinep, Martin. Cold injury: a review of current theories and their application to treatment. *Conn.Med.* 39:8-9, Jan. 1975.
8. Sessions, D. G., and others. Frostbite of the ear. *Laryngoscope* 8:1224, Aug. 1971.
9. Porter, J. M., and others. Intra-arterial sympathetic blockade in the trearment of frostbite. *Am.J.Surg.* 132:625, Nov. 1976.
10. Chohan, I. S., and others. Blood coagulation and immunological changes associated with frostbite at high altitude. *Intern J.Biometerol.* 19:152, Nov. 1975.
11. Lane, R. M. Cold injuries: frostbite and hypothermia. *J.Am Coll.Health Assoc.* 23:200-201, Feb. 1975.
12. Lindholm, A., and others. Epiphyseal destruction frostbite. *Arch Environ.Health* 17:683, Oct. 1968.

The Doctor's World

THE DOCTOR'S WORLD

Unnoticed Loss of Body Heat Can Kill

By LAWRENCE K. ALTMAN, M.D.

SUDDENLY John Reed became drowsy and forgetful. At age 84, he had been alert, read the newspapers, and was able to care for himself and walk around his nursing home. Now that he had become confused, attendants put him to bed. The next day he became even less communicative. A nurse stuck a thermometer in his mouth. He had no fever. His physician examined him and found no change in Mr. Reed's heart condition or the arteriosclerotic damage to his legs. Blood tests showed that his diabetes was not out of control.

The doctor's diagnosis — that the patient had suffered a small stroke — was only presumptive, based on the fact that diabetes predisposes individuals to a higher than usual incidence of strokes.

A day later, when Mr. Reed went into coma, the physician was more certain of the diagnosis. He doubted Mr. Reed would survive. Even if he did, the physician presumed that the effects of a stroke, added to other chronic medical problems, would seriously impair the quality of his life at such an advanced age. The doctor recommended that Mr. Reed be allowed to die.

However, to reassure the family, the doctor asked for a consultation from a specialist in geriatric medicine. When the specialist put his hands on Mr. Reed's body, he noted it was cool. Then, using a low-reading thermometer, that is, one that can record temperatures at a lower range than the conventional clinical thermometer, he

Continued on Page 15

Continued From Page 13

found Mr. Reed's temperature to be a startling 89 degrees.

Now the diagnosis was clearly documented: Mr. Reed had hypothermia, or low body temperature. It was a condition that would prove fatal unless he received prompt treatment. In the hospital, doctors and nurses wrapped blankets around Mr. Reed to conserve the small amounts of heat that his body was still producing and gave him intravenous fluids to counter dehydration and restore his body's chemical balance.

Twelve hours later, Mr. Reed's temperature was back to normal, and in a few days he was at the nursing home, alert and avidly following politics in the newspaper.

•

Hypothermia is the condition that results when the body temperature reaches 95 degrees Fahrenheit or below. It has been diagnosed for centuries among people who were inadequately protected against the cold while they worked or played outdoors. This form is called exposure hypothermia, and among its victims have been mountaineers, skiers, and seamen as well as vagrants who have fallen asleep in parks.

But only in the last few years has hypothermia been recognized as a common condition that affects people, particularly the elderly, who remain indoors without adequate protection against temperatures 65 degrees or below. This form is called accidental hypothermia.

Once the diagnosis of hypothermia is made, the doctor must determine its cause. Beyond that produced by cold environments, the condition can be caused by a lack of activity of the thyroid gland in the neck or the pituitary gland in the brain. The phenothiazines are a class of drugs that are among the most widely prescribed in the treatment of psychiatric conditions and for nausea and vomiting, among other problems. These drugs can provoke hypothermia. Also, symptoms of hypothermia can mimic those of Parkinson's disease.

With the costs of heating fuel straining the budgets of people living on pensions and fixed incomes this winter, concern is growing that the incidence of accidental hypothermia in the elderly might rise over the levels that existed when energy costs were much lower.

•

Accidental hypothermia is believed to be a major cause of death in the winter months in the United States, England, and other countries that experience cold weather. However, no one knows exactly how many people become hypothermic or die from it in this or any other country each year.

As many as 11 percent of the elderly living in England had temperatures of 95 degrees or below, and 3.6 percent of those admitted to hospitals in England were hypothermic, according to surveys done in the winter and published in medical journals.

Similar surveys have not been done in this country, according to Dr. Richard W. Besdine of Harvard Medical School and the Hebrew Rehabilitation Center for the Aged in Boston. In an article in the current issue of Geriatrics, he said that 2.5 million Americans are at risk of dying from hypothermia each year and that an estimated 50,000 old people enter hospitals with unsuspected hypothermia when cold temperatures grip the country.

Mr. Roger's life was saved because a geriatrics consultant, alerted to hypothermia by medical journal articles and lectures, carried a low-reading thermometer in his bag. These instruments look like the ordinary thermometer, but are calibrated to record a range from 88 to 108 degrees instead of the usual 94 to 108 degrees in the standard thermometer, the type that was used at the nursing home. A low-reading thermometer costs about $1.

Young, healthy people can balance heat loss by physiological methods such as regulating the amount of blood flow through the skin and by shivering.

•

Shivering, which increases heat production by about five times, is one of the body's major weapons against hypothermia. However, it can be strikingly absent for unknown reasons in elderly people.

Often, older people lose their perception of the sense of cold as hypothermia sets in. Those living in underheated homes may be unaware that their body temperature is below normal — but the only time such people may be able to protect themselves is before the onset of the phenomenon. Accordingly, it is imperative that older people protect themselves by wearing extra clothing when indoor temperatures are low.

One practical aid is for elderly people to ask friends or relatives to visit and check on their condition when the indoor temperature is expected to drop below 65 degrees.

Federal officials at the National Institute on Aging are revising a pamphlet explaining how people can protect themselves, while still conserving energy. Among the suggestions: dressing warmly day and night, even wearing hats, gloves and sox indoors; using thermal or electric blankets; and maintaining reasonable physical activity while indoors.

•

As doctors have gained more experience with accidental hypothermia in the elderly, they have learned to recognize a set of physiological changes that develops over a period of several hours to days. Falling body temperatures can lead to clumsiness, poor coordination, stiffness of joints and muscles. Also, hypothermia can depress brain and central nervous system function, resulting in progressive confusion, slurred speech, altered gait, seizures, and ultimately coma and death.

Further, hypothermia itself can lead to any number of complications such as pneumonia, heart failure, strokes and pancreatitis (a potentially fatal inflammation of the pancreas gland in the abdomen).

At any point, an individual can use poor judgment or fall, and the cause of death can be attributed to such an event instead of hypothermia. Similarly, hypothermia can aggravate chronic diseases such as diabetes or heart disease, and the cause of death can erroneously be attributed solely to those conditions. Sometimes, when elderly people are found dead at home, their deaths may be ascribed to natural causes or conditions other than the persistent chilling that truly killed them.

Inflatable PFDs- Why Not?

Tom Sheehan and Ladd Hakes

Coast Guard Boating Safety
Policy and Planning Staff

No one wants to be involved in a boating accident. The Coast Guard directs many technical, education and enforcement activities aimed at boating accident prevention. However, boating accidents do happen and all too often unsuspecting boaters find themselves in the water under conditions which can easily prove hazardous to life. It is for this reason that the Coast Guard requires the carriage of Coast Guard approved Personal Flotation Devices (PFDs) on all recreational boats.

At this time, the Coast Guard only approves PFDs which are inherently buoyant. This means that these devices are made of materials that are buoyant by nature (like kapok, closed cell foam, or fibrous glass). No mechanism is required to place air or other gas into the compartments. Due to this inherent buoyancy requirement, presently approved devices may sometimes be bulky, restrictive of the wearer's movement, and considered unattractive. In observational studies of recreational boaters, only 7.1% of the boating population routinely wear PFDs. This low percentage may in part be attributed to the requirement for inherent buoyancy.

From 1970 to 1978, approximately 11,000 victims of recreational boating accidents drowned. Of these victims over 75% did not wear or use PFDs. If these drowning victims had been wearing a PFD, their chances of survival would have been greatly improved. A critical review of the Coast Guard PFD standards and carriage requirements is being made to determine if:

1. The Coast Guard can significantly reduce the number of recreational boating drownings through the approval of a wider range of PFDs and by revising the carriage requirements to include the newly approved devices.
2. A "yardstick" can be developed to equitably measure the performance and potential usage of all styles of PFDs.

The Coast Guard is presently investigating such a "yardstick" to measure the lifesaving potential of PFDs. This "yardstick" is known as the Lifesaving Index (LSI). The LSI is a combination of factors that affect PFD performance and usage as they relate to recreational boating. These factors include:
1. Physical effectiveness - how well the PFD floats an individual and turns the wearer to an upright position.
2. Wearability - how likely the PFD is to be worn, and how easy it is to don in and out of the water.
3. Accessibility - how likely the PFD is to be near the boater in time of an accident.
4. Reliability - how likely the PFD is to fulfill its design requirements in continued actual service.

The LSI for a given PFD is based on how well the PFD does in tests designed to measure each factor.

The crucial question is, given that few recreational boaters wear presently approved PFDs, will the approval of a wider range of devices increase the number of PFDs worn? It could be that many recreational boaters would not wear a flotation wristwatch should there be such a thing. Initial Coast Guard research into this question indicates that certain inflatable PFDs would be worn more frequently than presently approved devices if they were less bulky and more comfortable and attractive. At present, inflatable PFDs are precluded from Coast Guard approval due to their susceptibility to total buoyancy loss, malfunction of the inflation mechanisms, and the amount of effort needed to keep the devices in good working condition.

The Coast Guard is now involved in an intensive technology assessment effort concerning inflatable PFDs. About 500 inflatable PFDs with questionaires have been distributed to Coast Guard Auxiliarists within the United States. The questionaires solicit the boater's attitudes on inflatables including their impressions of performance, wearability and reliability under normal use and during swim tests.

New actuation mechanisms based on cool gas generation rather than stored CO_2 are being developed and tested. Various performance tests on the inflatable devices used in the Auxiliary study are being run by an independent laboratory. Methods to train boaters on how to maintain and use inflatables are being investigated. This effort should be completed in 1980. The results of the effort should enable the Coast Guard to make a sound decision on the approval of inflatable PFDs.
If it can be shown that the wearability of inflatable PFDs is significantly higher than inherently buoyant devices and that the in water performance and reliability are not greatly diminished, you may see certain inflatable PFDs approved by the Coast Guard in the future.

Winter trauma

Help for the victim of hypothermia

Prepared in consultation with:

Cameron C. Bangs, MD
internist, Oregon City; clinical instructor of medicine, University of Oregon Medical School, Portland

Murray P. Hamlet, DVM
director, experimental pathology division, U.S. Army Research Institute of Environmental Medicine, Natick, Mass.

William J. Mills, Jr., MD
orthopedic surgeon, Anchorage, Alaska

Staff editor: Rebecca Skinner

Accidental hypothermia, a condition associated with a core temperature of 34.4°C (94°F) or lower, results when an individual loses more heat to the environment than he produces. Heat loss may occur rapidly, as from immersion in cold water, or slowly, as from prolonged exposure to wet, cold weather. Drugs, disease, or failure of the temperature-regulating mechanism may be underlying factors.

Although you will rarely encounter hypothermia, it's something you would not want to miss. If you're presented with a comatose or semicomatose patient who has a history of exposure to cold or wet, rule out hypothermia with a low-reading thermometer. A rectal reading is a much more accurate representation of core temperature than oral or axillary reading. If the temperature is 34.4°C (94°F) or lower, you're faced with an emergency situation requiring immediate intervention. The patient may be volume-depleted and in metabolic acidosis; he may develop serious arrhythmias, including atrial and ventricular fibrillation.

You do have one thing going for you, however, particularly if the hypothermia is due to prolonged rather than acute heat loss: The patient is literally in a metabolic icebox, which gives you time to lay out a plan of action. Once you begin rewarming the victim, changes will occur fast, requiring quick and sure actions.

