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Trismus in cold-stunned Kemp's ridley (*Lepidochelys kempii*) and loggerhead (*Caretta caretta*) sea turtles

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OBJECTIVE
To describe the presentation, clinical findings, diagnosis, treatment, and outcome of cases of trismus (lockjaw) in cold-stunned sea turtles.

ANIMALS
4 Kemp's ridley (*Lepidochelys kempii*) and 1 loggerhead (*Caretta caretta*) sea turtle.

METHODS
Cold-stunned sea turtles that presented with difficulty or inability to open their jaw between 2009 and 2023 were included. Information retrieved from medical records included signalment, physical exam findings, diagnostic information, definitive diagnosis via either advanced imaging or histopathology, treatment, and clinical outcome.

RESULTS
Turtles presented between 4 and 48 days into rehabilitation. Three were diagnosed by advanced imaging (CT or MRI), and 2 were diagnosed based on clinical signs and postmortem histopathology. Treatment was multimodal and consisted of antibiotics (5/5), nonsteroidal anti-inflammatories (5/5), vitamin E (3/5), intralesional steroid therapy (3/5), acupuncture (3/5), antifungals (2/5), anti-inflammatory parenteral steroids (2/5), physical therapy (2/5), therapeutic laser (2/5), and supportive feeding via either total parenteral nutrition (1/5), or tube feedings (2/5). Two animals were released, 2 died naturally, and 1 was euthanized.

CLINICAL RELEVANCE
Trismus (lockjaw) is an uncommon finding in stranded cold-stunned sea turtles that can have a significant impact on animal welfare if not diagnosed and treated. This report describes the condition to aid clinical case management and resource allocation in rehabilitation facilities.

Keywords: trismus, sea turtle, jaw, myositis, acupuncture

Nearly all species of sea turtle are classified as endangered by the International Union for Conservation of Nature,[1] with the Kemp's ridley sea turtle (*Lepidochelys kempii*) classified as Critically Endangered and the loggerhead sea turtle (*Caretta caretta*) as Vulnerable and decreasing. Both species inhabit the coastal waters of the eastern US and the Gulf of Mexico and are commonly seen in rehabilitation facilities for a variety of conditions.[2,3] Hundreds to thousands of sea turtles are found stranded in the US annually secondary to cold-stunning, which occurs following exposure to atypically cold environmental temperatures.[4–9] Chronic cold-stunning may

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lead to significant debilitation and secondary infections including bacterial pneumonia, osteomyelitis, and sepsis.[10–13]

Trismus (lockjaw), defined as restricted opening of the mouth, is most commonly caused by contraction of the muscles of mastication secondary to inflammation (myositis) or infection.[14,15] Many joint and nerve abnormalities localized to the head and neck can cause a similar presentation. Differential diagnoses include immune-mediated diseases such as masticatory muscle myositis; temporomandibular joint diseases such as ankylosis, arthritis, infection, and trauma; or extra-articular causes such as space-occupying lesions, abscesses, or hematomas leading to nerve trauma or pain.[15,16] Diagnosis is typically based on clinical signs and advanced imaging (CT or MRI, with MRI preferred due to superior soft tissue resolution).[15] Treatment is based on the underlying condition but may include analgesics, muscle relaxants, and/or heat and physical therapy.[17] While there are no peer-reviewed reports of trismus in stranded sea turtles, it has been briefly mentioned in sea turtle medical textbook chapters.[18,19] Most cases are treated based on clinical signs without a definitive diagnosis, and most animals survive (B Stacy, DVM, DACVP, National Marine Fisheries Service, and D Mader, DVM, The Turtle Hospital, email, May 2023). Trismus has been seen in stranded, large juvenile loggerhead sea turtles and a Kemp's ridley sea turtle.[18] The latter case was successfully treated after diagnosis of unilateral myositis of the adductor mandibulae musculature[18] and is one of the cases included in the present case series (case 1). Inflammatory or degenerative conditions of the tissues of the head and neck can cause trismus, and several such conditions have been described in sea turtles. Iatrogenic trauma caused by external jugular venipuncture could also contribute to muscular damage in this region. Cervical steatitis secondary to trauma, septicemia, or metabolic oxidation affects approximately 1% of cold-stunned Kemp's ridley sea turtles and could present as trismus.[9] A cold-stunned subadult loggerhead sea turtle that presented with stertorous breathing secondary to unilateral laryngeal paralysis was diagnosed at necropsy with idiopathic unilateral myofiber atrophy of the abductor arytenoideae muscle, suspected to be secondary to denervation atrophy.[20]

This retrospective case series details the clinical presentation, diagnostic imaging findings, histopathologic diagnoses, treatment modalities, and outcomes for 5 cases of trismus in hospitalized Kemp's ridley and loggerhead sea turtles from the eastern US. The data presented herein will inform diagnosis, clinical case management, and resource allocation for veterinarians and rehabilitators invested in sea turtle stranding response.

Methods

Ethical statement

Rehabilitation of sea turtles at the New England Aquarium during the years included in this study was authorized by the US Fish and Wildlife Service by Permits TE-697823 and ES69328D and at the National Aquarium by Permit TE-70312D.

Case selection criteria

Clinicians at sea turtle rehabilitation facilities along the eastern coast of the US were emailed in 2023 regarding cases of trismus in sea turtles previously in their care. Responses were received from veterinarians at the New England Aquarium, National Aquarium, North Carolina Aquariums, Karen Beasley Sea Turtle Rescue and Rehabilitation Center, South Carolina Aquarium, Georgia Sea Turtle Center, and The Turtle Hospital. Six cases of trismus were identified via memory of individual clinicians and medical database searches, with 3 facilities having no recorded cases and 1 facility having several cases in clinician memory but no longer having access to medical records (records were destroyed by a hurricane). Inclusion criteria for the present study included clinical evidence of trismus or signs of jaw pain and advanced diagnostic imaging (CT or MRI) or histopathologic evidence of disease in the head or neck. These criteria limited cases to those from the New England Aquarium and the National Aquarium, all of which were initially stranded due to cold-stunning. All included cases occurred between 2009 and 2023 and are presented in chronological order.

Consistent with established practices and common disease conditions, cold-stunned turtles were gradually warmed and reintroduced to water; assessed through physical examination, clinical pathologic analyses, and serial radiographs; and treated with parenteral fluid therapy, antibiotics, and nutritional support as needed.[21] Additional individual treatment plans were established based on cumulative clinical data. Herein we provide detailed descriptions as relevant to trismus diagnosis and management and only brief descriptions regarding important comorbidities and their management. Details of parenteral fluid therapy often vary daily based on physiologic status and are thus only summarized. The number of blood samples obtained by jugular venipuncture before the evaluation of trismus was recorded for each case to consider the potential for iatrogenic causes of cervical tissue injury. Treatment durations and intervals were determined relative to the date of initial rescue.

