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Clinical Report

Successful Rehabilitation and Release of a Bald Eagle (*Haliaeetus leucocephalus*) After Arthrodesis of a Metacarpophalangeal Joint Luxation

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Abstract: The metacarpophalangeal joint is a compound joint composed of the major and minor metacarpals and the minor and major digits. Although the motion of this joint is restricted, it plays an important role in minor adjustments in flight. The ability of birds to gain lift and fly with limited or inhibited function of this joint has not been well studied in raptors. This report represents the first published case of successful rehabilitation and release of a bald eagle (*Haliaeetus leucocephalus*) after complete arthrodesis of a metacarpophalangeal joint luxation. The patient was presented to the Louisiana State University Wildlife Hospital of Louisiana with a chronic, complete luxation of the left metacarpophalangeal joint and articular fracture of an unknown origin. Owing to the chronicity of the injury, a closed reduction and stabilization with conservative management were not achievable. Articular debridement and external fixation with a type 1A fixator were used to immobilize the joint. Complete anatomic reduction was not achieved; however, this did not inhibit the bird's ability to gain lift, land, and navigate in the air. Postrelease monitoring was not pursued for this patient. Arthrodesis should be considered a viable treatment option for metacarpophalangeal joint luxations in bald eagles or other large raptors.

Key words: Haliaeetus leucocephalus, bald eagle, arthrodesis, luxation, metacarpophalangeal, photobiomodulation therapy, avian, raptor

CLINICAL REPORT

An adult, 3.8-kg, presumed female bald eagle (*Haliaeetus leucocephalus*), based on morphometrics,[1] was presented to the Louisiana State University Wildlife Hospital of Louisiana by a state official from the Louisiana Department of Wildlife and Fisheries after a good Samaritan noted the bird to be on the ground and unable to fly. On initial presentation, the eagle was noted to have anisocoria, 180 degrees of posterior synechia, and early cataract formation in the left eye with a normal appearance to the right eye. Fundic examination was unremarkable, and there was no uveitis observed. Intraocular pressure was not recorded. The eagle's mentation was quiet to dull but responsive. There was mild, symmetric muscle atrophy of the pectoral muscles consistent with body condition (2/5), a superficial wound over the left pelvis, and laxity of the left metacarpophalangeal joint with an open wound on the ventral aspect that had cellulitis and necrosis present (Fig 1). The laxity of the left metacarpophalangeal joint was primarily a lateral deviation of the minor metacarpal bone relative to the major metacarpal bone. Increased rotation along the long axis of the wing about this site was also appreciated, although the degree of rotation was not measured.

Initial treatment consisted of lactated Ringer's solution (LRS; 50 mL/kg SQ once; Baxter Healthcare Corporation, Deerfield, IL, USA), hydromorphone (0.3 mg/kg IM; Hospira, Inc, Lake Forest, IL, USA), enrofloxacin (15 mg/kg IM; Baytril, Elanco US Inc, Greenfield, IN, USA), meloxicam (2 mg/kg IM; MWI, Boise, ID, USA), and wound care. Wound care initially consisted of copious lavage using 0.05% chlorhexidine (Nolvasan, Fort Dodge Animal Health, Fort Dodge, IA, USA) and 0.9% saline (Baxter Healthcare Corporation), superficial debridement of visibly necrotic skin and subcutis, and application of a wet-to-dry bandage. A figure-of-8

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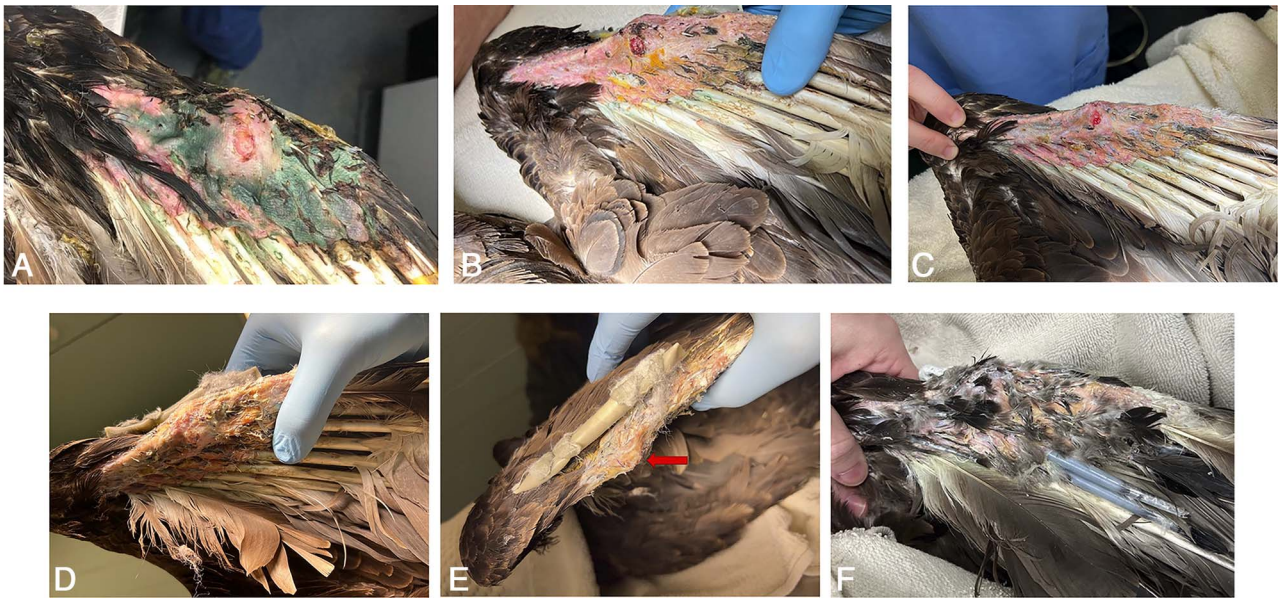