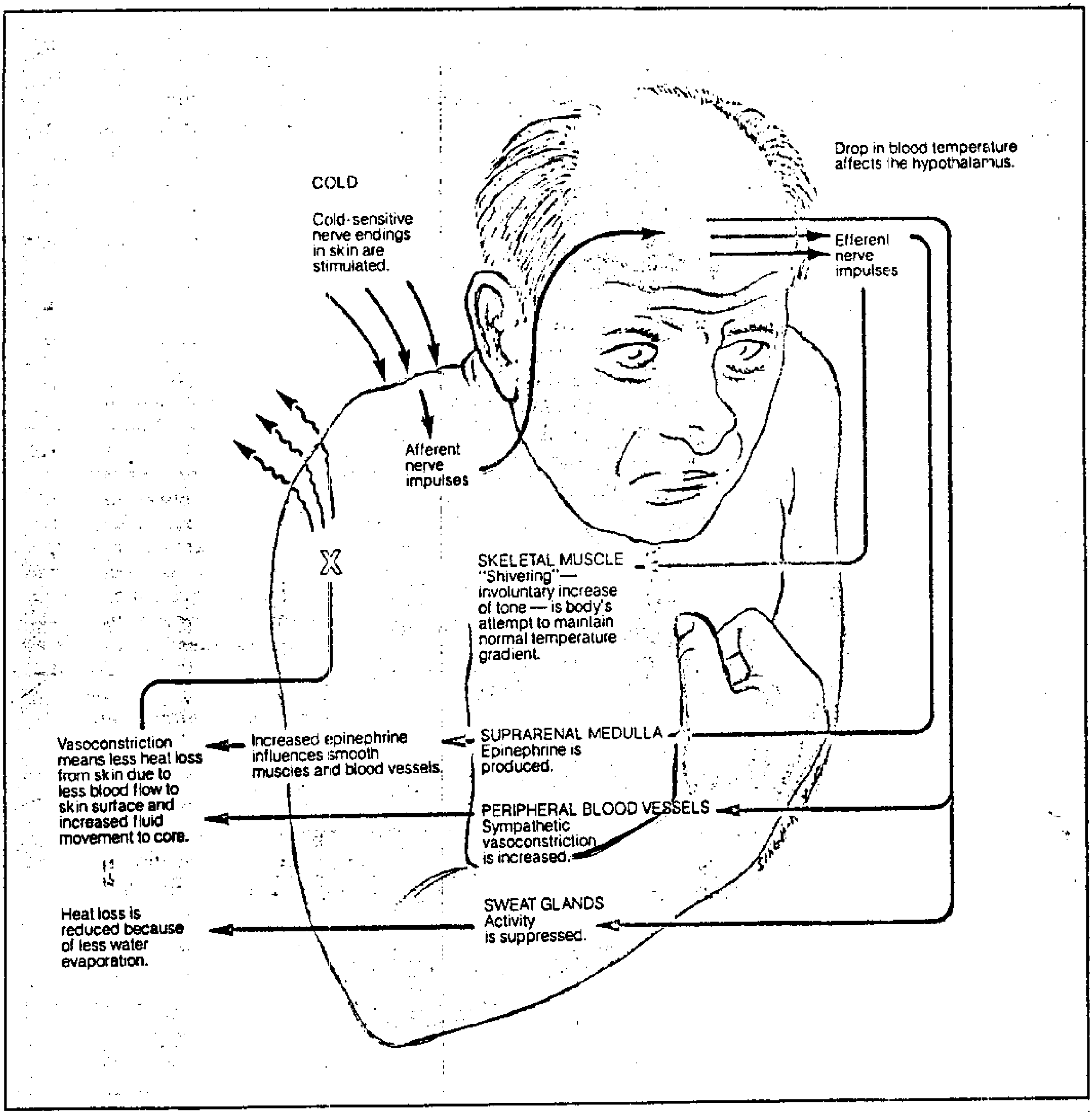
In the following article, you will find pointers on the diagnosis and management of hypothermia, a discussion of its physiologic changes, and tips for helping outdoor enthusiasts avoid hypothermia.

EXPRESS STOP

Making the diagnosis: The people most susceptible to hypothermia include drug abusers, trauma victims, those with debilitating diseases, and unprepared or injured hikers, hunters, and mountaineers. The person with hypothermia may present as withdrawn, depressed, and uncoordinated, with slurred speech; he may be in a state easily mistaken for death. Anyone with altered consciousness after cold and/or wetness exposure should have his temperature taken with a low-reading rectal thermometer.

Anything that modifies the body's ability to regulate temperature can contribute to the development of hypothermia in the patient exposed to cold—not necessarily freezing—temperatures and/or wetness. Some of the more common contributing factors are:

» *Drugs* Some drugs, such as alcohol, may render the person who abuses them unable or unwilling to seek shelter. Barbiturates,


COLD
Cold-sensitive nerve endings in skin are stimulated.
Afferent nerve impulses
Drop in blood temperature affects the hypothalamus.
Efferent nerve impulses
SKELETAL MUSCLE "Shivering"— involuntary increase of tone — is body's attempt to maintain normal temperature gradient.
SUPRARENAL MEDULLA Epinephrine is produced.
Increased epinephrine influences smooth muscles and blood vessels.
Vasoconstriction means less heat loss from skin due to less blood flow to skin surface and increased fluid movement to core.
PERIPHERAL BLOOD VESSELS Sympathetic vasoconstriction is increased.
SWEAT GLANDS Activity is suppressed.
Heat loss is reduced because of less water evaporation.

morphine, and phenothiazines may actually decrease body temperature.

» *Disease* A debilitating disease—particularly diffuse skin diseases and metabolic disorders such as myxedema—will make an individual more prone to develop hypothermia.

» *Trauma* An individual who suffers a head injury, fracture, or blood loss in a situation where rescue is delayed may become hypothermic. If an accident while ...ting or skin diving in cold water doesn't result in drowning, it's almost sure to result in hypothermia unless the victim is removed from the water in minutes.

» *Extremes of age* In premature births, hypothermia is a serious problem. In the very old, arteriosclerosis or central nervous system disease may impair the temperature-regulating mechanism.

Other people at risk are those whose occupation, avocation, or life situation exposes them to cold and/or wet. More hypothermia occurs in cities among derelicts and older people than in the wilderness among healthy people (see the patient-education aid, "Hypothermia: Rare but dangerous," at left).

Spelunkers and speleologists are at risk. The camper, hiker, mountaineer, or hunter who is unprepared for weather conditions or who gets injured or lost is susceptible. The big killers are moisture and wind; fatigue, dehydration, improper clothing, and ignorance about building shelters or fires are accomplices.

How the patient with hypothermia presents depends on how cold he is. Unless the patient is unconscious due to head injury or drunkenness, marked shivering, withdrawal, apathy, and depression occur first. Provided no further cooling occurs, a patient with these symptoms is not in serious trouble; his temperature is probably over 34.4°C (94°F).* At about 34.4°C (94°F), the victim will become indecisive, irritable, and uncoordinated. Shivering may stop. With a temperature of 31.1–32.2°C (88–90°F), a person may either be lethargic or combative. He may have hallucinations or be delirious. Under 31.1°C (88°F), the patient will become progressively delirious and uncoordinated, eventually comatose.

The severely hypothermic patient is often mistaken for dead. He may be in a state of rigor in a flexed or huddled position. He'll be cyanotic and pale, and his pupils may be fixed. You may find no audible heart sounds, palpable pulses, or visible respiratory excursions.

Rescuers sometimes find the semicomatose or comatose patient in a state of undress. The victim of hypothermia often attempts to remove clothing, which may lead police to suspect sexual assault.

Hypothermia is more common than realized. Suspect it whenever a patient presents with an altered consciousness following exposure to cold and/or wetness. Think of it in an older person found unconscious in a poorly heated apartment. The diagnosis is made by taking the patient's temperature. A low-reading thermometer is essential, and a rectal reading is preferable. A temperature of 34.4°C (94°F) or below is hypothermic.

In general, the healthy person has a good chance of recovery. If alcohol or drug abuse is involved, his chances are lowered. The individual with severe disease who develops hypothermia has a very poor chance of recovery.

*The temperatures provided are general guidelines. Some people are comatose at 33.3°C (92°F); others are conscious at 30°C (86°F).

EXPRESS STOP

Initial steps in care: Handle the patient gently. Ensure a patent airway; intubate only if necessary. Evaluate and plan your approach. Monitor temperature, ECG, and urinary output. Get a CBC, serum electrolyte determination, blood gases, and serum glucose determination.

Instructions for your patients*

Hypothermia: Rare but dangerous

Prevention

Hypothermia occurs when the body loses more heat than it produces. It can be fatal. The key to prevention is to be prepared for cold and wet when you venture into the wilds, whether for half a day or for weeks. Subfreezing temperatures are not needed for hypothermia to develop. Remember that if body temperature falls to 26.7°C (80°F)—the temperature of a summer day—most people die. Even in the summer, a tired hiker exposed to wind and rain may develop hypothermia.

To prevent heat loss, protect yourself against not just cold, but also moisture and wind. Water, whether from rain, snow, or perspiration, conducts heat away from the body about 26 times faster than air. The wind-chill factor has a marked effect on heat loss. If the thermometer reads 4.4°C (40°F) and the wind speed is 20 mph, the exposure is comparable to −7.8°C (18°F).

Proper clothing for cool and/or wet weather provides insulation from cold, ventilation so that perspiration can evaporate, and protection against wind, rain, or snow. Rather than one bulky, heavy, or constricting garment, wear several layers of light, loose clothing that will trap air, a very effective insulator, and provide adequate ventilation. Wool and polyester down substitutes retain some protective value when wet; cotton and goose or duck down do not. Be sure high heat loss areas such as the head, neck, and legs are covered and have a windproof and waterproof outergarment.

Good physical condition and adequate food and water intake are also important in preventing hypothermia. At night, camp early while you still have adequate energy to construct shelter from wind and rain. Valleys are coldest and the mountaintops windiest. Avoid fatigue. Shed clothing before soaked with perspiration. Replace before shivering starts.

Have emergency equipment such as space blankets, knife, large plastic bags, matches in a waterproof container, candy, and cord with you, even on day hikes. If a companion suffers injury, keep him covered and insulated from the ground while waiting for rescue.

Recognition

Hypothermia gives little warning. Two of the body's initial reactions to cold are goose pimples and shivering. If the heat produced by shivering doesn't keep up with heat being lost, the body's temperature will fall. The metabolic rate slows, resulting in mental and physical changes. The victim drops out of conversation and appears discouraged or depressed. He'll become uncoordinated, with slow, labored movements. Simple tasks such as fastening a zipper are difficult. He will become amnesic, and his judgment will fail completely. He'll be sleepy, lethargic, and confused. He may be combative and refuse care. He may hallucinate. Below a body temperature of 31.1°C (88°F) you can expect a loss of consciousness; muscles will become stiff and simulate rigor mortis.

Treatment in field

Try to prevent hypothermia before it occurs. If a companion is shivering, remove wet clothing, place him in a sleeping bag insulated from the ground, persuade him to drink warm fluids, find shelter, and build a fire. Avoid further heat loss, but administer warm fluids only if he's conscious, can talk with you, can breathe well, and generally seems to be thinking clearly. Move him to a hospital as soon as possible.

If his temperature is below 33.3°C (92°F)—that is, if he's very confused, uncoordinated, semiconscious, or unconscious—rewarming will cause severe physiologic changes that you will not be prepared to handle. Protect the patient from further heat loss, but do not attempt to warm him. Ensure an airway, but do not attempt cardiopulmonary resuscitation. Handle him very gently and move him to a hospital.

*This patient-education aid may be reproduced by office copier for distribution by physicians to their patients. Written permission is required for any other use

Check for other diseases or injuries. Begin correcting volume depletion in all patients except those with acute hypothermia.

Hospitalize the patient with hypothermia as soon as possible. As you treat the patient, keep in mind two general principles:

» Excessive manipulation of the patient can cause ventricular fibrillation, so handle him very gently.

» Most problems will resolve spontaneously with rewarming; be conservative and do not overtreat.

Establish a patent airway. If endotracheal intubation is necessary, use extreme caution to avoid fibrillation. Anesthetize topically. If the patient requires oxygen, consider administering 100 percent humidified oxygen, heated to 46.2°C (115°F), using positive pressure respiration. Do not overventilate; to do so increases the chance of ventricular fibrillation. Some physicians have observed that many patients with hypothermia exhibit a thick mucus that requires aspiration for adequate respiration.

Thoroughly evaluate the patient. Look for predisposing factors such as drunkenness or concomitant injuries that may affect rewarming methods or require additional care. If possible, find out how cooling occurred. Except in near-drowning victims, rapid cooling results in fewer metabolic alterations than slow cooling.

Plan your approach. Your major concerns, beyond returning the temperature to normal, will be correction of volume and acidosis and avoiding serious cardiac problems. Once rewarming begins, complications can arise quickly. The first 20 minutes of treatment are the most critical.