Results

Case 1

A 2.5-kg juvenile cold-stunned Kemp's ridley sea turtle was evaluated on day 48 of rehabilitation when staff noted that the animal had started to show interest in voluntary feeding but appeared reluctant or unable to open its mouth. The animal had been evaluated previously on day 12 of rehabilitation due to weakness and resting at the surface and was diagnosed with severe pneumonia via radiographs and tracheal lavage and treated with antimicrobials **(Supplementary Table S1)**. Blood culture was negative. Due to poor body condition and anorexia, tube

feeding was initiated every other day (10 mL/kg herring filet gruel, 25 mg/kg calcium carbonate, and Sea Tab B.T.F.S. multivitamin one-fourth tablet, days 11 to 47). For tube feeding, the mouth was opened manually by clinicians, a modified Nylabone (Central Garden & Pet Company) was used as a speculum to keep the mouth open, and a 14-French red-rubber catheter was passed to the distal esophagus or stomach. At the time of evaluation for trismus, hematologic and plasma biochemical analysis revealed a severely elevated creatine kinase (CK; 93,141 U/L), AST (1,337 U/L), LDH (> 36,000 U/L), and mild hypoproteinemia (total protein, 2.7 g/dL). Physical examination detected an apparent pain response characterized by muscle tremors of the flippers and withdrawal of the head during palpation of the caudal mandibular region. Skull and cervical radiographs were unremarkable. Seventeen jugular venipuncture procedures had been performed before trismus presentation. The condition was suspected to be caused or exacerbated by restraint of the jaw, so tube feedings and oral medications were discontinued and meloxicam (0.4 mg/kg, IM, q 24 h) was prescribed. Eight days later, the turtle remained interested in food but was unable to open its mouth wide enough to consume sufficient food mass. The turtle was anesthetized for oral evaluation, during which clinicians noted difficulty opening the mouth > 3 cm. The anesthesia doses were ketamine 5 mg/kg IV and medetomidine 0.05 mg/kg IV. Vitamin E/selenium (0.065 mg/kg selenium, 3.25 mg/kg vitamin E, IM, once weekly) and daily subcutaneous fluids (1 part lactated Ringer solution: 2 parts 2.5% dextrose and 0.45% saline; 10 mL/kg, q 24 h, days 49 to 76) were prescribed, and a single dose of methylprednisolone sodium succinate (0.8 mg/kg per site, 1.6 mg/kg total) was injected into the region of each jaw joint. True intraarticular injection could not be confirmed. Meloxicam was discontinued. Computed tomography and MRI were performed 2 days later and interpreted by a board-certified veterinary radiologist (JOB), using gadopentetate dimeglumine contrast (100 mg/kg, IV) for MRI. Computed tomography did not reveal an obvious cause for the observed clinical signs. Magnetic resonance imaging findings were consistent with right temporal and dorsal cervical muscle myositis, including marked inhomogeneous T2 hyperintensity of the temporalis muscle and right dorsal aspect of the neck to the level of the third cervical vertebra with marked inhomogenous enhancement **(Figure 1)**. The next day, acupuncture treatment was initiated by a Licensed Acupuncturist (CAM) and was continued weekly for a total of six 15- to 20-minute treatments. Acupuncture channels with fascial connections to the lateral head and jaw were activated using sterile 40-gauge filiform needles inserted less than 5 mm deep. Acupuncture points were located on the head, latissimus dorsi, between the radius and ulna, at the head of the fibula, and on the extremities of the limbs. Each treatment included extrapolated meridian points from the following list: LI4, TW5, GB21, ST4, GV20, GB32, GB34, ST 36, ST44, and LV3.

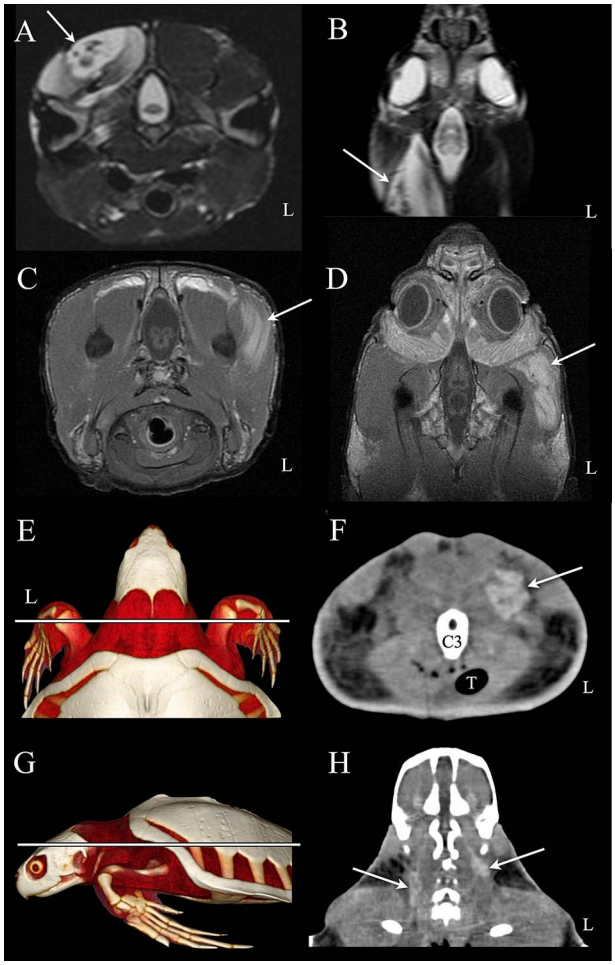

Figure 1—Precontrast T2-weighted MRI axial (A) and coronal (B) images of asymmetrical inhomogenous hyperintensity of the right temporal and dorsal cervical musculature (white arrows) consistent with myositis in a Kemp's ridley sea turtle (*Lepidochelys kempii*, case 1). Contrast enhancing T1-weighted MRI axial (C) and coronal (D) views of asymmetrical homogenous hyperintensity of the left temporal and dorsal cervical musculature (white arrows) consistent with myositis in a loggerhead sea turtle (*Caretta caretta*, case 3). Noncontrast CT images of asymmetrical inhomogenous hyperattenuating cervical musculature (white arrows) in a Kemp's ridley sea turtle (case 5). The 3-D volume renderings (E from a dorsal view and G from a left-sided view) represent the plane of the adjacent 2-D slices (F and H), indicated by a white reference line. Images F and H are displayed in a soft tissue window (window width, 33 HU; window level, 190 HU; 1-mm slice thickness). C3 = Third cervical vertebra. T = Cervical trachea. In A–D and F and H, the right side of the image represents the left (L) side of the animal.