Figure 1. Photographs of the wound at different time points in healing. The ventral aspect of the left wing 4 days postadmission (A) shows bruising, swelling, and a 1.5-cm abrasion over the metacarpophalangeal joint. By 11 days postadmission (B) (surgery performed day 5) the bruising had resolved. The soft tissue swelling has improved, and healthy granulation tissue has filled in the abrasion. By 21 days postadmission, (C) the soft tissue swelling has resolved, and the abrasion has decreased in size significantly. On day 26, (D) the abrasion has closed over. From a lateral aspect, (E) the external fixator can be seen on the dorsal aspect of the wing. The callus and residual subluxation are seen as a raised area marked with a red arrow. By day 43, (F) feathers have begun to regrow, and the underlying skin appears healthy.

bandage was placed on the left wing using cast padding (BSN Medical Inc, Charlotte, NC, USA) and a self-adherent bandage (BluePoint Laboratories, Conshohocken, PA, USA). Venous blood was collected from the medial metatarsal vein using a 3-mL syringe and a 25-G needle for triage diagnostics. The packed cell volume, total solids, and an estimated white blood cell count were within reference intervals for each parameter.[2] The eagle was initially housed in an 86 × 152 × 178-cm stainless steel enclosure in the Louisiana State University Wildlife Hospital of Louisiana. The bird was provided ad libitum municipal tap water and offered several different food items, including mice, capelin, and quail, which it readily consumed. The amount of each food item offered daily was calculated based on the daily caloric need and caloric density of each food item.

The following day, the eagle was continued on enrofloxacin (15 mg/kg PO q12hr x 24 days), meloxicam (2 mg/kg PO q12hr × 40 days), and hydromorphone (0.3 mg/kg IM q12hr × 9 days). Additionally, metronidazole (20 mg/kg PO q12hr × 24 days; Cadila Healthcare Ltd, India) and regional limb perfusions of the left wing were initiated with amikacin (20 mg/kg IV q24hr × 4 days; Emcure Pharmaceuticals Ltd, Sanand, Ahmedabad, India) before surgery due to the extent of the soft tissue cellulitis and necrosis and the potential concern for the bone becoming infected. Culture and sensitivity were not performed due to financial constraints. For the regional limb perfusions, the patient was induced and maintained on isoflurane as previously described. Heart and respiratory rates were monitored via a stethoscope, and supplemental heat was provided via warm air flow (Bair Hugger, Saint Paul, MN, USA). A 0.63-mm Penrose drain (Cardinal Health, Kansas City, MO, USA) was placed as a tourniquet at the level of the left elbow joint, and 20 mg/kg amikacin and lidocaine (2 mg/kg; MWI, Boise, ID, USA) were infused intravenously into a distal carpal vein. The tourniquet was removed after 20 minutes. Passive range of motion of the left elbow and carpus and patagial massage were performed during recovery. Wound care changed over the course of treatment. The initial wet-to-dry bandage was placed and changed on 3 consecutive days. The wound was flushed and cleaned with dilute iodine and sterile 0.9% saline (Abbott Labs, North Chicago, IL, USA) and covered with silver-hydrogel (Silvasorb, Medline Industries, Inc, Northfield, IL, USA) and a nonadherent telfa pad (Covidien LLC, Mansfield, MA, USA) to promote healthy granulation tissue growth. The wing was then wrapped in a figure-of-8 bandage to reduce motion and prevent any further damage to the left wing. The patient was continued on subcutaneous fluids (100 mL/kg LRS) during these intravascular