Begin monitoring temperature, ECG, and urinary output. As soon as possible, start an IV; a cutdown may be necessary. Try to obtain enough blood for a CBC, serum electrolytes, arterial blood gases, and serum glucose. Attempt a CVP reading, *but do not insert the catheter tip into the heart.* That can cause fibrillation. Remember to have the lab correct the results of blood gases for temperature. Insert a urinary catheter.

Unless sudden immersion in very cold water caused the patient's hypothermia, suspect volume depletion. Not only does heat loss increase diuresis, but usually the patient's intake is reduced. Begin volume expansion promptly, exerting caution if the fluid contains potassium. Warm the fluid in a blood warmer to 36.7–43.3°C (98–110°F), so that it runs in at about normal body temperature. Try to hold the central venous pressure at 5–10 cm H_2O. An otherwise healthy patient may require up to one liter of fluid in the first hour. Hyperglycemia (blood sugars up to 400 mg/dl) is not unusual because insulin is relatively inactive at low temperatures. Do not administer insulin. Hypoglycemia has also been reported in hypothermia victims; treat hypoglycemic patients with dextrose.

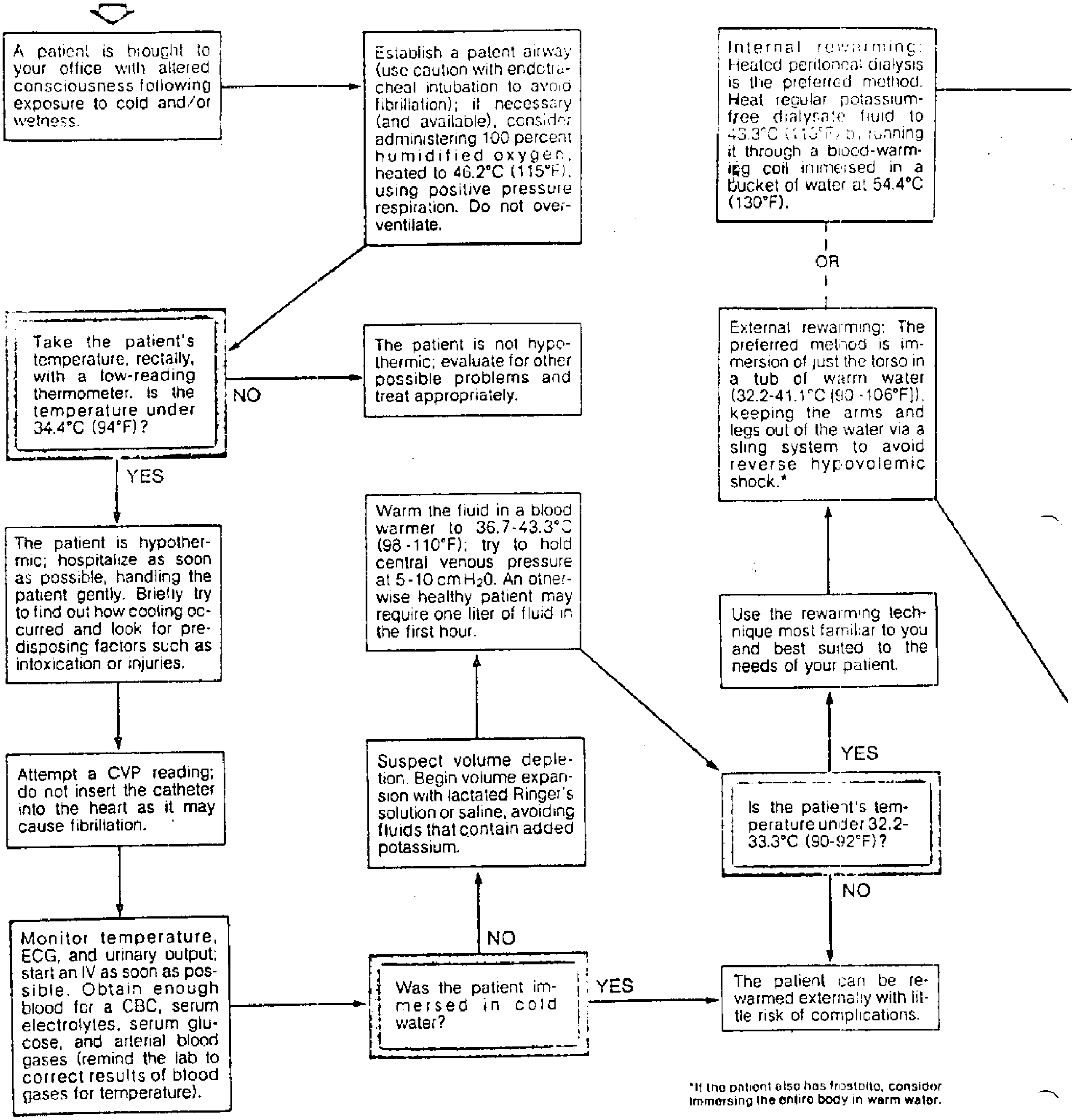
EXPRESS STOP

Rewarming: With a patient with hypothermia due to rapid heat loss or with a core temperature above 32.2–33.3°C (90–92°F), rewarm externally in a warm water bath. For other patients, internal rewarming may prevent a dangerous afterdrop in temperature. But with careful monitoring, external rewarming has been successful even in patients with very low temperatures. For internal rewarming, heated peritoneal dialysis with potassium-free dialysate fluid is used most often.

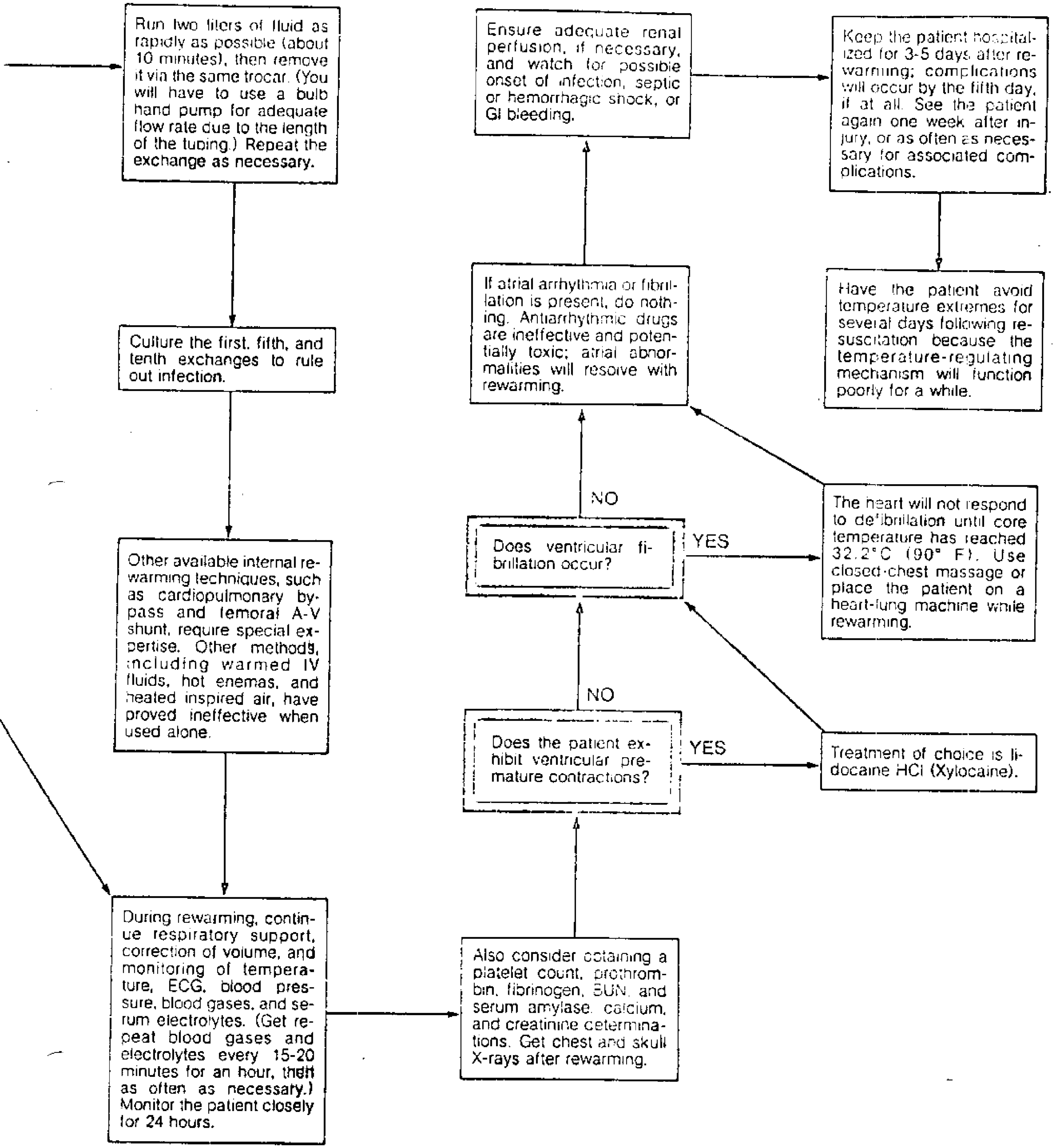
With careful monitoring of the patient, rewarming can be begun. Although the method of rewarming is a matter of controversy, all authorities agree that any patient whose temperature is over 32.2–33.3°C (90–92°F) can be rewarmed externally with little risk of complications attributable to the rewarming process. The patient with a lower temperature

WHEN YOUR PATIENT IS HYPOTHERMIC

(Decision points in heavy outline)



*If the patient also has frostbite, consider immersing the entire body in warm water.


Run two liters of fluid as rapidly as possible (about 10 minutes), then remove it via the same trocar. (You will have to use a bulb hand pump for adequate flow rate due to the length of the tubing.) Repeat the exchange as necessary.
Culture the first, fifth, and tenth exchanges to rule out infection.
Other available internal rewarming techniques, such as cardiopulmonary bypass and femoral A-V shunt, require special expertise. Other methods, including warmed IV fluids, hot enemas, and heated inspired air, have proved ineffective when used alone.
During rewarming, continue respiratory support, correction of volume, and monitoring of temperature, ECG, blood pressure, blood gases, and serum electrolytes. (Get repeat blood gases and electrolytes every 15-20 minutes for an hour, then as often as necessary.) Monitor the patient closely for 24 hours.
Also consider obtaining a platelet count, prothrombin, fibrinogen, BUN, and serum amylase, calcium, and creatinine determinations. Get chest and skull X-rays after rewarming.
Does the patient exhibit ventricular premature contractions?
YES
Treatment of choice is lidocaine HCl (Xylocaine).
NO
Does ventricular fibrillation occur?
YES
The heart will not respond to defibrillation until core temperature has reached 32.2°C (90° F). Use closed-chest massage or place the patient on a heart-lung machine while rewarming.
NO
If atrial arrhythmia or fibrillation is present, do nothing. Antiarrhythmic drugs are ineffective and potentially toxic; atrial abnormalities will resolve with rewarming.
Ensure adequate renal perfusion, if necessary, and watch for possible onset of infection, septic or hemorrhagic shock, or GI bleeding.
Keep the patient hospitalized for 3-5 days after rewarming; complications will occur by the fifth day, if at all. See the patient again one week after injury, or as often as necessary for associated complications.
Have the patient avoid temperature extremes for several days following resuscitation because the temperature-regulating mechanism will function poorly for a while.

due to cold water immersion can also be rewarmed externally with safety.

Some authorities maintain that external methods such as immersion in warm water may be harmful to some patients. The controversy involves the rewarming of

Quiz Answers

Questions on page 13

1. neonatal total blood exchange

2. (d) 1,000

3. (d) 20

4. (c) dextran

5. (d) hypersplenism

6. (b) false; for every unit of lost blood replaced by packed red cells, only 3 percent of the body albumin is removed.

7. (d) 12-14

8. stop the clotting consumption by administration of heparin; decrease the clotting depletion by administration of fresh frozen plasma and platelets

9. (d) factor-IX concentrate (prothrombin complex)

10. (e) all of the above

11. 34.4°C (94°F)

12. immersion in cold water.

13. within five days

14. peritoneal dialysis.

15. (b) false; asthma is not a psychological illness; its physiologic factors, usually built on a chronicity from immunologic and other levels, evolve as the patient sets up pathways through which he can express anxiety. No particular type of personality stamps a person as asthma prone.