Four days later, a biopsy of the right adductor mandibulae muscle was acquired at the base of the parietal bone under general anesthesia. The muscle appeared grossly discolored tan and was subjectively firm. Histopathologic evaluation, as interpreted by a board-certified veterinary pathologist (ER), revealed marked loss and fibrosis of skeletal muscle fibers and a mild histiocytic infiltrate **(Figure 2)**. This was accompanied by moderate diffuse histiocytic and

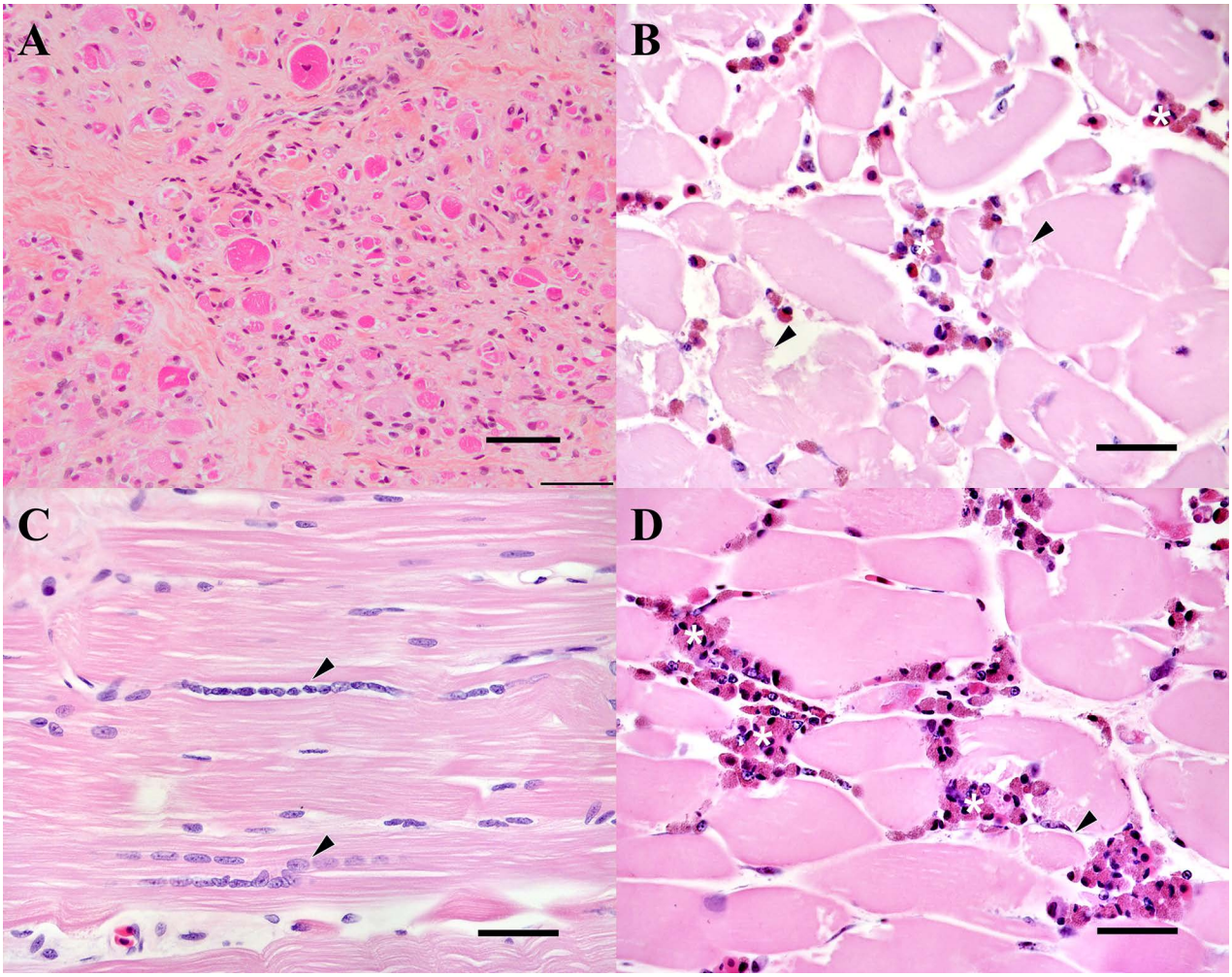

Figure 2—Histopathology images in cold-stunned Kemp's ridley (*Lepidochelys kempii*) sea turtles with trismus. Scale bar = 50 µm. A—Histopathology of right adductor mandibulae muscle (case 1). Myofibers are lost and replaced by orange-staining collagen with mild histiocytic infiltrates. Remaining fibers are necrotic or small and atrophic. Hematoxylin phloxine saffron. B—Histopathology of cervical skeletal muscle (case 2). Heterophils (asterisks) infiltrate the muscle and are associated with acute necrosis of individual myofibers (arrowheads). Hematoxylin and eosin. C—Histopathology of mandibular skeletal musculature (case 3). Muscle samples were collected postmortem with frequent regenerating myofibers exhibiting central rowing of nuclei (arrowheads). Hematoxylin and eosin. D—Histopathology of cervical skeletal muscle (case 4). Similarly to case 2 (B), heterophils (asterisks) infiltrate the muscle and are associated with acute necrosis of individual myofibers (arrowhead). Hematoxylin and eosin.

granulocytic steatitis. Bacterial and fungal cultures were negative. The animal ate squid rings 29 days after initial trismus presentation, 18 days after methylprednisolone injection, 11 days after starting weekly acupuncture, and 7 days after muscle biopsy. Vitamin E/selenium injections were discontinued, and the turtle continued to show improvements in the range of motion of the jaw and feeding response. Hematologic and plasma biochemical analysis performed 35 days after trismus presentation noted resolution of elevations in CK (89 U/L), LDH (3 U/L), and AST (832 U/L) and resolution of hypoproteinemia (total protein, 3.1 g/dL). Normal range of motion of the jaw was noted 48 days after trismus presentation, and frequency of acupuncture was reduced to every 2 weeks for 2 treatments and then monthly. The turtle subsequently developed diffuse steatitis and osteomyelitis, which prolonged rehabilitation but were successfully managed. Subsequent CT and MRI performed almost 4 months after trismus presentation noted near complete (> 90%) resolution of myositis. The sea turtle was released 8.5 months after admission.