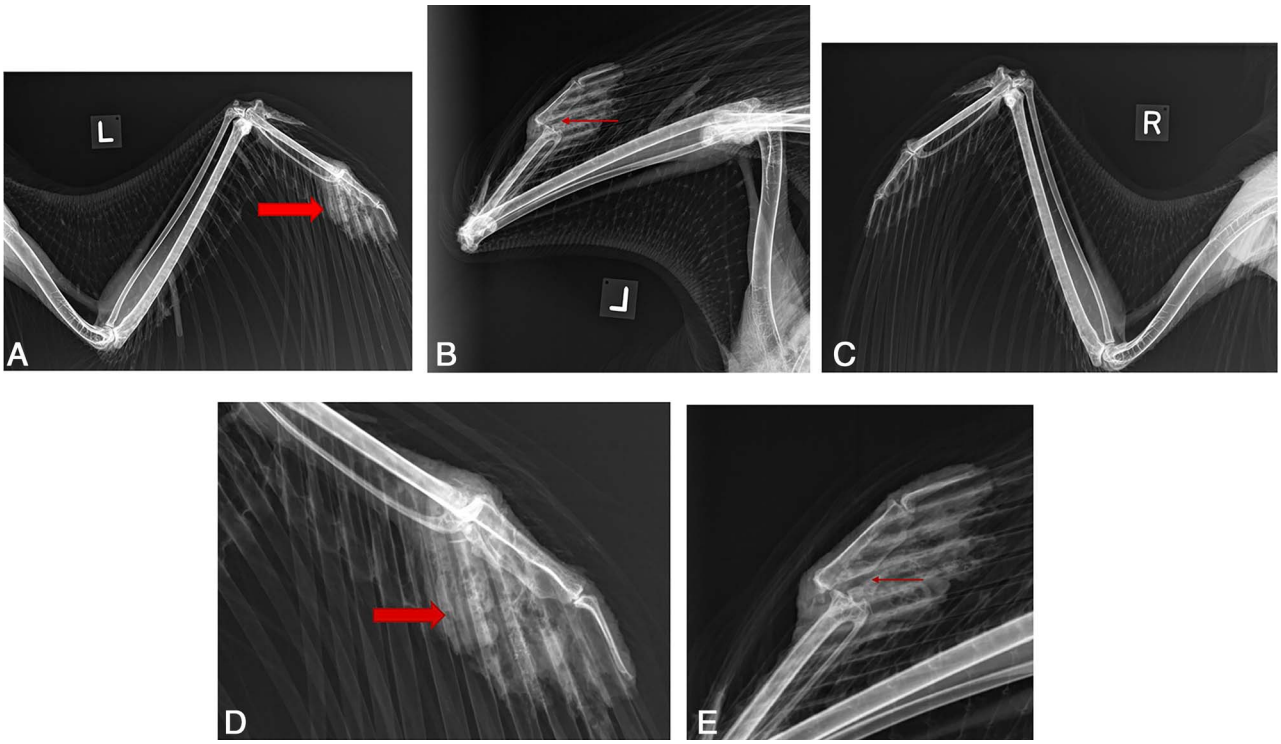

Figure 2. Ventrodorsal (A) and oblique (B) radiographic images of the left wing of a bald eagle (*Haliaeetus leucocephalus*) showing a complete, articular, oblique fracture of the first phalanx with caudal displacement and luxation of the left metacarpophalangeal joint. There is marked soft tissue swelling and subcutaneous emphysema surrounding the major digit (thick red arrow, ventrodorsal projection). The fracture site is marked with a thin red arrow on the oblique projection. A ventrodorsal radiograph (C) of the right wing is provided here for comparison. Higher magnification focused on the affected joint for the ventrodorsal (D) and oblique (E) views are also provided for reader ease.

perfusions of amikacin to prevent any potential adverse effects on the kidneys.

Survey whole body and wing radiographs were taken 2 days after intake to assess the luxation of the metacarpophalangeal joint. The eagle was premedicated with midazolam (1 mg/kg IM; West-Ward, Eatontown, NJ, USA) and hydromorphone (0.2 mg/kg IM) and anesthetized via a facemask with 5% isoflurane (Dechra, Overland Park, KS, USA) in 2 L of oxygen/min. Once the eagle was anesthetized, it was intubated with a 6.5-mm OD uncuffed endotracheal tube and maintained on 1–2% isoflurane in 2 L of oxygen/min. The radiographs revealed a complete, moderately caudally displaced, oblique fracture in the palmaroproximal articular margin of the first phalanx of the left major digit, and luxation of the left metacarpophalangeal joint with significant cranial displacement. Radiographs also revealed significant soft tissue swelling surrounding the joint (Fig 2). No other radiographic abnormalities were noted. The figure-of-8 bandage was replaced, and the eagle recovered uneventfully from anesthesia.