16. (b) false; refer patient and family for psychological evaluation as soon as you suspect that no medical management will work.

17. the Jacobson progressive relaxation procedures; breathing exercises may also help.

18. (c) 6-8

19. Palpation of the muscle posterior to the upper last molar will produce exquisite pain if spasm is present.

20. (a) true

21. elicit a positive jump response at the point of maximum deep hyperalgesia.

22. (a) dull and constant.

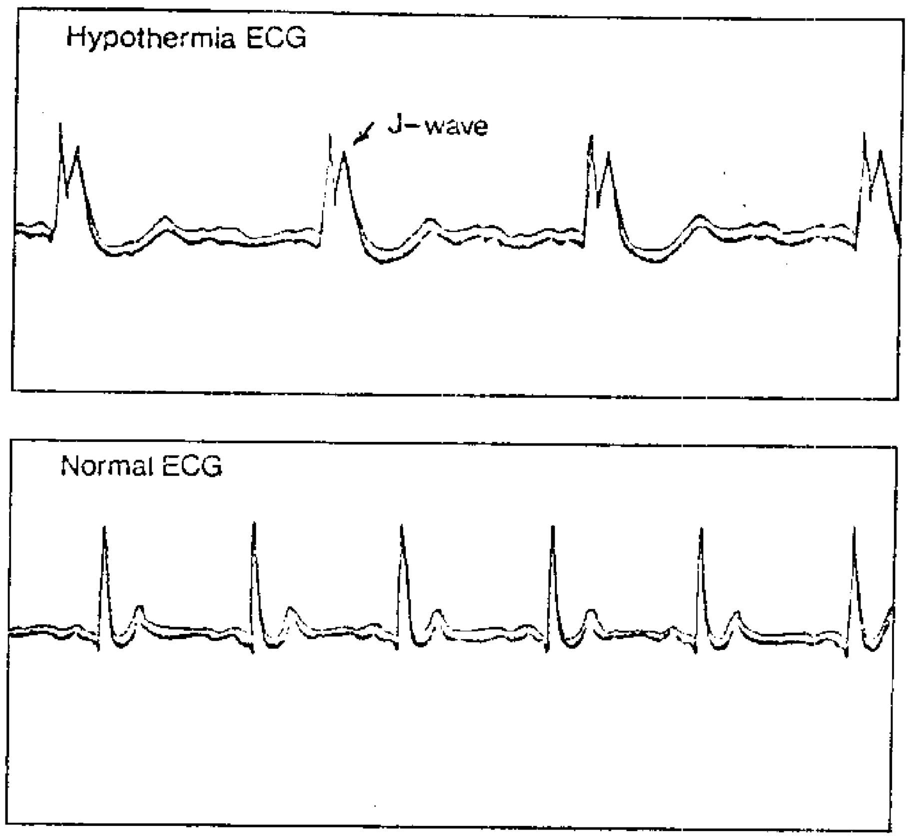
23. (c) ice packs

24. restore affected muscles to normal length.

a patient with a core temperature under 32.2–33.3°C (90–92°F), whose condition is due to prolonged exposure. Many physicians prefer internal rewarming, for the following reasons:

» In the individual whose body has cooled over a long period of time, acid and potassium have accumulated in the periphery of the body, which is also the coldest area (see "The physiology of hypothermia," page 67).

» External rewarming results in peripheral vasodilation so that blood from the core moves to the periphery, and cold, acidotic blood moves to the core. This may cause a drop in pH and in core temperature afterdrop of 0.6–1.7°C (1.3°F) and a rise in serum potassium. A type of hypovolemic shock (rewarming shock) may develop, and the patient's already life-threatening condition may worsen.



A positive deflection in the ST segment—called a J-wave or Osborne wave—is seen on the ECG of some patients with hypothermia. Another characteristic ECG change is the lengthening of all intervals—R-R, P-R, QRS, and Q-T.

A consultant for this article with considerable experience in treating cold injuries in Alaska* reports using external rewarming successfully for patients with temperatures as low as 23.9°C (75°F), particularly those who suffer both hypothermia and frostbite.** Rewarming in a tub of warm water (32.2–4.1°C (90–106°F]) treats both problems at once. Prior correction of the volume depletion with warm fluids and of acidosis with bicarbonate forestalls afterdrop in temperature, he says, and constant monitoring of the very rapid changes caused by thawing in a tub of warm water enables quick corrective action as necessary.

The preferred method of external rewarming is partial immersion in warm water (32.2–41.1°C [90–106°F]). Immersing just the torso—rigging up a sling system to keep the head, legs, and arms out of the water—may prevent some afterdrop in temperature by warming only the parts closest to the core. However, you may want to immerse the whole body when frostbite of feet or hands is a complication. A rewarming blanket set at 40.0–43.3°C (104–

*William J. Mills, Jr., MD

**See "When your patient suffers frostbite," *Patient Care*, February 1, 1977, page 132.

110°F) is less effective therapy.

For internal rewarming, many methods have been employed successfully, but heated peritoneal dialysis is used most often. Heat regular potassium-free dialysate fluid to 43.3°C (110°F) by running it through a blood-warming coil immersed in a bucket of water at 54.4°C (130°F). Add hot water to the pail as needed to keep the water at the proper temperature. (If time permits, the fluid may be heated in a water bath.)

Run in two liters of fluid as rapidly as possible—in about 10 minutes—and then immediately remove it via the same trocar. Repeat the exchange as necessary. Usually six exchanges (12 liters of fluid) are sufficient, but one patient required 18 liters of heated fluid to bring the core temperature from 26.7°C (80°F) to 35.6°C (96°F).

Because you need to dialyze the patient for only about two hours, the risk of infection is lower than for longer or repeated dialysis. But culture the first, fifth, and tenth exchanges.

Other effective techniques for internal rewarming are of limited usefulness because they require an expertise not readily available in many community hospitals. Examples are cardiopulmonary bypass and femoral A-V shunt.

Internal rewarming techniques that have proved ineffective when used alone include warmed IV fluids, hot enemas, and heated inspired air. These techniques are good adjuncts to other rewarming methods.

Peritoneal dialysis in hypothermia

Rewarming hypothermia victims by peritoneal dialysis gets the heat to the core of the body where it is needed most. The dialysate fluid is heated to about 43.3°C (110°F) by running it through a blood-warming coil that is submerged in a bucket of hot water. Two liters of dialysate are run in and then are immediately withdrawn.

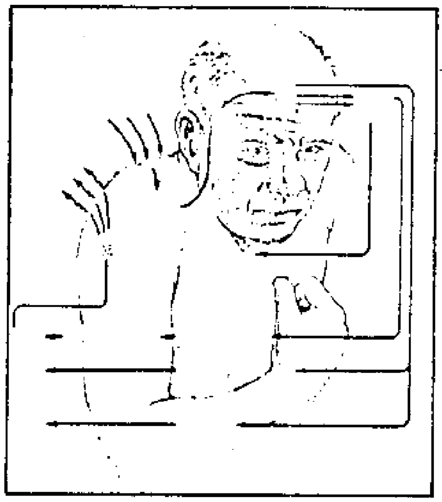
EXPRESS STOP

During and after rewarming: Continue respiratory support, correction of volume, and monitoring temperature, ECG, blood gases, and serum electrolytes. Obtain any other tests that you feel are necessary. Correct acidosis cautiously. Most cardiac problems resolve spontaneously, but lidocaine HCl may be indicated for ventricular premature contractions. Defibrillation only works on warm hearts. Ensure adequate renal perfusion, using mannitol if necessary. Complications such as pneumonia or renal failure will occur by the fifth day.

The physiology of hypothermia

What happens as the body loses heat? The cutaneous sensors for hot and cold send their messages to the hypothalamus, which serves as a "computer" for temperature regulation; the information is integrated, and impulses are transmitted to the various effector organs to correct for heat loss or gain. When the body comes in contact with a cold environment, the somatic and autonomic nervous systems and the endocrine systems are all involved with counteracting the cooling process. If these responses fail and the body continues to cool below 34.4°C (94°F), the metabolic rate slows, oxygen consumption decreases, and heart rate slows.

Two of the defense mechanisms against the cold—vasoconstriction and shivering—are of particular concern clinically because of their roles in the development of alterations in pH, electrolytes, and volume. Vasoconstriction causes fluid to move from the periphery of the body, where heat is easily transferred to the environment, to the core, thereby preventing heat loss. The body interprets this shift as overhydration and shuts off the production of antidiuretic hormone. The resulting diuresis produces volume depletion. In most cases, the individual does not replace the lost fluid.



Shivering, an involuntary muscle contraction that is sometimes violent, produces a considerable amount of heat. Shivering may elevate the basal metabolic rate five times, increasing the muscles' need for oxygen and glucose. Lactic acid and other metabolites accumulate.

When the body cools enough for the metabolic rate to slow down, oxygen supply is depressed, contributing to metabolic acidosis. Cardiac irritability occurs, in part due to electrolyte imbalance and the slowed heart rate. At this point, the individual exhibits the symptoms of a slowed metabolic rate—altered consciousness and incoordination, eventually coma.

The longer the body is cold, the more severe the metabolic alterations. The patient whose heat loss is acute due to cold water immersion exhibits only the effects of a slowed metabolism. On the other hand, the patient with slow heat loss from exposure exhibits severe disturbances of pH and electrolytes as well as of volume. These abnormalities are often aggravated by an underlying condition such as diabetic ketoacidosis or alcohol intoxication.

During rewarming, continue respiratory support, correction of volume, and monitoring of temperature, ECG, blood pressure, blood gases, and serum electrolytes. A determination of serum or urine osmolality will help you monitor volume. Other helpful tests to follow include CBC, platelet count, prothrombin, fibrinogen, BUN, and serum glucose, amylase, calcium, and creatinine determinations.

After rewarming the patient, obtain chest X-rays to check for pneumonia and skull X-rays to rule out any head injury.

Most victims of hypothermia are in metabolic acidosis. (A caution: Patients who have undergone considerable stress may [rarely] exhibit a Curling's ulcer and alkalosis.) Blood gas and electrolyte measurements change rapidly as rewarming progresses; get repeat readings at 15–20 minute intervals for an hour, then as often as you feel is necessary. Remind the lab to correct blood gas readings for temperature. Correct the acidosis with sodium bicarbonate, but move cautiously. Do not try for normal measurements; as the patient rewarms, he will revert to normal spontaneously. Too vigorous correction may result in alkalosis.

Avoid cardiac complications by not inserting the CVP or Swan-Ganz catheter tip into the heart, by correcting volume and pH, and by *careful* rewarming. Cardiac stimulants are rarely indicated.

Atrial arrhythmia or fibrillation is a common complication of hypothermia. Sometimes the ECG exhibits a positive deflection in the ST segment—a J-wave or Osborne wave. The Q-T duration is usually prolonged. These abnormalities will make you feel you should be doing something about them, but in hypothermia, *do nothing.* Antiarrhythmic drugs are ineffective and potentially toxic; atrial arrhythmias and ECG abnormalities will resolve with rewarming.

Ventricular arrhythmias and fibrillation also may occur. The treatment of choice for ventricular premature contractions is lidocaine HCl (Xylocaine). The heart will not respond to defibrillation when the patient is cold. If fibrillation occurs, use closed chest compression during internal rewarming or put the patient on a heart-lung machine. Once the temperature reaches 32.2°C (90°F), defibrillation may work.

Ensure adequate renal perfusion, using mannitol (Osmitrol) if necessary.

Pneumonia is the most common sequela of hypothermia. It is probably a result of bronchorrhea. Manage it or any other infection that develops with appropriate antibiotics.

A concomitant injury resulting in hemorrhage may require the administration of blood. GI bleeding may be a consequence of hypothermia.

For several days—maybe even weeks—after resuscitation, the patient's temperature-regulating mechanism will function poorly, and he should avoid temperature extremes. His temperature may fluctuate 2–3°. A few patients who recover from severe hypothermia complain of temperature-regulating problems for years.

Renal failure rarely occurs if renal perfusion is maintained and hypovolemia is corrected. Hypertension is a warning sign. Very rare complications include pancreatitis, disseminated intravascular coagulation, episodes of hypotension, peritoneal infection from dialysis, ileus, psychiatric disorders, and myocardial infarction.

Hypothermia alone does not cause brain damage—even in patients who were comatose.