Case 2

A 2.4-kg juvenile cold-stunned Kemp's ridley sea turtle with a history of dorsal neck swelling (recorded initially on day 4), signs of weakness (uncoordinated swimming, decreased responsiveness, and inability to lift its head), and severe pneumonia was evaluated on day 12 of rehabilitation for trismus, manifest as staff having difficulty opening the turtle's mouth. Hematologic and plasma biochemical analysis 8 days prior had revealed a mild heterophilic leukocytosis (WBCs, 16.6 k/µL; heterophils, 72%), severely elevated CK (> 120,000 U/L), AST (24,242 U/L), ALP (3,691 U/L), and LDH (> 36,000 U/L). Five jugular

venipuncture procedures had been performed before trismus presentation. Medications prescribed included parenteral antimicrobials (Supplementary Table S1), carprofen (1 mg/kg, IM, q 72 h, days 10 to 13), and SC fluid therapy (details not available). The next day the animal was found deceased. On necropsy, craniodorsal cervical muscles were thickened and edematous. Significant histopathologic findings, as interpreted by a board-certified veterinary pathologist (BAS), included severe subacute heterophilic bronchopneumonia with intralesional bacteria and moderate, predominantly heterophilic cervical myositis with associated myonecrosis and hemorrhage (Figure 2).

Case 3

A 25-kg juvenile cold-stunned loggerhead sea turtle with a history of mild pneumonia, bilateral corneal keratopathy, and anorexia since admission presented on day 31 of rehabilitation for minimal appetite and weak attempts to prehend food. Diagnostics including survey radiographs, gastrointestinal contrast radiographs, and blood culture failed to reveal a cause for anorexia. Eleven jugular venipuncture procedures had been performed before presentation. Flunixin meglumine (1 mg/kg, IM, q 72 h, days 24 to 38) had already been prescribed for possible pain and/or inflammation. Levothyroxine (0.04 mg/kg, PO, q 72 h, days 33 to 57) and tube feedings (8 mL/kg herring gruel, procedure as described in case 1, days 31 to 47) were prescribed every 3 days, and parenteral antibiotics (Supplementary Table S1) were continued. Five days later, head tremors and repetitive jaw movements, interpreted as a sign of pain, were noted and tube feedings and flunixin were discontinued. Hematologic and plasma biochemical analysis at this time revealed mild leukocytosis (15.0 K/µL) and mildly elevated CK (16,724 U/L). Computed tomography and MRI were performed by a board-certified veterinary radiologist (JOB), using gadopentetate dimeglumine contrast (75 mg/kg, IV) for MRI. Computed tomography diagnoses included pneumonia in the right caudal lung field and intestinal ileus without obstruction. Magnetic resonance imaging revealed marked multifocal T2 hyperintensity of the left muscles of mastication with smaller foci on the right and marked homogenous enhancement following contrast administration (Figure 1). Six days later, fine needle aspiration of the left adductor mandibulae was unsuccessful. Therapeutic laser therapy (continuous wave, 10 J/cm^2, 360 J total dose) was initiated, directed posterior to the left eye and craniomedially toward the supraoccipital region, and continued every 3 days. Triamcinolone (0.1 mg/kg, IM) was administered intralesionally once, posterior to the jaw. A Licensed Acupuncturist (CAM) performed 3 acupuncture treatments. The initial 2 treatments were 10 days apart, and the final treatment was a month later. Acupuncture channels with fascial connections to the lateral head and jaw were activated using sterile 38-gauge filiform needles, inserted 3 to 7 mm. Acupuncture points were located on the latissimus dorsi, between the radius and ulna, at the head of the fibula, and on the extremities of the limbs. Each treatment included the following points: LI4, LIV3, TW5, GB34, and GB21.

The animal ate well the day after the first acupuncture treatment and 2 days after triamcinolone injection and continued to eat well for 24 days when the animal's behavior changed, showing a preference for herring filets. Triamcinolone injection was repeated in the same location with no clinical improvement. A CBC revealed mild relative heterophilic leukocytosis (WBCs, 17.0 k/µL; heterophils 74%); plasma biochemical values were normal, and a blood culture was negative. Subsequent MRI (with and without contrast) revealed diffuse muscle changes consistent with myositis of the head and cranial neck. A muscle biopsy was acquired from the dorsal cervical region during recovery from general anesthesia following imaging. Histopathologic evaluation, interpreted by a board-certified veterinary pathologist (BAS), found chronic myopathic change interpreted as severe muscle atrophy, with no evidence of myositis or infectious etiologies. Laser therapy (10 J/cm^2, 360 J total dose, q 72 h, days 82 to 97), vitamin E/selenium (0.065 mg/kg selenium, 3.25 mg/kg vitamin E, IM, q 6 d, days 91 to 105), flunixin (1 mg/kg, SC, q 72 h, days 94 to 105), and daily SC fluids (lactated Ringer solution) were prescribed. Over the next few days, the animal developed severe coelomic effusion, weight gain, anorexia, lethargy, difficulty surfacing, and multifocal firm SC tissue in the neck, shoulders, prefemoral fossa, and perineum. Radiographs showed evidence of aspiration pneumonia. Due to clinical decline and lack of response to multiple salvage therapies including an additional antimicrobial (Supplementary Table S1) and steroids (stanozolol at 2 mg/kg, IM, once on day 105), the animal was euthanized using pentobarbital at 108 mg/kg, IV. Histopathologic evaluation (BAS) noted diffuse severe, necrotizing steatitis with numerous gram-positive bacterial emboli within adipose tissue; indications of septicemia in multiple organs, including intravascular bacterial emboli in the liver and vasculitis of colonic vessels and mild to moderate bronchopneumonia with intralesional fungi and bacteria. Nonspecific myofiber regeneration consistent with a previous insult was observed within the mandibular musculature. As with the biopsy, there was no evidence of active myositis as suggested by the MRI.

Case 4

A 2.9-kg juvenile cold-stunned Kemp's ridley sea turtle was evaluated 8 days into rehabilitation for intermittently moving the mouth, attempting to swallow, and being unable to open its mouth > 1 cm. Radiographs were consistent with pneumonia. The turtle was treated with parenteral antimicrobials (Supplementary Table S1), SC fluids (lactated Ringer solution; 10 to 20 mL/kg, SC, q 1 to 6 d, with frequency based on serial clinical pathology data, 4 doses, days 8 to 16), vitamin E/selenium (0.065 mg/kg selenium, 3.25 mg/kg vitamin E, IM, q 6 d, days 6 to 17), and ketoprofen (2 mg/kg, IM,

q 24 h, days 12 to 17). The turtle received a single physical therapy session and bilateral jaw laser therapy (continuous wave, 10 J/cm^2, 120 J total dose) daily for 3 doses (days 14 to 17). On day 17, the turtle had moderate soft tissue swelling in the craniodorsal neck, became hypoglycemic and unresponsive, did not respond to medical management, and died naturally. Nine jugular venipuncture procedures had been previously performed. Postmortem muscle biopsies of the craniodorsal cervical muscle were obtained and evaluated by a board-certified veterinary pathologist (BAS). Histopathologic findings included moderate acute heterophilic myositis with myonecrosis, intravascular thrombus formation, and hemorrhage (Figure 2).