Based on the reduction in swelling and exudate, the formation of a granulation bed noted in the soft tissue injury of the distal wing tip over the initial 5-day course of medical treatment, and the continued instability of the metacarpophalangeal joint, the authors elected to pursue a surgical arthrodesis of the joint to increase the likelihood that the eagle could be released back to the wild. Surgery was performed 5 days after intake. The patient was administered midazolam (1 mg/kg IM) and hydromorphone (0.5 mg/kg IM) for sedation and then induced and maintained on isoflurane as described previously. A visual brachial plexus block was performed on the left wing with lidocaine (2 mg/kg) via an axillary approach after the procedure described in da Cunha et al.[3] No measures were taken to assess the effectiveness of this block. The patient was placed in dorsal recumbency and monitored with a multiparameter patient monitor (VetSpecs SM100, VetSpecs Inc., Canton, GA, USA) that included electrocardiography, capnometry, and an esophageal temperature probe. Active warming was provided with the Bair Hugger and a water-heating blanket (Hot Dog Veterinary Patient Warming, Eden Prairie, MN, USA). The patient received 10 mL/kg/hr LRS IV during the procedure. The patient experienced 2 episodes of

bradycardia (90–110 bpm) and was treated with a single fluid bolus (15 mL/kg LRS over 15 min: first episode of bradycardia) and a single dose of atropine (0.42 mg/kg IV; Intas Pharmaceuticals Limited, Ahmedabad, India: second episode of bradycardia). Ventricular premature contractions were noted after administration of atropine. Except for the bradycardia, there were no other anesthetic complications.

All feathers except the remiges over the dorsal and ventral surfaces of the carpus, metacarpus, and digits were removed to prepare the surgical site. The flight feathers and proximal wing were wrapped with a self-adherent cohesive bandage to limit contamination and preserve flight feathers. The surgical site was aseptically prepared with 2% chlorhexidine and 70% isopropyl alcohol. The wing was sterilely draped, and the distal wing was wrapped with a sterilized self-adherent bandage to allow manipulation by the surgeons. A ventral surgical approach was made over the metacarpophalangeal joint. The fibrous callus was debrided with a 1.5 × 10-mm curved Friedman rongeur to allow for visualization and alignment of the articular surfaces. The articular surfaces of the joint were then curetted with a Volkman bone curette to remove the articular cartilage. The articular surfaces were scraped until chondral bone was visualized. The joint capsule was closed, and adjacent tendons were tacked with simple interrupted 3-0 polydioxanone suture (Ethicon, LLC, San Lorenzo, Puerto Rico). The skin was then closed with 3-0 polydioxanone in a simple continuous pattern. A Jacob's chuck was used to place 4 positive interface stainless-steel pins, each engaging 2 cortices (2 mm; IMEX Veterinary Inc, Longview, TX, USA) into the carpometacarpus (2 pins) and major phalanx (2 pins) (Fig 3). A 1.3-cm Penrose drain was placed over the 4 pins, and the joint was held in a reduced position while the drain was pushed through the pins so that it sat approximately 5 mm above the skin. With 1 end of the drain occluded with hemostats, the drain was filled with polymethyl methacrylate (PMMA; Thermo Fisher Scientific, Waltham, MA, USA) via a 60 mL catheter-tipped syringe. Sterile moist gauze was temporarily placed between the drain and the skin to prevent contact with the PMMA material. The apparatus and joint were held in place until the PMMA dried and solidified, creating a Type 1 external skeletal fixator. The syringe, hemostats, and gauze were then removed, and the wing was wrapped in a figure-of-8 bandage as previously described to limit motion. Recovery from the surgical and anesthetic events was uneventful.

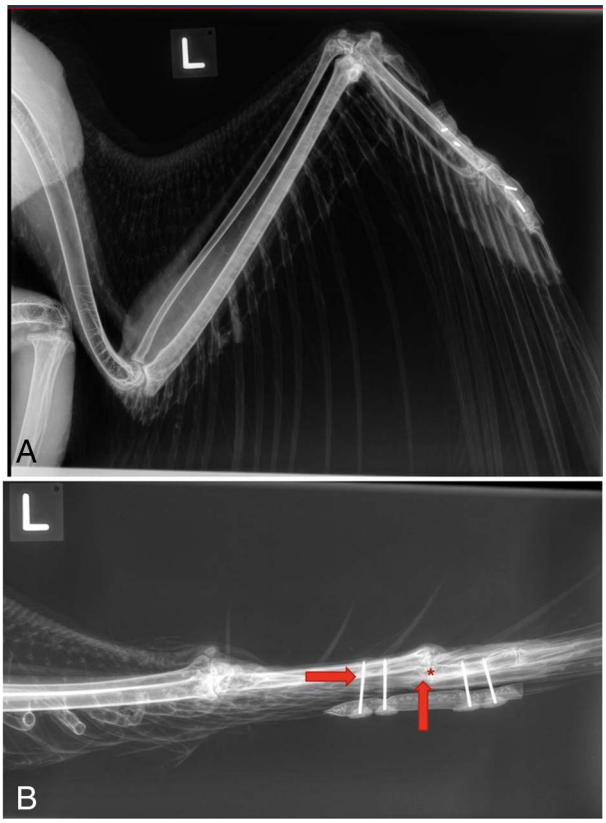

Figure 3. Ventrodorsal (A) and lateral (B) radiographic images of the bald eagle (*Haliaeetus leucocephalus*) described in Figure 2, 16 days postsurgery. Soft tissue swelling and subcutaneous emphysema have resolved. Mild bony remodeling can be appreciated surrounding the pins and along the articular surfaces (red arrows). The hardware remains in place; however, there is still moderate, lateral subluxation of the metacarpophalangeal joint. A red asterisk overlies the subluxated joint in the ventrodorsal projection.