With mild hypothermia—over 33.3°C (92°F)—you can simply rewarm the patient and send him home, unless he has other injuries requiring treatment. The patient whose temperature is below 33.3°C (92°F) should be monitored very closely for 24 hours. Most should remain hospitalized for 3–5 days after rewarming. Complications, if they occur, usually do so by the fifth day.

As a general rule, see the patient again about a week after the injury. Further follow-up varies, depending on other injuries, such as frostbite or fractures, or underlying factors such as diabetes or alcoholism. □

REFERENCES

1. Burton AC, Edholm OG: *Man in a Cold Environment.* New York, Hafner, 1970 (reprint of 1955 ed.).
2. LeBlanc J: *Man in the Cold.* Springfield, Ill., CC Thomas, 1975 (American Lectures in Environmental Studies Series).
3. Popovic V, Popovic P: *Hypothermia in Biology and in Medicine.* New York, Grune & Stratton, 1974.
4. Robertshaw D (ed): *Environmental Physiology.* Baltimore, University Park Press, 1974 (International Review of Science–Physiology Series Vol. 7).
5. Robertshaw D (ed): *Environmental Physiology II.* Baltimore, University Park Press, 1977 (International Review of Science–Physiology Series Vol. 15).

Winter problems

When your patient suffers frostbite

Prepared in consultation with:

Cameron C. Bangs, MD
internist, Oregon City; clinical instructor of medicine, University of Oregon Medical School, Portland

John A. Boswick, Jr., MD
chief, hand surgical service, University of Colorado School of Medicine, Denver

Murray P. Hamlet, DVM
director, experimental pathology division, U.S. Army Research Institute of Environmental Medicine, Natick, Mass.

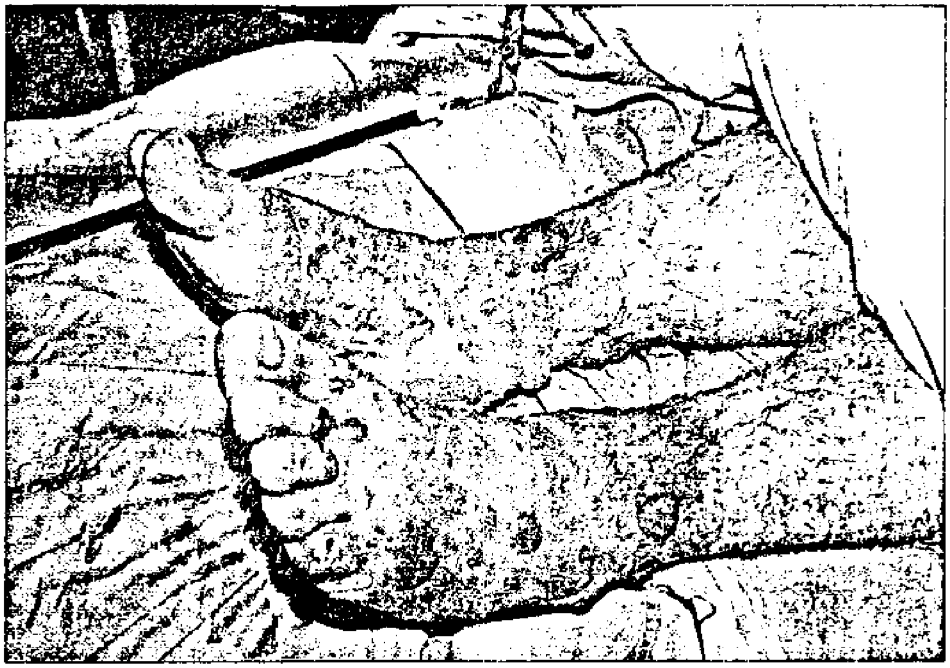
David S. Sumner, MD
professor of surgery, Southern Illinois University School of Medicine, Springfield

R.C.A. Weatherley-White, MD
assistant clinical professor of surgery, University of Colorado School of Medicine, Denver

Reviewed prior to publication by:

William J. Mills, Jr., MD
orthopedic surgeon, Anchorage, Alaska

Staff editor: Rebecca Skinner



Hazards of frostbite extend beyond winter and subtemperate zones; this patient was locked for 24 hours in a railroad refrigerator car with a temperature of −20° F (−28.9° C). His feet were most severely affected because boots constricted the circulation

With winter resorts drawing weekenders from thousands of miles away, you don't need to be in an area where temperatures dip below freezing to see patients who have suffered partial or total freezing of tissues. Anyone exposed to subfreezing temperatures without adequate protection is a candidate for frostbite. Especially at risk are sports enthusiasts—hikers, skiers, hunters, and skimobilers. Also at high risk are those individuals whose sensorium is disturbed by alcohol or other drugs.

In the following article, authorities in the care of the victims of frostbite provide a review of the fundamentals of prevention and therapy. They also discuss new modes of therapy now being investigated and current thinking on controversial procedures purported to minimize tissue loss from frostbite.

Other highlights of the article include a patient education aid, "How to avoid frostbite," on page 136, which you may reproduce for your patients; "Rapid thaw for frostbitten extremities," on page 140, describing this tissue-saving technique; and, on page 141, a concise discussion of hypothermia, the life-threatening condition that in some instances accompanies frostbite.

EXPRESS STOP

Basic treatment: Hospitalize the patient. Treatment of hypothermia (indicated by rectal temperature) has precedence over frostbite therapy. For frostbite, begin rapid rewarming in 100°-110°F (37.8°-43.3°C) water; continue rewarming until the tips of the part flush. Prescribe an analgesic for pain. The mainstay of postrewarming therapy is whirlpool baths, with an antiseptic solution added, for 20-30 minutes, 2-3 times per day. Active physical therapy helps prevent contracture. Avoid dressings.

While still frozen, even severely frostbitten tissue may appear almost normal. Frozen tissue usually looks pale and feels firm to the touch. Sometimes a slight purplish discoloration and insensitivity to light touch are the only indications that a part is frostbitten. As a rule, the patient describes the affected part as bulky or "clublike," implying numbness. He may also report that the part was very painful before it became numb. Often, however, the frostbitten area will have thawed before you see the patient. In that case, he will tell you that as the area warmed he felt throbbing, burning pain, and a "pins and needles" sensation. Blisters may not appear for a day or two after injury.

Patients with frostbite often suffer from hypothermia, the treatment of which (see page 141) takes precedence over—and sometimes conflicts with—frostbite therapy. Also examine the patient for other injuries such as fractures or dislocations.

You will not be able to judge the extent of injury when you first see the patient. To get some idea, however, take a careful history of the kind and length of exposure; ask about protection from clothing and verify the temperature and wind velocity at the time of exposure from the local weather station. Also find out about his preinjury physical condition, particularly relating to the vascular and peripheral nervous systems.

Hospitalize every frostbite victim. The first step in emergency care is *rapid* rewarming in water at 100°-110°F (37.8°-43.3°C); use a thermometer and keep the water temperature within this range (see page 140). Slower rewarming—starting with cold water and slowly adding warmer water—contributes to tissue loss. Rewarming at temperatures higher than 112°F (44.4°C) may add burn injury to the frostbite. An ear or nose may be thawed by pouring warm water over the part. Continue the rewarming process until the *tips* of the part flush, which may require 45 minutes or longer.

During rewarming, aspirin provides sufficient analgesia for some patients; others require as much as 100 mg of meperidine HCl (Demerol) or 15 mg of morphine sulfate in order to tolerate the treatment. Remember, however, that hypothermia may prolong opiate metabolism.

After rapid rewarming, the mainstay of therapy is vigorous whirlpool baths in a solution to which an antiseptic such as povidone-iodine (Betadine) or hexachlorophene has been added. Repeated for 20-30 minutes, 2-3 times a day, whirlpool therapy debrides the injury safely, alleviates pain, and helps control infection. While the patient is in the whirlpool, active, continuous, complete range-of-motion physical therapy should be done to prevent flexion contracture during the healing process.

Keep the patient hospitalized at least until you can estimate the severity of injury. Home care is satisfactory for most superficial injuries that are limited to ears, nose, and knees. More severe injuries and most injuries to hands and feet may require perhaps several months of hospitalization.

A fairly accurate estimate of extent of injury can be made by palpating the pulses, ordering a Doppler scan or technetium-99mm studies, and noting evidence of tissue demarcation and necrosis. Researchers are investigating the

The frostbitten ear: Stages in healing


1


2


3


4

1 Marked edema and blister formation denote deep frostbite. The blisters are reddish and not translucent.

2 Two days later, the area has been debrided, and the tissue underneath is red and sensitive looking.

3 Ten days after frostbite, areas of thick black crusts appear.

4 Two weeks postfrostbite, it is obvious that no tissue loss on the ear will ensue. This patient, however, lost all fingers on both hands as a result of his exposure to cold.

use of infrared thermography to help determine the severity of injury, make early decisions on surgery, and assess the progress of therapy.

If the feet are involved, prescribe bed rest and a cradle to keep bedclothes off the injury. Elevate frostbitten hands on pillows or with a sling. Separate frozen digits with small wedges of cotton. Avoid dressings, but loosely wrapped sterile towels are permissible to help protect the extremity. Make sure sterile sheets are used on the bed.

Forbid smoking for the patient recovering from frostbite; vasoconstriction caused by nicotine may aggravate the injury.

Authorities disagree on whether removing blisters or leaving them intact best prevents infection. All agree that puncturing the skin and allowing the blister to collapse without debriding invite infection. The patient may be more comfortable with large blisters removed. When blisters do break spontaneously, be sure to debride them to avoid overhanging edges.

Tetanus prophylaxis* is indicated for patients with frostbite, but prophylactic antibiotics are not. If signs of infection develop around the injury, do a Gram's

Folk medicine favorites

Has your knowledge of a patient's medical folk belief ever given you an insight that helped patient care? If you have an amusing or interesting anecdote that is also instructive, send it to Folklore Editor, Patient Care, 16 Thorndal Circle, P.O. Box 1245, Darien, CT 06820. If we publish it, we'll pay you $25.

*See "The who, what, and when of tetanus prophylaxis," *Patient Care*, August 1, 1976, page 144.

How to avoid frostbite

To avoid frostbite when you are exposed to subfreezing temperature, you must protect yourself against not just cold but also the conditions that increase body heat loss: moisture and wind. Because moisture conducts heat, it is of utmost importance to remain dry. Wetness, whether from rain, snow, or perspiration, speeds heat conduction away from your body.

Wind has a marked effect on heat loss. If the thermometer reads 20°F (−6.7°C) and the wind speed is 20 mph, the exposure is comparable to −10°F (−23.3°C). This is called the wind chill factor. A rough measure of wind velocity is: If you feel the wind on your face, the velocity is about 10 mph; if small branches move or dust or snow is raised, 20 mph; if large branches are moving, 30 mph; and if a whole tree bends, about 40 mph. To obtain an idea of the relative degrees of danger according to combinations of wind speed and thermometer reading, study the wind chill factor chart.

Proper clothing for winter weather provides insulation from cold, ventilation so that perspiration can evaporate, and protection against wind, rain, or snow. Rather than one bulky, heavy, or constricting garment, wear several layers of light, loose clothing that will trap air, a very effective insulator, and provide adequate ventilation. Wool and polyester down substitutes retain some protective value when wet; cotton and goose or duck down do not.

For ideal protection, wear underclothing made of cotton (or cotton-lined); it will absorb perspiration. Wear layers of wool or synthetic down between underwear and the outer layer of a water-repellent and windproof covering. (Waterproof clothing is *not* recommended since it holds in the moisture produced by your body.) Protect your head and neck with a scarf and a hat or hood and your face with a mask. Wear two pairs of socks — both wool or one cotton and the other wool — and well-fitting boots high enough to protect your ankles.

Your hands are better protected by mittens than gloves, but keep in mind that since mittens limit what you can do with your fingers, you may need to remove them frequently. By wearing lightweight gloves under mittens, you will still have protection against heat loss if you remove the mittens.