Case 5

A 2.76-kg juvenile cold-stunned Kemp's ridley sea turtle was evaluated 12 days into rehabilitation at a long-term care facility and 24 days after rescue in Massachusetts, due to anorexia, tremors when opening its mouth, and inability to open its mouth > 1 cm. Eight venipuncture procedures had been performed before trismus presentation. The turtle had multiple episodes of dull behavior, weakness, and bradycardia over the next 2 weeks. Hematologic and plasma biochemical analysis revealed mild anemia (18% to 21%), a normal total leukocyte count (12.2 k/µL) with immature and toxic heterophils (61%) and vacuolated monocytes (30%), severely elevated CK (> 13,500 U/L) and AST (3,920 U/L), and mild hypoproteinemia (2.4 g/dL). The animal showed interest in eating but was not able to prehend or swallow food. Medications included parenteral and nebulized antibiotics (Supplementary Table S1), fluid therapy (Normosol-R), ketoprofen (2 mg/kg, IM, q 24 h, days 30 to 49), and vitamin E (6.7 mg/kg, IM, q 72 h, days 30 to 100). Mouth opening remained decreased at < 1 cm despite ketoprofen administration for 1 week. Due to persistent anorexia, concerns for progressive hypoproteinemia and fluid overload, and to avoid oral manipulation, fluids were weaned and total parenteral nutrition (TPN; 48 g amino acids [Travasol 10%], 13.5 g dextrose, and 40 g intralipid 20%) at 2.5 mL/kg, IV, was administered every 3 days from days 44 to 59. A CT scan was performed with and without iohexol (1 mL/kg, IV) contrast and interpreted by a board-certified zoological veterinary radiologist (MI). Findings included nonspecific myositis of the dorsal cervical muscles characterized by multifocal bilateral areas of asymmetrical hyperattenuation precontrast, pneumonia, and superficial erosions of the carapace and plastron (Figure 1). Treatment for myositis consisted of a single intralesional injection of methylprednisolone sodium succinate (total dose of 0.8 mg/kg, split among the 2 most severe lesions in the neck via CT and radiographic guidance), serial acupuncture, and physical therapy. Supportive treatments (TPN; antibiotics, antifungals, nebulization) were continued based on the animal's clinical needs. Acupuncture consisted of 15-minute treatments, while the animal underwent nebulization therapy and was performed once daily for the first week, then every 3 days for 6 weeks, and then once weekly until clinical resolution (3 months). Acupuncture channels with fascial connections to the lateral head and jaw were activated using sterile 32-gauge filiform needles inserted less than 10 mm deep at extrapolated meridian points (Yintang, GV20, GV16, LI4, LU07, LI11, BL10, TW5, GB20, and GB21) based on consultation and photographs from the New England Aquarium team **(Figure 3)**. Physical therapy initially consisted of 5 repetitions of 10- to 15-second manual extension of the mouth using carwash strips with equal, opposing pressure (Figure 3) and was performed once daily for the first 5 days, twice daily for 2 weeks, once daily for 6 weeks, and then weaned to

Figure 3—Acupuncture therapy (A) for a cold-stunned Kemp's ridley sea turtle (*Lepidochelys kempii*) sea turtle (case 5) with cervical myositis. Acupuncture at extrapolated meridian points (Yintang, GV20, GV16, LI4, LU07, LI11, BL10, TW5, GB20, and GB21) was performed once daily for the first week, then every 3 days for 6 weeks, and then once weekly until clinical resolution (3 months). Needles were well tolerated and left in place for 15 minutes. Physical therapy (B and C) treatment initially consisted of 5 repetitions of 10 to 15 seconds of manual extension of the mouth using carwash strips with equal, opposing pressure (B). The use of a foam block (C) to stretch the muscles of mastication before manual opening (B) was added once the animal could comfortably open its mouth 3 cm. Physical therapy was performed once daily for the first 5 days, twice daily for 2 weeks, once daily for 6 weeks, and then weaned to 3 times per week and then once weekly until clinical resolution.

3 times per week and then once weekly until treatment was discontinued.[18] An unaffected Kemp's ridley sea turtle that was concurrently in rehabilitation had a mouth opening of 5 cm, which was used as a point of reference for a normal range of motion.

Only 1 day after methylprednisolone injection, the animal was able to open its mouth 1 cm and ate 6 chopped pieces of squid. The next day, however, the animal was unable to eat again and exhibited floating, quiet behavior. Dexamethasone sodium phosphate (0.1 mg/kg, IM, q 24 h, days 55 to 57) was prescribed for additional anti-inflammatory relief, and hetastarch (5 mL/kg, IV, over 20 minutes, q 4 d, days 50 to 63) was administered to support the animal's persistent hypoproteinemia, in addition to continuing TPN. One week after methylprednisolone injection, the animal was eating 2% body weight in squid and mahi mahi strips and was able to open its mouth 3 cm. Supportive medications (TPN, hetastarch, and dexamethasone) were discontinued; vitamin E was continued along with antimicrobials for concurrent pneumonia. One month into treatment the turtle was voluntarily opening its mouth 3 cm and eating fish. Physical therapy was altered to the use of a foam block to stretch the muscles of mastication before manual opening (Figure 3). Three months after methylprednisolone injection, the mouth opening measured between 4 and 4.5 cm, the turtle was eating all whole fish offered, and CT confirmed the resolution of cervical myositis. The animal continued rehabilitation due to pneumonia and was released 8 months after admission.