Postoperative care and photobiomodulation therapy

The patient received a bandage change 2 days after surgery and continued to receive bandage changes 2 to 3 times per week along with passive range of motion therapy. Bandaging continued throughout the rehabilitation process to limit the likelihood of the eagle striking and damaging the apparatus on the enclosure walls. The bandage consisted of topical Iodosorb (Smith & Nephew Medical Limited, Hull, England), a non-adherent pad of appropriate length, cast padding, and self-adherent wrap in a figure-of-8 bandage around the left wing. The incision site and tissue surrounding the external skeletal fixator pins were cleaned with dilute chlorhexidine after each bandage removal. Photos were taken after every bandage change, and the cosmetic appearance (eg, discharge present, bruising, crusting, inflammation, or edema) of the incision site was

recorded. The patient received photobiomodulation (PBM) therapy at the time of bandage changes for a total of 12 PBM sessions over 8 weeks. A Companion Animal Health Class 4 Laser (Companion CTX, Model: LTC-1511-C-B6, LU21006029, Companion Animal Health, New Castle, DE, USA) was used. The dosages of PBM used were precalculated based on the manufacturer's recommendation. A pulse rate of 20 Hz, a wavelength of 810 nm/980 mm, a total power output of 3 W, and a total dose of 780 J were delivered for 8 minutes and 40 seconds to the site of injury. Photobiomodulation stimulation was applied perpendicularly to the wing, rotating the laser probe circumferentially around the arthrodesis, including the healthy, nonsurgical margins of the wing. Occupational Safety and Health Administration-approved safety glasses were worn by all personnel in the room during PBM treatment. To decrease stress and protect the patient's eyes, a small, opaque towel was placed over the head, with care taken not to obstruct the nares. The patient was manually restrained and conscious of these treatments and showed no signs of distress from handling or manipulation. After PBM therapy, the patient received passive range of motion exercises for the left wing and massages to the patagium to prevent joint contracture and stiffness.

The cortical pins were removed 8 weeks postsurgery (Fig 4), and the patient was transferred to a 36 × 7.3 × 6.1-m flight cage for continued rehabilitation. The decision to remove the pins was based on the solid callus and stability of the joint as assessed on physical examination. The callus was palpably firm with no rotation or movement about the joint before pin removal. The stability of the joint remained after removal of the pins. The now fused metacarpal bone and major digit moved as one. There was comparable extension of the carpal joints between the left and right sides (exact measurements of extension were not recorded). Although the 2 sets of postoperative radiographs showed that the joint was slightly subluxated, there was no movement in the joint at either time of imaging, and the subluxation could not be palpated because of the significant bone remodeling. A decision to remove the pins earlier was discussed; however, the clinicians were concerned the remodeling would not suffice because of the previous report of failure in an eagle,[4] and thus the decision was made maintain the pins for 8 weeks. In the flight cage, the bird was exercised for 3 months and found to have normal wing extension, lift, turning ability, and an ability to tuck its legs during flight and land appropriately. Before release, the bird was moved to an "L" shaped cage that measured 15.2 × 3 × 5.5 m + 30.4 × 6 × 5.5 m. The eagle was allowed to familiarize herself with this cage overnight before assessing locomotion in this larger cage. The bird was examined from outside the flight cage and seen moving around the cage, flying from one side to the other, and flying from the ground to elevated perches (approximately 3 m from the ground). Then, to further assess flight and endurance, the eagle was encouraged to fly back across the cage and around the turn of the cage by having an evaluator follow the bird. The bird was able to fly across and around (approximately 40–45 m) 10 times without showing a significant increase in respiratory rate and effort, and while maintaining steady landings. This is a standard approach for assessing flight in raptors before release at this institution. Locomotion was assessed by multiple clinicians standing at different

