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Original Study

Outcomes of Birds of Prey with Surgical or Traumatic Wing Amputation: A Retrospective Study from 1995 to 2017

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Abstract: Surgical amputation of a limb is often required to treat raptor orthopedic injuries at rehabilitation centers. In some cases, amputation is an alternative to euthanasia if the bird's welfare is deemed appropriate under human care. The outcome for raptors maintained in a captive setting following wing amputation is poorly documented. A retrospective study was conducted in a Canadian raptor rehabilitation facility to assess the outcomes and complications observed in captive and free-living raptors with partial or complete, surgical or traumatic amputations of the wing. Data from raptors admitted to the rehabilitation center from 1995 to 2017 were reviewed. Overall, 32 records were included in this retrospective study from 11 species of raptors with surgical or traumatic wing amputations. Survival times of the 23 birds with an amputated wing (median: 1070 days, range: 68 days to 13 years and 1 month) were significantly ($P = .02$) longer than the survival times of the 404 non-amputated birds (median: 696 days, range 37 days to 27 years and 3 months). Complications occurred in 13 of 30 birds (43%) during the recovery period, with 9 of 30 (30%) birds developing life-threatening complications. Maladaptation to captivity was the leading cause of euthanasia during this period. After placement in captivity, 3/23 (13%) birds developed complications related to the amputation site. Based on this study, we conclude that some birds can tolerate partial or complete wing amputation, but the decision to place a bird in a captive setting should encompass the bird's ability to cope with human interaction and the availability of an adapted and safe enclosure for the animal.

Key words: wing, surgical, traumatic, avian, raptors, amputation

INTRODUCTION

Traumatic injuries are a very common cause of morbidity or death in free-living raptors, and in some studies trauma has been found to be the leading cause of death.[1,2] Traumatic injuries involving the wing are considered the most common type of trauma reported in free-living birds.[3] Numerous surgical and non-surgical techniques have been described for injuries involving the joints, soft tissues, and bones of raptor wings.[3-7] Return to function is the main goal when treating wing injuries in free-living raptors, but fracture-repair complications may also be encountered. Examples of unmanageable orthopedic conditions involving raptor wings include severe intractable infectious or neoplastic disease, other painful conditions that cannot be medically alleviated (eg, severe osteoarthritis, neurologic pain), chronic radial nerve paralysis, and fracture malunion or nonunion.[8] Raptors that cannot be released back into the wild are typically euthanized at most institutions. However, under some circumstances, long-term care facilities are available for flightless raptors and wing amputation may be indicated for these individuals.

In the United States, raptors are protected by the Migratory Bird Treaty Act of 1918; therefore, they are federally protected under the jurisdiction

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of the United States Fish and Wildlife Service (USFWS). When raptors are presented to veterinarians, clinicians are allowed to care for sick or injured animals but need to comply with regulations enforced by the USFWS. Under these regulations, the amputation of a foot or leg is prohibited in raptors, as is amputation of a wing at, or proximal to, the elbow, unless a derogation can be obtained. Indeed, amputation of a wing proximal to the elbow has been described as a procedure interfering with the bird's ability to balance properly on a perch, although this information appears to be based on anecdotal data.[9] This conclusion has yet to be supported by controlled studies. In Canada, raptors are protected by provincial and federal legislations[10] but there are no regulations regarding amputation site. Therefore, it would be relevant to describe the outcome of birds of prey with various amputation sites. Wing amputations have been performed on non-releasable raptors deemed to be good candidates to be kept in captivity. Good candidates for captivity include birds with minimal or no flight reaction to human presence or activity, an appropriate appetite, and no occurrence of self-mutilation or self-harm.

The objective of this study was to describe the survival times, outcomes, and complications encountered by birds of prey having undergone surgical or traumatic wing amputation at the Clinique des oiseaux de proie from 1995 to 2017. An additional objective was to compare the survival times of captive amputated birds of prey and other captive birds maintained in the same environment.