Discussion

This retrospective case series describes 5 cases of trismus or jaw pain in cold-stunned sea turtles. All turtles presented with difficulty or inability to open the jaw between 4 and 48 days into rehabilitation following cold-stunning in Massachusetts **(Table 1)**. Clinical signs were attributed to inflammation of muscles of mastication, dorsal cervical muscles, and/or cervical steatitis. Three turtles were diagnosed using advanced imaging (CT or MRI) interpreted by board-certified radiologists, and 4 were diagnosed or confirmed via muscle biopsy, antemortem (2, along with imaging) and postmortem (2), interpreted by board-certified pathologists. Possible etiologies for muscle and fat lesions included hematogenous infection, nutritional deficiency, metabolic oxidation effects, and trauma, including iatrogenic trauma via jugular venipuncture. All turtles had received systemic antibiotics by the time of muscle biopsy, which may have led to the absence of bacteria on histopathologic evaluation. An association of trismus with systemic infection and potential nutritional deficiency appears most likely based on the frequency of infections and steatitis reported in cold-stunned sea turtles.[9,12,13,21] As the timeline to onset of trismus varied among cases, iatrogenic trauma via venipuncture cannot be ruled out but is considered less likely in these cases, particularly in those for which the time to onset was less than 1 week (cases 2 and 4). Blood analysis is an important part of medical management for cold-stunned turtles, and serial sampling is often required to monitor acid-base, blood gas, glucose, and electrolyte abnormalities.[5,6,8,22,23] Venipuncture is routinely performed by trained personnel at both facilities, and the number of venipuncture procedures for the cases described here is not atypical. Nevertheless, venipuncture remains one possible cause for cervical tissue injury and, thus, should be completed as efficiently as possible. While none of the cases included in this series were the result of joint disease, it would be reasonable to consider that jaw injuries, such as those caused by trauma, could also lead to trismus in sea turtles.

Clinical pathologic commonalities at the time of trismus presentation included mild heterophilic or

Table 1—Summary of clinical case findings, including method of diagnosis, treatment, complications, outcome, time to resolution, and time to release (where applicable) in 5 sea turtles presenting with trismus following cold-stunning in Massachusetts.

Case no.	Species	Time to onset	Method of diagnosis	Treatments	Comorbidities	Complications	Outcome	Time to myositis resolution	Time to release
1	*L kempii*	48 d	Imaging (MRI, CT), muscle biopsy	Antibiotics,* antifungals,* meloxicam, tube feed, vitamin E/selenium, intralesional methyprednisolone, acupuncture	Pneumonia, steatitis	None	Released	Normal range of motion 1 mo, CT 5 mo	8 mo
2	*L kempii*	4–12 d	Histopathology	Antibiotics,* carprofen	Pneumonia	N/A	Died naturally	N/A	N/A
3	*C caretta*	30 d	Imaging (CT, MRI), muscle biopsy	Antibiotics,* tube feed, flunixin, laser, intralesional triamcinolone, acupuncture, vitamin E/selenium, laser, stanozolol parenteral	Ocular ulcers, pneumonia, steatitis, coccidia	Sepsis, aspirated	Euthanized following recurrence of trismus due to steatitis	N/A	N/A
4	*L kempii*	6–12 d	Histopathology	Antibiotics,* ketoprofen, 1 physical therapy session, laser therapy	Pneumonia	N/A	Died naturally	N/A	N/A
5	*L kempii*	12 d	Imaging (CT)	Antibiotics,* antifungals,* ketoprofen, intralesional methylprednisolone, parenteral dexamethasone SP, acupuncture, physical therapy, vitamin E	Pneumonia	None	Released	CT 3 months	8 mo

*Details of antimicrobial therapy for each case are provided in Supplementary Table S1.

monocytic leukocytosis (2/4) (with/without toxicity), elevated CK (4/4), elevated AST (3/4), elevated ALP (1/4), elevated LDH (2/4), and hypoproteinemia (2/4). Heterophilia and monocytosis are common in newly admitted cold-stunned sea turtles and were likely multifactorial in origin as all turtles had concurrent pneumonia.[22–24] Plasma tissue enzyme concentrations (eg, CK, AST, and LDH) also tend to be elevated in cold-stunned turtles upon admission, likely secondary to generalized cellular injury and physical exertion during the stranding process.[22,23] However, the persistent severe elevations of these enzyme concentrations in 3 cases (cases 1, 2, and 5) after admission were significant and likely attributable to muscle inflammation. Hypoproteinemia was likely secondary to anorexia in these cases although gastrointestinal loss may have also contributed.

Treatment for trismus in these cases was multimodal, consisting of antibiotics (5/5), nonsteroidal anti-inflammatories (5/5), vitamin E (3/5), intralesional steroid therapy (3/5), acupuncture (3/5), antifungals (2/5), anti-inflammatory parenteral steroids (2/5), physical therapy (2/5), therapeutic laser (2/5), and nutritional support via either total parenteral nutrition (1/5) or tube feedings (2/5) (Table 1). In the cases that were successfully managed, the authors feel that intralesional steroids accompanied by acupuncture, physical therapy, vitamin E, antibiotics, antifungals, and supportive care were key to case management, both for myositis and comorbidities including pneumonia, steatitis, and osteomyelitis. Nonsteroidal anti-inflammatories were discontinued due to a lack of clinical effect in these patients. With intralesional steroid use, animals began eating within 1 to 18 days. Whether this was truly causal cannot be determined and improvement may have been due to systemic effects that nonspecifically increased the patients' appetite in addition to anti-inflammatory effects. Time to release in successfully treated cases was 8 months, largely due to the time required to resolve concurrent pneumonia. Myositis lesions resolved within 3 months based on follow-up diagnostic imaging.

Aside from vitamin E administration, therapies initiated in these cases were consistent with treatments for trismus in other species.[14–16,25] In dogs, NSAID or anti-inflammatory to immunosuppressive steroid doses, in addition to physical therapy and antibiotics, have been used to successfully treat a variety of conditions causing trismus, including trigeminal nerve paralysis, postoperative trismus following temporomandibular joint surgery, polymyositis, and masticatory muscle myositis.[15] Interventional therapies, including acupuncture, physical therapy, laser, and ultrasound therapy, have not been extensively evaluated in sea turtles. Physical therapy was well tolerated in case 5, and the authors would recommend its use to other clinicians treating similar cases. The treatment plan for physical therapy was based on a report[18] on a loggerhead sea turtle and amended for this Kemp's ridley sea turtle based on anecdotal experience. The authors' experience also shows that acupuncture is a low-cost intervention that is well tolerated by sea turtles. Acupuncture techniques, when performed by trained professionals, are minimally invasive and minimally stressful and can be paired easily with other treatments such as nebulization, laser, or physical therapy. A review comparing interventions for trismus in humans following head and neck cancer surgery that evaluated exercise only, exercise with low-level laser therapy, low-intensity ultrasound, or exercise with a jaw rehabilitation device found no clear optimum treatment. However, adherence to one treatment protocol appeared more beneficial than changing the treatment regimen.[25] Similarly, adherence to a treatment protocol, rather than the specific modality of that treatment protocol, could be beneficial in sea turtles experiencing trismus.