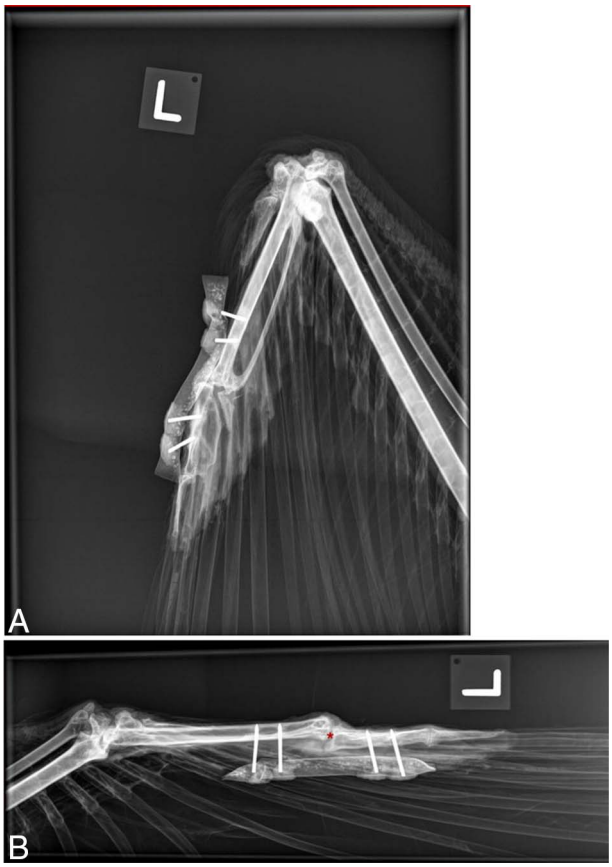

Figure 4. Ventrodorsal (A) and lateral (B) radiographic images of the bald eagle (*Haliaeetus leucocephalus*) described in Figure 2, 23 days post-surgery. The orthopedic hardware is still in place, and bony remodeling can be appreciated surrounding the pins and articular surfaces. The joint is similarly moderately subluxated like Figure 3. A red asterisk overlies the subluxated joint in the ventrodorsal projection.

locations in and outside the flight cage to assess from different angles. Weekly in-hand physical examinations were performed while in the large flight cage to assess symmetrical flexion and extension of the carpal and cubital joints, appropriate body condition, symmetric pectoral muscling, lack of pododermatitis, and lack of other abnormalities. The bird was released 5 months after presentation at the site where she was found. The release was uneventful, and the bird was observed to fly more than 1 km before disappearing from view. No identification band or transmitter was used to monitor the patient postrelease.

DISCUSSION

Traumatic injuries are a common presenting complaint for raptors to wildlife hospitals, and surgical correction of fractures and luxations to the limbs is one of the most common procedures performed in wildlife hospitals.[5–9] Vehicular trauma and collision with buildings, powerlines, and wind turbines are frequent causes of orthopedic trauma to raptors and other birds.[5–9] The prognosis for survival and return to function of a limb posttrauma is highly variable and often dependent on the location of the injury, chronicity, severity, and the capacity and experience of the institution where the animal is being treated.[10,11] The cause of the specific injury in this eagle was unknown but suspected to be traumatic.

The metacarpophalangeal joint is the connection between the distal ends of the major and minor metacarpals and the proximal ends of the minor digit and the proximal phalanx of the major digit.[12] The motion of this joint is restricted to minimal extension and flexion, rotation, elevation, and depression. While the degree of motion is restricted, it does serve an important role in flight. Flexion of this joint leads to increased overlap of the primary feathers and, therefore, decreased overall surface area of the wing.[13] Along with rotation and elevation of the joint, these minor adjustments act to increase stability in flight and may contribute to lift generation during takeoff.[14] In this case, we were able to assess flight in a large "L" shaped flight cage that permitted evaluation of takeoff, landing, and turning. On intake, this bird was unable to fly. After surgical repair, the bird was able to perform all these tasks: takeoff, land on low perches, land on high perches, and fly around a sharp turn with no detectable difference in left versus right directional flight.

Regardless of species or joint, the primary goals of treatment for a luxation are reduction of the joint back into anatomic positioning and stabilization of that joint. Reduction can be either closed or open, and there exist several techniques for stabilization.[15,16] Luxations should be reduced as soon as possible because delayed reduction can lead to cartilage damage, muscle spasticity, and fibrosis and callus formation.[15] If reduction and stabilization cannot be achieved or fail, surgical intervention is warranted with either arthrodesis or amputation.[15]

Amputation of the distal wing can be well tolerated in raptors and is a potential option for raptors, so long as they can be placed in long-term care and can cope with daily human interaction.[11,17] However, with placement options for long-term resident birds limited and variable by species, amputation is not a consistently reliable approach to fracture or luxation of the metacarpophalangeal or other joints of the wing in raptors. Alternatively, arthrodesis of the metacarpophalangeal joint, due to its limited role in flight, poses a promising solution. However, prognosis and release rates for raptors undergoing arthrodesis of the metacarpophalangeal or other joints are limited.[4] This case serves to provide a successful example of a bald eagle having an arthrodesis of the metacarpophalangeal joint secondary to a chronic luxation and surviving to release with regained function and flight capability. Further postrelease monitoring was unable to be pursued due to financial limitations, but it is recommended to assess long-term outcomes.