Be sure that your clothing is not tight. Heat in your extremities is supplied by your blood and anything that hampers blood flow will increase the

Wind chill factor chart

Estimated wind speed (in mph)	Actual thermometer reading						
	°F (°C) 50 (10)	°F (°C) 40 (4.4)	°F (°C) 30 (−1.1)	°F (°C) 20 (−6.7)	°F (°C) 10 (−12.2)	°F (°C) 0 (−17.8)	°F (°C) −10 (−23.3)
	EQUIVALENT TEMPERATURE						
calm	50 (10)	40 (4.4)	30 (−1.1)	20 (−6.7)	10 (−12.2)	0 (−17.8)	−10 (−23.3)
5	48 (8.9)	37 (2.7)	27 (−2.7)	16 (−8.9)	6 (−14.4)	−5 (−20.6)	−15 (−26.1)
10	40 (4.4)	28 (−2.2)	16 (−8.9)	4 (−15.6)	−9 (−22.8)	−24 (−31.1)	−33 (−36.1)
15	36 (2.2)	22 (−5.6)	9 (−12.7)	−5 (−20.6)	−18 (−27.8)	−32 (−35.6)	−45 (−42.8)
20	32 (0)	18 (−7.8)	4 (−15.6)	−10 (−23.3)	−25 (−31.7)	−39 (−39.4)	−53 (−47.2)
25	30 (−1.1)	16 (−8.9)	0 (−17.8)	−15 (−26.1)	−29 (−33.9)	−44 (−42.2)	−59 (−50.6)
30	28 (−2.2)	13 (−10.6)	−2 (−18.9)	−18 (−27.8)	−33 (−36.1)	−48 (−44.4)	−63 (−52.8)
35	27 (−2.7)	11 (−11.7)	−4 (−20)	−20 (−28.9)	−35 (−37.2)	−51 (−46.1)	−67 (−55)
40	26 (−4.4)	10 (−12.2)	−6 (−21.1)	−21 (−29.4)	−37 (−38.3)	−53 (−47.2)	−69 (−56.1)
(Wind speeds greater than 40 mph have little additional effect.)	LITTLE DANGER (for properly clothed person). Maximum danger of false sense of security.				INCREASING DANGER Danger from freezing of exposed flesh.		

Note: Hypothermia, trenchfoot, and immersion foot may occur at any point on this chart.

risk of frostbite. For this same reason do not remain in a sitting or kneeling position for long periods of time.

Many people suffer frostbite when their cars break down in freezing weather. Be sure to keep protective clothing in your car if there's any risk of breakdown in an isolated area. When working on a car in the cold, avoid getting gasoline on your hands. While it doesn't freeze, it takes on the temperature of the surrounding area and cools skin by evaporation. Avoid bare skin contact with metal; don't try to make repairs without gloves.

Don't walk through the snow in low shoes. If you lack proper protective clothing, stay in the car. As a rule, a rescue team is more likely to find you if you remain close to your vehicle.

For whatever reason you're stranded in the cold, if possible use the auto heater with a window open slightly to guard against carbon monoxide poisoning or build a fire. Protect yourself from the wind as much as possible; if there is no shelter, make one with tree boughs and/or snow. But don't work so fast that you get wet from perspiration or overtired, both of which make you more susceptible to cold injury. Insulate yourself from the ground with tree boughs.

Don't drink alcoholic beverages "to keep warm." Alcohol makes your face red and gives you a warm feeling, but the warmth is deceptive. By widening the blood vessels near the surface of the skin, alcohol makes your body lose heat more quickly.

Smoking constricts your blood vessels, limiting the blood supply to your arms and legs and adds to the risk of frostbite.

F° (°C) −20 (−28.9)	°F (°C) −30 (−34.4)	°F (°C) −40 (−40)	°F (°C) −50 (−45.6)	°F (°C) −60 (−51.1)
−20 (−28.9)	−30 (−34.4)	−40 (−40)	−50 ([illegible])	−60 (−51.1)
−26 (−32.2)	−36 (−37.8)	−47 (−43.9)	−57 (−49.4)	−68 (−55.6)
−46 (−43.3)	−58 (−50)	−70 (−56.7)	−83 (−6[illegible])	−95 (−70.6)
−58 (−50)	−72 (−57.8)	−85 (−65)	−99 (−72.8)	−112 (−80)
−67 (−55)	−82 (−63.3)	−96 (−71.1)	−110 (−7[illegible].9)	−124 (−86.7)
−74 (−58.9)	−88 (−66.7)	−104 (−75.6)	−118 (−83.3)	−133 (−91.7)
−79 (−61.7)	−94 (−70)	−109 (−78.3)	−125 (−87.2)	−140 (−95.6)
−82 (−63.3)	−98 ([illegible])	−113 (−80.5)	−129 ([illegible])	−145 (−98.3)
−85 (−65)	−100 (−73.3)	−116 (−82.2)	−132 (−91.[illegible])	−148 (−100)
		GREAT DANGER		

stain and culture and prescribe antibiotics accordingly. Staphylococci, streptococci, and *Pseudomonas* are the most common infecting organisms. If an erythematous response typical of streptococcal infection appears, it is permissible to start penicillin or alternative therapy immediately and modify the regimen as culture results indicate.

Some authorities feel a patient who has undergone rapid rewarming and has no tissue loss may be discharged as soon as eschars are dry if treatments can be continued at home with a portable whirlpool.

EXPRESS STOP

New or controversial therapy: Medical sympathectomy with intra-arterial reserpine is showing promise in initial investigations. Fasciotomy is being reintroduced as therapy for frostbitten extremities that swell enough to occlude circulation. Less support can be found for the use of low-molecular-weight dextran, surgical sympathectomy, heparin, or hyperbaric oxygen.

Tissue loss from frostbite is related both to thrombosis of the microvascular nutritive vessels and to direct cellular injury from dehydration, enzymatic action, and the mechanical effect of ice crystals. Frequently, the vascular damage is the deciding factor, since damaged cells are often capable of survival if they are given an adequate blood supply. Years of research have not yet

Rapid thaw for frostbitten extremities

You can minimize tissue loss from frostbite by thawing the frozen part rapidly. The following technique is recommended by Cameron C. Bangs, MD, Oregon City internist, authority on frostbite treatment:

1. Inspect all extremities—not just the one about which the patient complains—for frostbite. Early changes may be minimal. Look for violaceous discoloration, pallor and slight swelling. Occasionally a frozen part will have a woody, hard feeling. The patient may report paresthesia and numbness.

2. Carefully remove any clothing covering affected areas so as not to inflict further tissue damage. If you encounter gloves, boots, or socks that have been frozen on, proceed with rewarming and remove the clothing when it can be done without force.

3. Totally submerge the frostbitten part in a 5-10 gallon vessel of water at 100°-110°F (37.8°-43.3°C). The part should float freely without touching the sides of the vessel. Circulate the water either manually or with a whirlpool. This photo demonstrates how to thaw all four extremities at one time. Note that the patient's heart is being monitored; be alert for arrhythmias if hypothermia accompanies frostbite.

4. Use a thermometer to monitor water temperature during the thawing process. Maintain the temperature above 100°F (37.8°C) by alternately bailing out cooler water and adding hot water. *Caution: Do not pour hot water directly on the extremity.* When more than one extremity is involved, assign one person to each container to maintain the temperature and circulate the water.

5. Continue the process until the extremity is no longer frozen and the color has returned to normal (20-45 minutes). Once the tissue has thawed, handle the part gently and with sterile technique. Advise the patient not to use the extremity.

yielded a sure way of improving the microcirculation following freezing.

Specialists in frostbite management have begun using intra-arterial reserpine to provide temporary medical sympathectomy.* It is said to achieve vasodilation without the complications of surgical sympathectomy. In one regimen, 0.5 mg of reserpine is injected intra-arterially proximal to the frostbitten limb on admission to the hospital and repeated every 2-3 days over the first week. Generally, reserpine has no systemic effect, but some vasodilation may occur in other extremities.

Phenoxybenzamine HCl (Dibenzyline) also appears to be effective in achieving medical sympathectomy.* The suggested regimen is 10 mg/day, increased gradually to 20-60 mg/day if needed.

Fasciotomy, an old treatment for frostbite, is now being reintroduced.* It is performed when swelling in a frostbitten extremity occludes circulation. The procedure increases blood flow into the extremity, a benefit that outweighs the added risk of superficial infection.

Low-molecular-weight dextran (Dextran 40, L.M.D., Rheomacrodex, etc.) is thought by some physicians to be of value in promoting microcirculation. Immediately after rewarming, they start

*Porter JM, et al: Intra-arterial sympathetic blockade in treatment of clinical frostbite. *Am J Surg* 132:625-30, 1976.

*Mills WJ: Summary of treatment of the cold injured patient. Mountain Medicine Symposium, Seattle, October 9-12, 1976.

*Mills WJ: Frostbite: A discussion of the problem and a review of an Alaskan experience. *Alaska Med* 15:27-59, 1973.

Recognizing and treating hypothermia

Any patient with a history of exposure* should have his temperature taken, preferably with a low-reading rectal thermometer. If his temperature is 94°F (34.4°C), or below, he is hypothermic, and aggressive treatment should be instituted immediately.

Find out the type and length of exposure. Acute hypothermia from rapid heat loss, such as occurs in cold water immersion, may be treated with rapid external rewarming; in chronic hypothermia, however, rapid external rewarming may be fatal. Chronic hypothermia results from a series of small heat losses. In attempting to conserve heat, blood vessels constrict and warm blood is shunted inward: the periphery of the body—40-50 percent of the body by weight—becomes volume-depleted. The periphery is also the coldest area and is the area where acid and potassium accumulate. To further complicate the situation, most victims of chronic hypothermia are dehydrated.

*The patient with hypothermia need not have been exposed to subfreezing temperatures. Wind chill, wet or insufficient clothing, or fatigue can precipitate hypothermia at temperatures well above freezing.

External rewarming causes a peripheral vasodilation. Blood from the core moves to the periphery, and cold, acidotic blood moves to the core, resulting in a drop in core temperature and pH. As blood is shunted to the periphery, a type of hypovolemic shock (rewarming shock) may develop; the end results may be cardiac arrhythmia and death.

Specialists in hypothermia management recommend a two-fold treatment consisting of volume expansion and rewarming from the core out. Any type of volume expander may be used. Methods used for rewarming include heated peritoneal dialysis, administering warm fluids IV, heated extracorporeal circulation (taking blood out, heating it, and putting it back in), or heating inspired air. When rewarming from the core out is not feasible, authorities recommend warming only the trunk and not the extremities.

The patient recovering from hypothermia should be monitored for cardiac arrhythmias, the usual cause of death in hypothermia. Blood gases, serum potassium, and serum glucose also should be followed closely.

Instructions for your patient*

Emergency treatment for frostbite

How to tell if it's frostbite
If you're caught out in severe cold without adequate protection, you may end up with frostbite. You can tell if part of your body is frostbitten by the way it feels. If it feels numb—what many people describe as "clublike" or bulky—freezing of tissue has probably occurred. Some people report the part was painful at first, then became numb; however, don't think that because you feel no pain, you are not getting frostbitten.

What to do about it
Get to a physician or hospital as soon as possible. Only if you can't get medical help should you attempt to thaw frozen tissue yourself, and even then *only when you have reached shelter where there will be no chance of the part being refrozen.* Having a part of your body frozen solid for several hours poses much less risk of severe injury than improper thawing or refreezing after thawing.

Protect the frozen part. Don't rub it to restore circulation, and especially do not rub it with snow, which only adds to the damage. Massage increases the injury to frozen tissue. If you suspect your foot is frostbitten, avoid walking on it. However, if being carried will delay your getting to a medical facility by several hours, it is better to walk on it.

If you must thaw the part yourself (remember, do so only if there is no chance of its refreezing), follow this procedure to minimize tissue damage: Immerse the part in water at 100°-110°F (37.8°-43.3°C); if a thermometer is not available, keep the water at a temperature that feels comfortably hot to *normal* tissue; continue the rewarming until the tips of your toes or fingers flush; a foot takes 20-45 minutes to thaw. There may be pain as the part gets warm.

Do not immerse the injured part in cold water and add warmer water gradually.

Do not put the affected part in a warm oven, close to a heat source, or in water hotter than normal tissue can stand (over 112°F or 44.4°C). Frozen tissue loses its ability to feel; you can add a burn to the frostbite injury without feeling it.

If blisters form quickly after thawing, do not try to break them. Also, do not put bandages, salves, or ointments on the part. Separate thawed fingers and toes with wedges of cotton or small pieces of clean cloth. And, if necessary, while traveling to a medical facility, protect the part from refreezing with towels or blankets.