Vitamin E, both with and without selenium, was used in 3/5 sea turtles for muscular support against oxidative stress as reported in other species.[26,27] Additionally, low vitamin E levels have been detected in cold-stunned Kemp's ridley sea turtles and are associated with the development of steatitis, suggesting that vitamin E supplementation and dietary changes may be important for the prevention of steatitis in cold-stunned sea turtles.[9] Pharmacokinetic data regarding vitamin E dosing in sea turtles are lacking; dosages reported were at the clinician's discretion. Additionally, while vitamin E and selenium act synergistically as antioxidants[28] and traditionally are compounded together in veterinary products, there has been no evidence that sea turtles are selenium deficient. Given that selenium can be toxic when overdosed, some clinicians have chosen to eliminate selenium from treatments and give vitamin E alone.

In this series, 2 affected turtles died naturally, and 1 was humanely euthanized. This survivorship rate is lower than that anecdotally communicated by experienced sea turtle clinicians in the US (D Mader, DVM, The Turtle Hospital, email, May 2023). This may partly be due to the inclusion criteria for the present study, which required either advanced diagnostic imaging or histopathology, which limited cases to cold-stunned turtles originating from Massachusetts. One case that did not meet the inclusion criteria and was not cold-stunned was a lethargic loggerhead sea turtle that underwent 2 years of assist feeding and physical therapy, with intermittent benzodiazepine treatment for signs of trismus before release (S Boylan, DVM, Georgia Sea Turtle Center, email, May 8, 2023). As such, it is possible that survivorship for trismus may be higher than that represented in this case series as cold-stunned sea turtles often have multiple comorbidities.[9–13]

Histopathologic findings for cases of trismus, as shown in Figure 2, ranged from early heterophilic cervical myositis with associated myonecrosis and hemorrhage as seen in cases 2 and 4 to more chronic atrophy and fibrosis of skeletal muscle in cases 1 and 3. Curiously, in case 3, despite the diagnostic imaging changes, myositis was not histologically diagnosed. The specificity of abnormal MRI signal intensity in muscle is low for diagnosing myositis in humans, and concurrent biopsy is recommended.[29–31] The

specificity of MRI for diagnosis of myositis in sea turtles has not been studied, but the present cases provide preliminary insight. While muscle biopsy is considered the gold standard for diagnosing myositis,[30] its diagnostic utility relies heavily on lesion localization. It is possible that the focal biopsy and postmortem sampling sites in case 3 provided an incomplete representation of the variable degrees of chronicity that may have been present throughout the lesions.[31] Further documentation of the progression of myositis histologically and its correlation to advanced imaging findings is warranted for sea turtles.

Limitations of the present study include potential inadvertent exclusion of cases from other secondary care facilities due to reliance on clinician memory and medical database review. Staffing changes at rehabilitation facilities may have limited the recollection of cases within the eastern US at the time of investigation. Additionally, for case 3, there was no record of reduced ability to open the jaw (trismus), but head tremors and repetitive jaw movements interpreted as signs of jaw discomfort were noted. This, accompanied by diagnostic imaging consistent with myositis, led to inclusion in this case series although it did not technically fit the definition of trismus.

Clinical management of sea turtles is evolving, and a number of important pharmacokinetic studies have been published since several of the described cases were managed. As such, some of the drug doses, routes, and frequencies that are reported in this study would no longer be used. For example, recommendations for meloxicam use in sea turtles have evolved with recently described substantial differences in pharmacokinetics among 3 sea turtle species, and flunixin has been anecdotally associated with fatal gastroenteritis in green turtles.[32,33] In some situations, eg, corticosteroid use, sea turtle clinicians must use medications empirically in the absence of pharmacokinetic and pharmacodynamic data. Caution is advised when using high doses of steroids in the presence of infection due to the potential for immunosuppression with chronic use.

Cervical and masticatory myositis and associated trismus appear to be a rare clinical condition in cold-stunned sea turtles but may be associated with substantial morbidity and mortality. The New England Aquarium admitted nearly 5,000 cold-stunned sea turtles during the time period of this study, yet only 5 well-characterized cases of trismus were documented. Clinicians treating sea turtles affected by trismus should pursue advanced imaging, histopathology, and early multimodal medical management. By documenting additional cases and etiologies, the pathogenesis of this condition may be better defined, and evidence-based management plans may evolve to improve outcomes.

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References

1. The IUCN red list of threatened species. Version 2023-1. International Union for Conservation of Nature (IUCN). Accessed January 22, 2024. https://www.iucnredlist.org
2. Baker L, Edwards W, Pike DA. Sea turtle rehabilitation success increases with body size and differs among species. *Endanger Species Res.* 2015;29:13–21. doi:10.3354/esr00696
3. Innis CJ, Finn S, Kennedy A, et al. A summary of sea turtles released from rescue and rehabilitation programs in the United States, with observations on re-encounters. *Chelonian Conserv Biol.* 2019;18(1):3–9. doi:10.2744/CCB-1335.1
4. Foley AM, Singel KE, Dutton PH, Summers TM, Redlow AE, Lessman J. Characteristics of a green turtle (*Chelonia mydas*) assemblage in northwestern Florida determined during a hypothermic stunning event. *Gulf Mex Sci.* 2007;25(2):4. doi:10.18785/GOMS.2502.04
5. Innis CJ, McGowan JP, Burgess EA. Cold-stunned loggerhead (*Caretta caretta*): initial vs. convalescent physiologic status and physiologic findings associated with death. *J Herpetol Med Surg.* 2019;29(3–4):105–112. doi:10.5818/19-06-204.1
6. Keller K, Innis C, Tlusty MF, Kennedy AE, Bean SB, Cavin JM, Merigo C. Metabolic and respiratory derangements associated with death in cold-stunned Kemp's ridley turtles (*Lepidochelys kempii*): 32 cases (2005–2009). *J Am Vet Med Assoc.* 2012;240(3):317–323. doi:10.2460/javma.240.3.317
7. Morreale SJ, Meylan AB, Sadove SS, Standora EA. Annual occurrence and winter mortality of marine turtles in New York waters. *J Herpetol.* 1992;26(3):301–308. doi:10.2307/1564885
8. Stacy NI, Innis CJ, Hernandez JA. Development and evaluation of three mortality prediction indices for cold-stunned Kemp's ridley sea turtles (*Lepidochelys kempii*). *Conserv Physiol.* 2013;1(1):cot003. doi:10.1093/conphys/cot003
9. Turner RC, Innis CJ, Stacy BA, et al. Steatitis in cold-stunned Kemp's ridley sea turtles (*Lepidochelys kempii*). *Animals (Basel).* 2021;11(3):898. doi:10.3390/ani11030898
10. Innis CJ, Braverman H, Cavin JM, et al. Diagnosis and management of *Enterococcus* spp. infections during rehabilitation of cold-stunned Kemp's ridley turtles (*Lepidochelys kempii*): 50 cases (2006–2012). *J Am Vet Med Assoc.* 2014;245(3):315–323. doi:10.2460/javma.245.3.315
11. Innis C, Nyaoke AC, Williams CR 3rd, et al. Pathologic and parasitologic findings of cold-stunned Kemp's ridley sea turtles (*Lepidochelys kempii*) stranded on Cape