This individual presented with unilateral metacarpophalangeal joint luxation and severe overlying soft tissue wounds. The eagle was released into the wild after arthrodesis of the metacarpophalangeal joint and medical management with antimicrobials and analgesics. The limited motion of the metacarpophalangeal joint poses a unique opportunity for the successful release of birds' postarthrodesis, where arthrodesis of more proximal joints would inhibit flight and likely survival outside of human care. The individual adapted well and showed no difficulty gaining lift, soaring, or landing after being released. Postoperative radiographs showed that a slight subluxation of the joint remained postsurgery; however, this did not appear to affect the bird's flight. The length of the major metacarpus and proximal phalanx limited the number of pins that could be placed. However, in retrospect, a third pin in each bone should be considered in the future to further reduce the forces acting on the joint. Additionally, the wing was wrapped in a figure-of-8 bandage to prevent damage to the hardware and wing during capture and handling. Bandaging is a common practice in our hospital because of concerns for the birds injuring themselves in the smaller hospital enclosures, and doing so has eliminated any failures in the orthopedic hardware during convalescence. The radiographic subluxation noted in Figures 2 and 3 in the bald eagle in the present case is similar to the images for the great

horned owl (*Bubo virginianus*) in the only other publication documenting the success of performing a metacarpophalangeal arthrodesis and releasing the bird postsurgery.[4] In that article, the great horned owl was bandaged with a silk tape wrap around the body for 5 weeks, and, similar to this case, had only 2 pins placed in each bone.[4]

Owing to the chronicity of the luxation in this eagle, as evidenced by the significant callus formation, reduction and stabilization, which would be considered the preferred treatment for an acute luxation of any appendicular joint, was not an option. Because of the irreversible nature of the procedure and the potential negative impact of flight, arthrodesis should not be the first treatment attempted for acute luxation when closed or open reduction and stabilization are options.[15,16] The addition of an articular fracture of the first phalanx prevented closed reduction. This case, in agreement with the 2 cases of raptors (prairie falcon [*Falco mexicanus*] and great horned owl) at the Raptor Center at the University of Minnesota (St Paul, MN, USA), which were managed with metacarpophalangeal arthrodesis and released into the wild, supports the notion that this surgical intervention poses a viable option for repair of this joint.[4] At this same institution, prior management of metacarpophalangeal luxations in a bald eagle and a red-tailed hawk (*Buteo jamaicensis*) by closed reduction and/or splinting did not restore joint stability and resulted in an unsatisfactory outcome.[4] Ultimately, case success will depend on the presenting injury, natural history, and flight or hunting styles of the bird, as well as how the bird adapts to the procedure.[4,11,15] The authors of the paper on the prairie falcon and great horned owl did have the single previously noted comment that the metacarpophalangeal luxation procedure was not successful in a bald eagle[4]; however, they did not include any information about the type of injury the eagle sustained, so it is difficult to compare with the present case. Regardless, any surgery being performed in a bird must consider the specific situation of that patient when determining a prognosis. Arthrodesis of the elbow joint has been described in a bald eagle deemed nonreleasable.[17] Fracture and luxation repair through arthrodesis has also been described in captive psittacine birds with varying degrees of success.[18,19] Successful repair of a coracoid-sternal luxation and release of a bald eagle has been reported.[20] In a review of wild white-tailed sea eagles (*Haliaeetus albicilla*) in Germany, 7 cases of luxation including 1 metacarpophalangeal luxation were reported; none of which were released.[21] The current literature lacks cases of arthrodesis in raptors with long-term follow-up from which evidence-based clinical decisions can be made or prognostic indicators inferred.

The management of this case also included broad-spectrum antimicrobials due to the extensive soft tissue wounds over the distal wing tip. Because of the extensive nature of the wound, empirical antibiotics were selected to provide coverage against Gram-negative bacteria (eg, enrofloxacin) and possible anaerobic bacteria because of the emphysematous cellulitis (eg, metronidazole). A limitation in this case was that a sample was not collected for microbiological culture before initiating antibiotics. Financial limitations are a common reason empirical antibiotics are prescribed for wildlife cases.[4,22] For the authors, although this was also a limitation, it is worth noting that microbiological culture can have limited sensitivity, which can result in false-negative results or false-positive results due to contamination from benign skin microflora.[23,24] Next-generation sequencing can provide more sensitive data, including resistance factors, but also comes at a cost. When resources are available, microbiological culture or next-generation sequencing should be pursued to guide the clinician and limit the likelihood of antimicrobial resistance developing. Hardware-associated infection and progression of the infection, making the limb inviable, were major risks in this case because of the wingtip cellulitis, which is why broad-spectrum antimicrobial coverage was initiated and continued for a total of 24 days, at which point the soft tissue wounds appeared to be healing, the pins showed no signs of infection, and radiographs did not show changes consistent with osteomyelitis. Antimicrobial resistance is a growing concern for wildlife hospitals, with bacteria like *Escherichia coli* and *Enterococcus faecalis* showing multidrug resistance genes being identified in wild raptors.[25,26] Multidrug coverage, although controversial, may be necessary until diagnostic tools are more easily accessible and economically feasible. Meloxicam, a COX-2-specific nonsteroidal anti-inflammatory, was given from intake for a total of 40 days. The analgesic and anti-inflammatory properties were likely beneficial in the initial phase of healing, postsurgical healing, and in reducing pain and inflammation associated with physical therapy. More research is needed to understand the duration of action, efficacy, and adverse effects of long-term nonsteroidal anti-inflammatory drug use in birds.