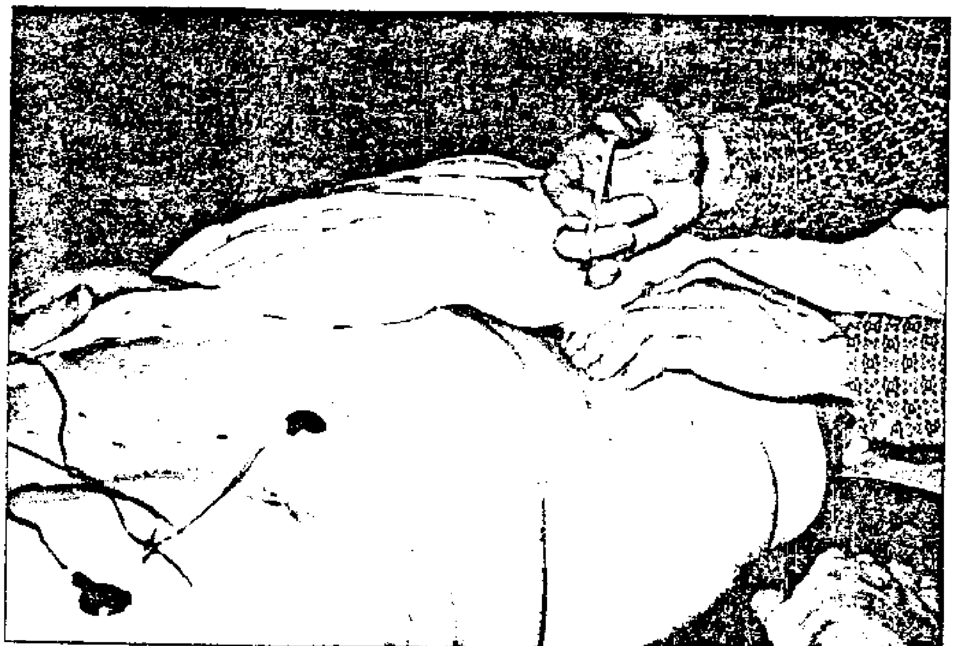
low-molecular-weight dextran, giving 1.5 gm/kg IV on the first day, followed by 0.75 gm/kg IV daily for five days. The rationale for the use of low-molecular-weight dextran is that it may stimulate flow in the damaged capillaries and venules if begun within hours of the thaw. Some authorities—because they feel there is insufficient clinical evidence supporting efficacy, and because dextran infusion is not without risk—recommend dextran for only those patients in whom tissue loss is likely.

Surgical sympathectomy as an early measure (24-48 hours after injury) is supported by only a few experts in frostbite treatment. Advocates of early sympathectomy contend that the procedure relieves vasospasm and results in more rapid resolution of edema and earlier distal demarcation. Opponents counter that possible adverse effects of sympathectomy such as impotency are too great a penalty for the possible benefits.

Administration of an anticoagulant such as heparin may be helpful, but its use is controversial. Diathermy, in the experience of some physicians, only increases tissue loss, and the use of hyperbaric oxygen has not been established as efficacious.

EXPRESS STOP

Prognosis: The course of recovery depends on the extent of injury. Permanent tissue loss is unlikely with superficial or partial-thickness skin loss injury. Deeper injuries may require grafting or amputation. Most victims of frostbite experience sequelae; the treatment of this postfrostbite syndrome is largely symptomatic and supportive, although medical sympathectomy shows promise.



To provide vasodilation, reserpine may be injected in the femoral artery of a patient with a frostbitten foot, lessening pain and paresthesia. Administer it immediately after the part thaws.

In a superficial injury, swelling and tenderness subside over a period from several days to several weeks. Fingertips or toe tips may heal in a few days to a week, but if the entire foot is involved, the patient may require bed rest for three weeks or more. Skin peeling may occur.

With partial-thickness skin loss, blisters form anywhere from minutes to hours after the injury and enlarge for several days. After 5-10 days, if they have not been punctured, they become soft and rupture; infection is likely to occur at this point. Thick black crusts may develop and separate, leaving reddish, sometimes sensitive skin. Joints usually stiffen.

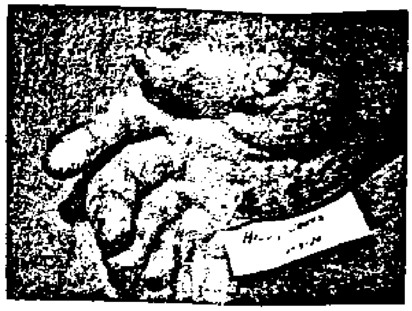
In a deep injury with full-thickness skin loss, blisters, if present, are small and dark colored and situated proximally. They do not extend to the tips of the digits. (Lack of blisters is usually a poor prognostic sign.) The skin becomes black and develops a tough eschar, which may require incision to prevent constriction. When the eschar separates, a layer of granulation tissue will be left. If there is a large area of involvement, it may necessitate grafting, and, possibly, amputation.

When the injury extends into the muscle and bone, there are no blisters and no edema. The part remains cold and bloodless; it is senseless, and the patient is unable to move it. The skin becomes dark and loses volume. In time the part will amputate itself; however, most patients prefer surgery to autoamputation. Surgical intervention too early may result in more tissue loss than is necessary. Do not consider amputation for at least six weeks after frostbite injury unless there is infection present or there is a clear line of demarcation of destroyed tissue.

Regardless of the degree of injury, any patient with frostbite may develop paresthesia, cold sensitivity, excess sweating, causalgia, and symptoms similar to Raynaud's syndrome. In deeper injury, bone and joint changes

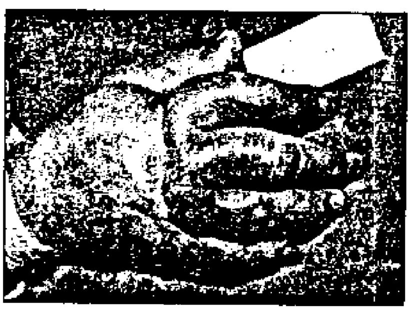
Severe frostbite of the hands: Admission to amputation

Frostbite is apparent on the patient's left hand, shown shortly after hospital admission.

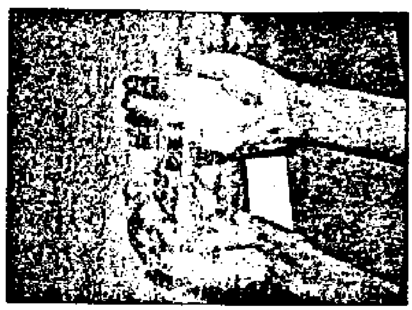


The thumb of the same patient's right hand has an early, large dark-red blister and was the only digit to be saved in total.

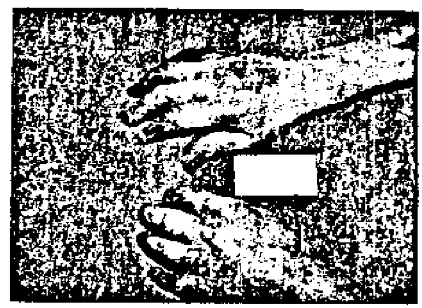
Note the debrided area and continuing cyanosis of the left-hand fingers.



Note the unpunctured blister on the thumb of the right hand, three days postadmission.



Twelve days after admission, areas of necrosis can be seen on the palmar surfaces of both hands, but no lines of demarcation are as yet clear.



The dorsal aspect of the hands also shows areas of necrosis but no clear-cut lines of demarcation.

One month later, the right thumb is healing; lines of demarcation are clearly seen on all other digits.

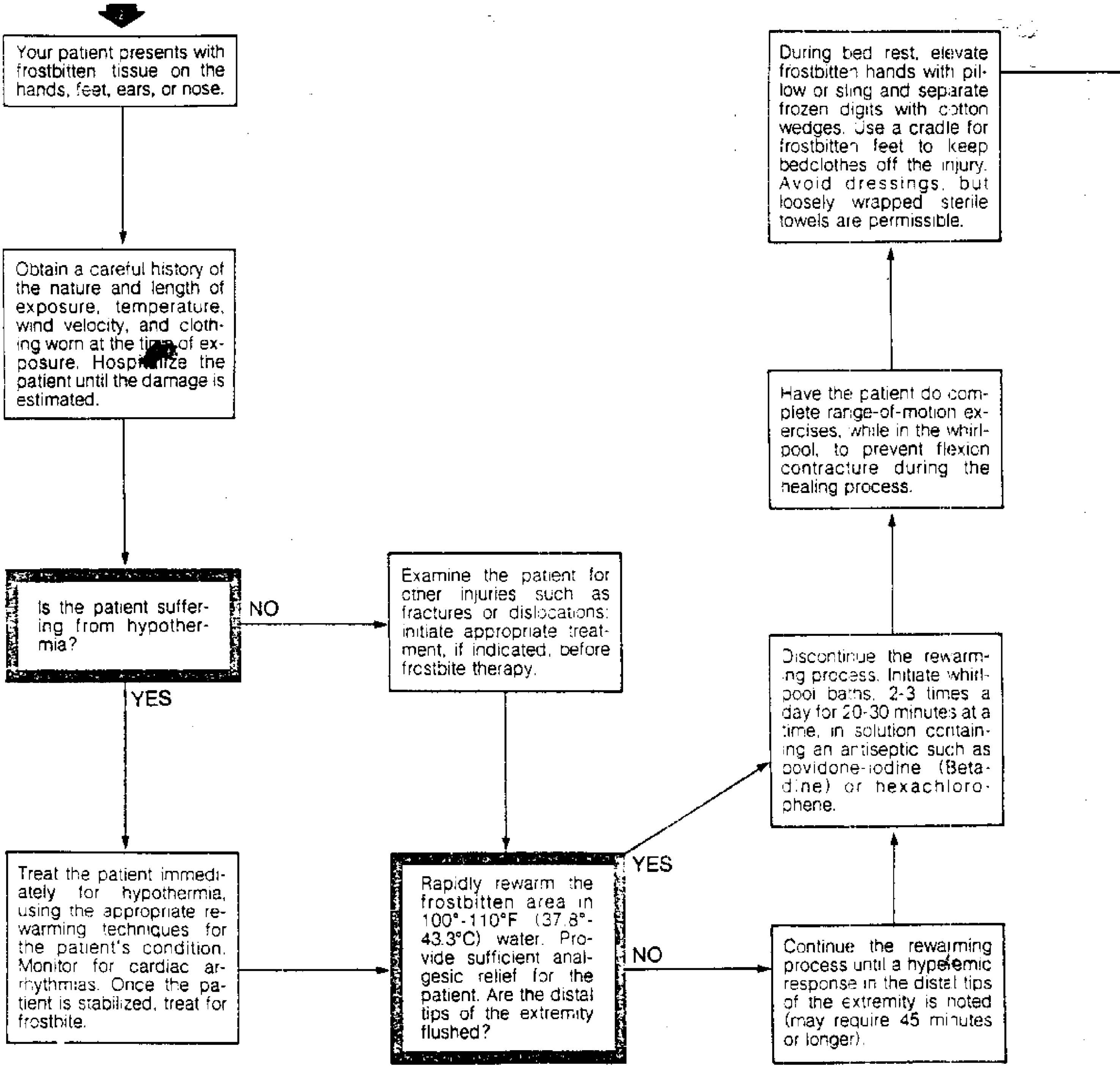
In this photo of the patient's hands after surgical amputation, note that the only digit retained in full is the right thumb.