Cod, Massachusetts, 2001–2006. *J Wildl Dis.* 2009;45(3):594–610. doi:10.7589/0090-3558-45.3.594
12. Powell AL, Tuxbury KA, Cavin JM, et al. Osteomyelitis in cold-stunned Kemp's ridley sea turtles (*Lepidochelys kempii*) hospitalized for rehabilitation: 25 cases (2008–2018). *J Am Vet Med Assoc.* 2021;259(10):1206–1216. doi:10.2460/javma.20.08.0443
13. Stockman J, Innis CJ, Solano M, et al. Prevalence, distribution and progression of radiographic abnormalities in the lungs of cold-stunned Kemp's ridley sea turtles (*Lepidochelys kempii*): 89 cases (2002–2005). *J Am Vet Med Assoc.* 2013;242:675–681. doi:10.2460/javma.242.5.675
14. Dhanrajani PJ, Jonaidel O. Trismus: aetiology, differential diagnosis and treatment. *Dent Update.* 2002;29(2):88–92. doi:10.12968/denu.2002.29.2.88
15. Gatineau M, El-Warrak AO, Marretta SM, Kamiya D, Moreau M. Locked jaw syndrome in dogs and cats: 37 cases (1998–2005). *J Vet Dent.* 2008;25(1):16–22. doi:10.1177/089875640802500106
16. Marien M Jr. Trismus: causes, differential diagnosis, and treatment. *Gen Dent.* 1997;45(4):350–355.
17. Amin B, Chandra SB. Recognizing trismus symptoms, prevention and treatment. *Med-Science.* 2019;8(3):766–769. doi:10.5455/medscience.2019.08.9037
18. Mettee N, Valente ALS, Stacy BA, Wyneken J. Musculoskeletal system. In: Manire CA, Norton TM, Stacy BA, Innis CJ, Harms CA, eds. *Sea Turtle Health and Rehabilitation.* J. Ross Publishing; 2017:285–286.
19. Tristan TE, Norton TM. Physical examination. In: Manire CA, Norton TM, Stacy BA, Innis CJ, Harms CA, eds. *Sea Turtle Health and Rehabilitation.* J. Ross Publishing; 2017:113.
20. Reckendorf A, Tuxbury K, Cavin J, et al. Laryngeal paralysis in a loggerhead sea turtle. *J Herpetol Med Surg.* 2016;26(1–2):20–25. doi:10.5818/1529-9651-26.1-2.20
21. Innis C, Staggs L. Cold-stunning. In: Manire CA, Norton TM, Stacy BA, Innis CJ, Harms CA, eds. *Sea Turtle Health and Rehabilitation.* J. Ross Publishing; 2017:675–688.
22. Innis CJ, Ravich JB, Tlusty MF, et al. Hematologic and plasma biochemical findings in cold-stunned Kemp's ridley turtles: 176 cases (2001–2005). *J Am Vet Med Assoc.* 2009;235(4):426–432. doi:10.2460/javma.235.4.426
23. McNally KL, Innis CJ. Plasma biochemistry and hematologic values of cold-stunned loggerhead sea turtles (*Caretta caretta*). *J Herpetol Med Surg.* 2020;30(2):88–95. doi:10.5818/19-08-209.1
24. Stacy NI, Innis CJ. Clinical pathology. In: Manire CA, Norton TM, Stacy BA, Innis CJ, Harms CA, eds. *Sea Turtle Health and Rehabilitation.* J. Ross Publishing; 2017:177–185.
25. Chee S, Byrnes YM, Chorath KT, Rajasekaran K, Deng J. Interventions for trismus in head and neck cancer patients: a systematic review of randomized controlled trials. *Integr Cancer Ther.*2021;20:1–12. doi:10.1177/15347354211006474
26. Breed D, Meyer LCR, Steyl JCA, Goddard A, Burroughs R, Kohn TA. Conserving wildlife in a changing world: understanding capture myopathy—a malignant outcome of stress during capture and translocation. *Conserv Physiol.* 2019;7(1):coz027. doi:10.1093/conphys/coz027
27. Hill KE, Motley AK, Xia L, May JM, Burk RF. Combined selenium and vitamin E deficiency causes fatal myopathy in guinea pigs. *J Nutr.* 2001;131(6):1798–1802. doi:10.1016/j.nutres.2009.02.006
28. Hu Q, Zhang Y, Lou H, et al. GPX4 and vitamin E cooperatively protect hematopoietic stem and progenitor cells from lipid peroxidation and ferroptosis. *Cell Death Dis.* 2021;12(7):706. doi:10.1038/s41419-021-04008-9
29. May DA, Disler DG, Jones EA, Balkissoon AA, Manaster BJ. Abnormal signal intensity in skeletal muscle at MR imaging: patterns, pearls, and pitfalls. *Radiographics.* 2000;20(Spec No):S295–S315. doi:10.1148/radiographics.20.suppl_1.g00oc18s295
30. Pipitone N. Value of MRI in diagnostics and evaluation of myositis. *Curr Opin Rheumatol.* 2016;28(6):625–630. doi:10.1097/BOR.0000000000000326
31. Van de Vlekkert J, Maas M, Hoogendijk JE, De Visser M, Van Schaik IN. Combining MRI and muscle biopsy improves diagnostic accuracy in subacute-onset idiopathic inflammatory myopathy. *Muscle Nerve.* 2015;51(2):253–258. doi:10.1002/mus.24307
32. Norton TM, Clauss T, Sommer R, et al. Pharmacokinetic behavior of meloxicam in loggerhead (*Caretta Caretta*), Kemp's ridley (*Lepidochelys kempii*) and green (*Chelonia mydas*) sea turtles after subcutaneous administration. *J Zoo Wildl Med.* 2021;52(1):295–299. doi:10.1638/2019-0143
33. Wyneken J, Mader DR, Weber ES, et al. Medical care of sea turtles. In: Mader DR, ed. *Reptile Medicine and Surgery.* 2nd ed. WB Saunders; 2006:972–1007.

Supplementary Materials

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