MATERIALS AND METHODS

The electronic medical record database (Microsoft Access 2013, version 15.0.4945.1001, Microsoft Canada Inc, Mississauga, Ontario, Canada) of the Clinique des oiseaux de proie of the Centre Hospitalier Universitaire Vétérinaire, Saint-Hyacinthe, QC, Canada, which is affiliated with the Université de Montréal, was searched from 1995 to 2017 to review medical records of birds of prey that underwent partial or complete amputation of a wing. Birds from the orders Accipitriformes, Cathartiformes, and Strigiformes were included in this study. Cases included free-ranging birds admitted for rehabilitation, maintained in zoological institutions, or those in falconry settings. Birds admitted with a traumatic amputation that was healing without intervention or having undergone a surgery to complete amputation were included in this study. Traumatic amputation was defined as a missing distal section of the wing, affecting digits 2 or 3, the carpometacarpus, antebrachium, or humerus, resulting from a traumatic incident that did not require surgical intervention. Information regarding species, age, sex, reason for amputation, amputation site, type of amputation (surgical or traumatic), anatomic location of surgical procedure, presence or absence of complications, and the bird's outcome were retrieved from each medical record, when available. Complications were classified as minor or major. Minor complications included wound dehiscence that resolved without an additional surgical procedure and ingrown feather cysts at the wing amputation site. Major complications included peri-anesthetic death, euthanasia due to failure to thrive in captivity or due to a problem related to the stump, wound dehiscence requiring an additional surgical procedure, repeated trauma to the surgical site (maladaptation), and necrosis at the amputation site. Outcome was classified as placement in captivity (C), euthanized (E), or died (D). The change in outcome for birds that were euthanized or died after placement in captivity were classified as C→E and C→D, respectively. Captivity was recorded as the outcome only if the bird was considered completely recovered from either the surgical procedure or care related to traumatic amputation. Complete recovery from a surgical or traumatic amputation was defined as complete healing of surgical, traumatic, or dehiscence wounds; voluntary feeding; and cessation of medical treatment. Mortality causes were deemed either related or unrelated to the amputation based on postmortem evaluation. Euthanasia was further classified as related or unrelated to the amputation. Euthanasia was deemed related to the amputation if the bird was determined to be maladapted to captivity. Maladaptation to captivity was recorded when raptors repeatedly exhibited strong flight reactions to humans leading to injury, long-term anorexia without any identifiable underlying medical condition, and/or sustained numerous self-injuries from interaction with the environment. Euthanasia was considered to be unrelated to the amputation for any other medical reason. Length of survival in captivity was calculated for amputated and non-amputated captive birds held at the Union québécoise de rehabilitation des oiseaux de proie's educational facility Chouette à voir!, Saint-Jude, QC, Canada. The birds were sexed, when possible, based on dimorphism for the species, history of egg laying, or DNA testing. Age groups were identified based on annual changes in

plumage and classified as nestling (N), hatching year (HY), after hatching year (AHY), second year (SY), after second year (ASY), third year (TY), and after third year (ATY). The distinction between ASY and ATY was dependent on the bird species, as plumage evolves between the second and third year only in certain species (eg, red-tailed hawks [*Buteo jamaicensis*] and bald eagles [*Haliaeetus leucocephalus*]).[11]

For birds that presented with traumatic amputation, wound treatment was performed daily, including necrotic tissue debridement, until the granulation phase was reached. Hydrotherapy and intrasite gel (Smith and Nephew, Mississauga, Ontario, Canada) were provided 2 to 3 times a week during the granulation phase and standard wound dressing (Melolite, Smith and Nephew; Tegaderm, 3M, Saint-Laurent, Quebec, Canada) was applied. A semi-permeable bandage (Tegaderm) was placed during the epithelialization phase at the amputation site.