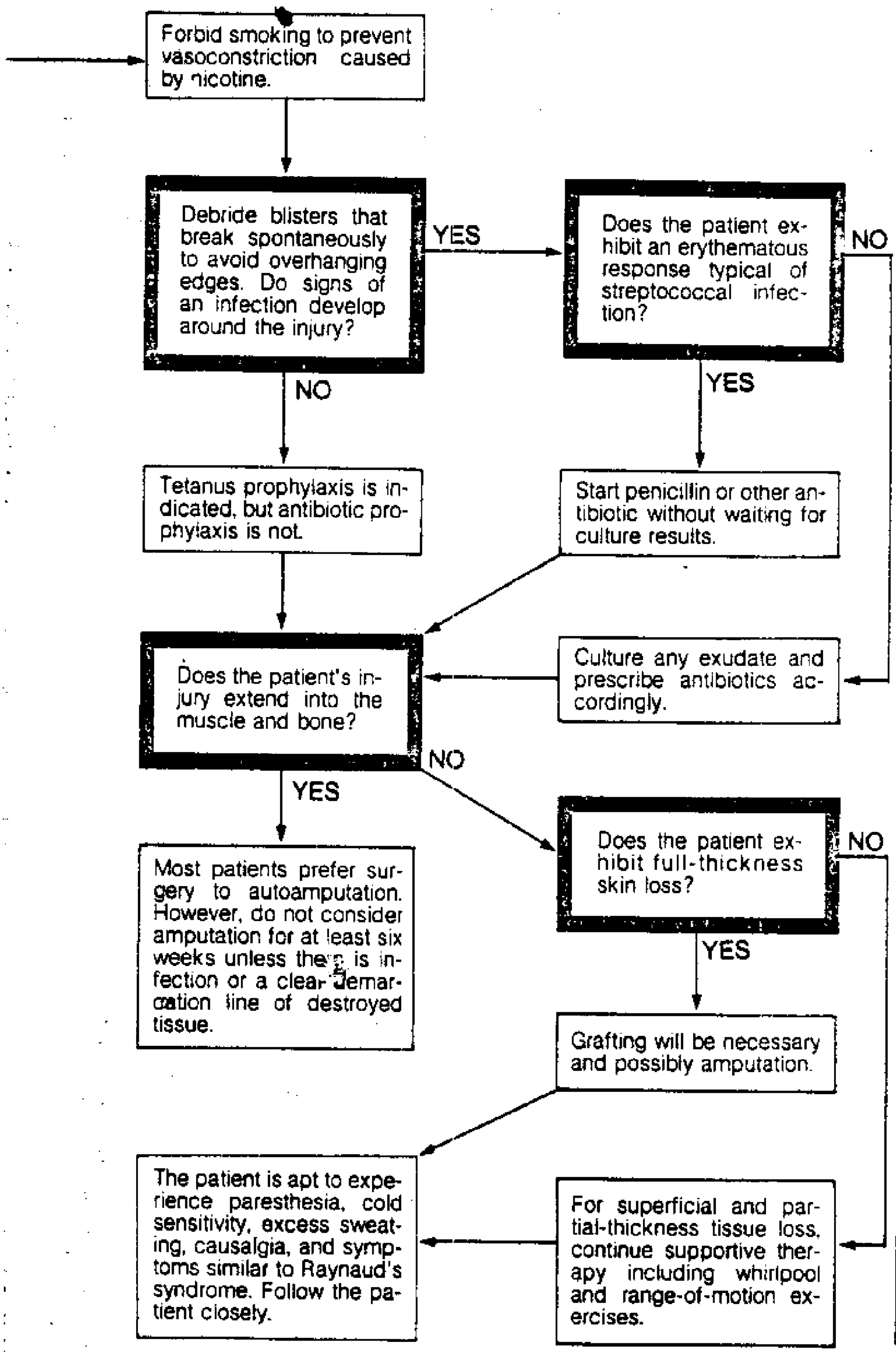
continued

patient FlowChart

TREATING FROSTBITE

(Decision points in heavy outline)





may occur, including small, punched-out areas in the bone. Loss of subcutaneous tissue, which may also occur, will result in a reduction of sensitivity in the affected part.

Treatment of frostbite sequelae is largely supportive and symptomatic, but researchers are investigating the use of intra-arterial reserpine in the postfrostbite syndrome. Initial reports show gratifying results, with most patients obtaining instant, lasting relief.

When frostbite involves the epiphyses in a child, you can expect growth impairment. In black patients loss of pigmentation is not uncommon; in milder cases, this will be temporary, but in more severe cases, it may be permanent. □

REFERENCES

1. Dinep M: Cold injury: A review of current theories and their application to treatment. *Conn Med* 39:8-10, 1975.
2. Gage AA, Ishikawa H, Winter PM: Experimental frostbite and hyperbaric oxygenation. *Surgery* 66:1044-50, 1969.
3. Gralino BJ, Porter JM, Rosch J: Angiography in the diagnosis and therapy of frostbite. *Radiology* 119:301-5, 1976.
4. Holm PC, Vanggaard L: Frostbite. *Plast Reconstr Surg* 54:544-51, 1974.
5. Kyösola K: Clinical experiences in the management of cold injuries: A study of 110 cases. *J Trauma* 14:32-6, 1974.
6. Meriwether WD, Goodman RM: Severe accidental hypothermia with survival after rapid rewarming. *Am J Med* 53:505-10, 1972.
7. Mills WJ: Out in the cold. *Emergency Med* 8:134-9, 142, 144-7, Jan 76.
8. Snider RL, Porter JM: Treatment of experimental frostbite with intra-arterial sympathetic blocking drugs. *Surgery* 77:557-61, 1975.

Leading causes of all deaths

Cause	No. of Deaths	Death Rate*
All Ages	1,899,597	878
Heart disease	718,850	332
Cancer	386,686	179
Stroke**	181,934	84
Accidents	**103,202**	**48**
Motor-vehicle	49,510	23
Falls	13,773	6
Drowning	7,126	3
Fires, burns	6,357	3
Other	26,436	13
Under 1 Year	46,975	1,485
Anoxia	10,604	335
Congenital anomalies	8,420	266
Complications of pregnancy and childbirth	5,786	183
Immaturity	3,714	117
Pneumonia	1,665	53
Accidents	**1,173**	**37**
Ingestion of food, object	275	9
Motor-vehicle	253	8
Mech. suffocation	206	6
Fires, burns	159	5
Other	280	9
1 to 4 Years	8,307	69
Accidents	**3,297**	**27**
Motor-vehicle	1,219	10
Drowning	650†	5
Fires, burns	608	5
Ingestion of food, object	168	1
Falls	121	1
Other	531	5
Congenital anomalies	1,066	9
Cancer	631	5
5 to 14 Years	12,579	35
Accidents	**6,305**	**17**
Motor-vehicle	3,142	9
Drowning	1,110†	3
Fires, burns	550	1
Firearms	344	1
Other	1,159	3
Cancer	1,733	5
Congenital anomalies	676	2
15 to 24 Years	47,986	117
Accidents	**25,619**	**63**
Motor-vehicle	18,092	44
Drowning	2,150†	5
Poison (solid, liquid)	709	2
Firearms	665	2
Other	4,003	10
Suicide	5,565	14
Homicide	5,196	13
25 to 44 Years	103,042	182
Accidents	**23,460**	**42**
Motor-vehicle	13,031	23
Drowning	1,690†	3
Poison (solid, liquid)	1,349	2
Fires, burns	1,081	2
Falls	956	2
Other	5,353	10
Cancer	16,753	30
Heart disease	14,392	25
45 to 64 Years	437,795	1,000
Heart disease	153,652	351
Cancer	132,514	303
Stroke**	22,926	52
Accidents	**19,167**	**44**
Motor-vehicle	8,000	18
Falls	2,245	5
Fires, burns	1,481	4
Drowning	940†	2
Surg. complications	865	2
Other	5,636	13
Cirrhosis of liver	17,166	39
Suicide	8,368	19
65 to 74 Years	445,595	3,054
Heart disease	182,354	1,250
Cancer	115,[illegible]87	792
Stroke**	37,896	260
Diabetes mellitus	9,611	66
Accidents	**9,006**	**62**
Motor-vehicle	3,060	21
Falls	1,995	14
Fires, burns	843	6
Surg. complications	767	5
Ingestion of food, object	447	3
Other	1,891	13
Pneumonia	8,335	57
Cirrhosis of liver	6,208	43
75 Years and Over	797,318	8,941
Heart disease	366,141	4,106
Stroke**	116,753	1,309
Cancer	116,675	1,308
Pneumonia	30,487	342
Arteriosclerosis	23,683	266
Accidents	**15,175**	**170**
Falls	7,762	87
Motor-vehicle	2,713	30
Surg. complications	1,030	12
Fires, burns	1,023	11
Ingestion of food, object	723	8
Other	1,924	22
Diabetes mellitus	13,993	157
Emphysema	6,190	69

Source: Deaths are for 1977, latest official figures from National Center for Health Statistics, Public Health Service, U.S. Department of Health, Education and Welfare.
*Deaths per 100,000 population in each age group. Rates are averages for age groups, not individual ages.
**Cerebrovascular disease
†Partly estimated.

Accidents vs other causes of death

Accidents are the leading cause of death among all persons aged 1 to 38. Among persons of all ages, accidents are the fourth leading cause of death. The following table shows the number of deaths and death rates for all ages and selected age groups by leading causes in 1977 (latest official figures) separately for male and female.

For youths aged 15 to 24 years, accidents claim more lives than all other causes combined, and about five times more than the next leading cause of death. Four out of five accident victims in this group are males.

Cause	Number of Deaths			Death Rates*		
	Total	Male	Female	Total	Male	Female
All Ages						
All Causes	**1,899,597**	**1,046,243**	**853,354**	**877.8**	**993.9**	**766.0**
Heart disease	718,850	396,482	322,368	332.2	376.6	290.1
Cancer	386,686	210,459	176,227	178.7	199.9	158.6
Stroke (cerebrovascular disease)	181,934	77,351	104,583	84.1	73.5	94.1
Accidents	**103,202**	**71,935**	**31,267**	**47.7**	**68.3**	**28.1**
Motor-vehicle	49,510	35,804	13,706	22.9	34.0	12.3
Falls	13,773	7,226	6,547	6.4	6.9	5.9
Drowning	7,126	6,006	1,120	3.3	5.7	1.0
Fires, burns	6,357	3,866	2,491	2.9	3.7	2.2
Poison (solid, liquid)	3,374	2,024	1,350	1.6	1.9	1.2
Pneumonia	49,889	27,109	22,780	23.1	25.8	20.5
Diabetes mellitus	32,989	13,632	19,357	15.2	12.9	17.4
Cirrhosis of liver	30,848	20,167	10,681	14.3	19.2	9.6
Arteriosclerosis	28,754	11,648	17,106	13.3	11.1	15.4
Suicide	28,681	21,109	7,572	13.3	20.1	6.8
Homicide	19,968	15,355	4,613	9.2	14.6	4.2
Emphysema	16,376	12,594	3,782	7.6	12.0	3.4
1 to 14 Years						
All Causes	**20,886**	**12,620**	**8,266**	**43.1**	**51.0**	**34.8**
Accidents	**9,602**	**6,275**	**3,327**	**19.8**	**25.4**	**14.0**
Motor-vehicle	4,361	2,677	1,684	9.0	10.8	7.1
Drowning	1,760	1,330	430	3.6	5.4	1.8
Fires, burns	1,158	642	516	2.4	2.6	2.2
Firearms	391	308	63	0.8	1.2	0.3
Cancer	2,364	1,407	957	4.9	5.7	4.0
Congenital anomalies	1,742	902	840	3.6	3.6	3.5
Homicide	766	421	345	1.6	1.7	1.5
Pneumonia	687	365	322	1.4	1.5	1.4
Heart disease	545	282	263	1.1	1.1	1.1
Meningitis	294	181	113	0.6	0.7	0.5
15 to 24 Years						
All Causes	**47,986**	**35,620**	**12,366**	**117.1**	**172.7**	**60.7**
Accidents	**25,619**	**20,101**	**5,518**	**62.5**	**97.5**	**27.1**
Motor-vehicle	19,092	13,794	4,298	44.1	66.9	21.1
Drowning	2,150	1,950	200	5.2	9.5	1.0
Poison (solid, liquid)	709	505	204	1.7	2.4	1.0
Firearms	665	592	73	1.6	2.9	0.4
Suicide	5,565	4,492	1,073	13.6	21.8	5.3
Homicide	5,196	3,992	1,204	12.7	19.4	5.9
Cancer	2,672	1,665	1,007	6.5	8.1	4.9
Heart disease	1,035	646	389	2.5	3.1	1.9
75 Years and Over						
All Causes	**797,318**	**355,616**	**441,702**	**8,940.5**	**10,982.6**	**7,778.4**
Heart disease	366,141	158,068	208,073	4,105.6	4,881.7	3,663.3
Stroke (cerebrovascular disease)	116,753	43,075	73,678	1,309.2	1,330.3	1,297.1
Cancer	116,675	60,435	56,240	1,308.3	1,866.4	990.1
Pneumonia	30,487	14,754	15,733	341.9	455.7	277.0
Arteriosclerosis	23,683	8,728	14,955	265.6	269.5	263.3
Accidents	**15,175**	**7,023**	**8,152**	**170.2**	**216.9**	**143.6**
Falls	7,762	2,980	4,782	[illegible]	92.0	84.2
Motor-vehicle	2,713	1,622	1,091	30.4	50.1	19.2
Surg. complications	1,030	532	498	11.5	16.4	8.8
Fires, burns	1,023	503	520	11.5	15.5	9.2
Diabetes mellitus	13,993	4,732	9,261	156.9	146.1	163.0
Emphysema	6,190	4,891	1,299	69.4	151.1	22.9

Source: National Center for Health Statistics. *Deaths per 100,000 population.