Regional limb perfusions were also performed with amikacin for 4 consecutive days before surgery. These perfusions were intended to increase the antibiotic concentration at the surgical site and clear any Gram-negative bacteria from the surgical site before the

implantation of metal hardware. Again, the extent of soft tissue damage at the wing tip was a concern, and we wanted to limit the likelihood that the surgical site could be seeded with bacteria. Regional limb perfusions using amikacin have been described and appear to be tolerated and efficacious in avian species. The authors have used them with success for raptors and waterfowl with similar injuries.[27,28] Postoperative radiographs did not show any evidence of osteomyelitis at the pin sites or elsewhere.

Another aspect of care included in this case was PBM therapy, which is increasing in popularity in veterinary hospitals. Photobiomodulation has been widely used as a noninvasive treatment method for various clinical conditions to decrease inflammation and pain, while increasing the rate of healing and blood flow to a stimulated area.[29–31] Mitochondria contain endogenous chromophores, and when stimulated with PBM, increase the synthesis of adenosine triphosphate and cellular metabolism.[29] Photobiomodulation has vasodilatory effects on the vessels and increases the blood flow to the stimulated tissue.[29–32] In cases with bone healing, Fujihara et al[33] found that PBM can also act as a proliferative stimulus. In this case, PBM was used as a component of an integrative therapy plan that also included antibiotics, analgesics, nonsteroidal anti-inflammatories, and surgery to manage this case. At our facility, PBM is routinely used as a component of therapy to manage our surgical cases. There remains a dearth of evidence in support of PBM, but there also remains a dearth of evidence regarding standard Western medicine (eg, pharmacokinetic and pharmacodynamic data) for avian species. For example, a search on PubMed and Google Scholar (July 1, 2024) using the key words bald eagle and enrofloxacin, meloxicam, metronidazole, hydromorphone, or amikacin revealed no evidence-based articles for this species. For these reasons, it is important to report our findings from our cases, beginning with case reports, and progressing to evidence-based hypothesis-driven research.

This individual presented with anisocoria, 180 degrees of posterior synechia, and early cataract formation in the eye ipsilateral to the luxation. Fundic examination was unremarkable, and serial ophthalmic examinations over the course of hospitalization and rehabilitation were static. These findings were likely secondary to ocular trauma and were chronic. It is unknown when the eagle sustained the injury to her eye; however, it likely predated the luxation based on the degree of chronicity noted by a board-certified veterinary ophthalmologist. It is possible that this eagle sustained the traumatic luxation secondary to impaired vision on the left side; however, between December 2023 and July 2024, our hospital had 15 bald eagles present with suspected or confirmed traumatic wing injuries and no ocular injury, suggesting these animals are subject to traumatic injuries regardless of their visual status. The chronic ocular lesion was considered in our release assessment. Ultimately, the decision was made that this individual was a fair candidate for release based on her demonstrated ability to fly without limitation, land on perches without difficulty, find food within her flight cage, feed trial live prey, and because the dietary habits of eagles include stealing or scavenging prey, which would not require strong, binocular vision.[34]

Bald eagles are heavy-bodied raptors, and the force that acts on their metacarpophalangeal joint is high. Therefore, stability of this joint is needed to prevent inappropriate extension of this joint during the power stroke of flight. Arthrodesis ensures that this force is distributed across the adjacent bones. The minor adjustments that this joint makes to enhance flight may be negligible in a bald eagle, which feeds mostly by scavenging and ambush-hunting fish. However, bald eagles do engage in an elaborate mating display that involves the pair interlocking their talons and free-falling before releasing their grip and hitting the ground.[35] The biomechanics of this maneuver and the impact that arthrodesis of the metacarpophalangeal joint would have on a bird's ability to perform this display are unknown. Additionally, more information would be needed to see if this is an appropriate method of surgical repair for species, such as Accipiters, that hunt fast-moving and agile prey. A single case report in a prairie falcon suggests it may be possible, but that bird, as with this eagle, was not followed postrelease to determine their ultimate success. Future support and funding, including postrelease tracking, would enable wildlife hospitals to assess the long-term prognosis for novel or rare surgical techniques.

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