Thoracic limb amputation at the level of the proximal humerus was elected if the injury involved the brachium, antebrachium, or brachial plexus, as this technique had subjectively resulted in fewer chronic post-operative complications (eg, trauma at the amputation site). Radiosurgery (Surgitron®, Ellman, Hucksville, NY, USA) was used for hemostasis as needed. Nerves were identified during the surgical procedure and a splash block of local anesthetic (lidocaine, Lurocaine, 20 mg/mL; Vetoquinol, Lavaltrie, QC, Canada) provided. After any transverse ostectomy, muscle flaps were sutured with a monofilament absorbable suture material (Monocryl 4-0, Ethicon; Johnson & Johnson, Markham, ON, Canada) over the amputation site to protect the distal portion of the bone. Scapulohumeral disarticulation was occasionally performed, as a last resort, for disease of the scapulohumeral joint. When amputation is performed at the level of mid-radius and ulna, there is a lack of muscle to properly cover the stump. Therefore, once sectioned, the radius and ulna were fused using cerclage wire and the *propatagialis pars longus* sutured over the distal ends of the bones to cushion the amputation site. For fractures of the carpometacarpal bones, the amputation was performed at the level of the proximal carpometacarpus by resection of the carpometacarpus and surrounding soft tissues. In cases of carpometacarpophalangeal luxation or open fracture of phalanges, amputation was performed by carpometacarpophalangeal disarticulation. Post-operative surgical wound management included daily bandage changes for the first 3 days with standard dressing (Melolite, Tegaderm) and then the wound was left to heal without a bandage.

The Clinique des oiseaux de proie adopts a minimally invasive approach throughout the rehabilitation period. Handling is minimal and frequently performed under sedation or general anesthesia to decrease the potential for self-inflicted injury. Numerous factors are evaluated prior to deciding to place a bird of prey in a long-term facility, including the ability for the raptor to interface with humans for feeding and cleaning, as well as tolerate visitors. Non-releasable birds showing repeated strong flight reactions to humans that can lead to injuries are not selected for captivity and are euthanized.

Descriptive statistics (range and median time of survival) were calculated for the survival times of birds maintained in captivity after surgical or traumatic amputation of the wing, including birds still alive at the time of the study. Birds euthanized on admission or that did not survive post-operative hospitalization before placement in captivity were not included in the calculation of survival times. Prevalences were calculated for amputation complications by each anatomic location. To compare survival times between amputated and non-amputated captive birds, a Kaplan Meier survival analysis and logrank test were conducted using a commercial statistical software (MedCalc Statistical Software version 17.5.5, Ostend, Belgium). Differences were considered significant at $P < .05$.

RESULTS

A total of 8,197 raptors (yearly average of 356) were presented to the Clinique des oiseaux de proie of the Faculté de médecine vétérinaire of the Université de Montréal from 1995 to 2017. Medical records of 32 birds with traumatic or surgical wing amputation were identified and retrieved. Two ospreys (*Pandion haliaetus*) with traumatic amputations were euthanized upon arrival (1 male, 1 unknown sex). Therefore, 30 birds were admitted for care. Information regarding the cause of wing amputations and bird signalment is presented in Table 1. Twelve males, 15 females, and 5 birds of unknown sex were included in the study. Birds from the order Strigiformes were overrepresented (n=15) and represented 50% of the cases.

Twenty-one birds underwent surgical wing amputation, including 2 scapulohumeral disarticulations, 15 proximal humeral amputations, 1 amputation at the level of the proximal third of

the antebrachium, and 3 proximal carpometacarpal amputations. Seven birds were treated for incomplete traumatic amputation of 1 or both wings, without requiring surgical amputation proximal to the trauma site. In addition, 2 birds presented with bilateral suspected frostbite leading to partial bilateral wing amputation, without requiring surgical intervention.

Complications occurred in 43% (13/30) of the birds undergoing treatment, with 30% (9/30) developing life-threatening complications. Two birds died within 24 hours of the surgical wing amputation procedure. The post-mortem reports from the 2 birds that died shortly after surgery stated the cause of death was determined to be unrelated to the surgical procedure, but an anesthetic cause could not be completely ruled out. Five birds were euthanized during the recovery phase. Of these 5 birds, a turkey vulture (*Cathartes aura*) was euthanized due to endocarditis and osteomyelitis of numerous toes, and 1 snowy owl (*Bubo scandiacus*), 1 Cooper's hawk (*Accipiter cooperii*), and 1 osprey were euthanized during hospitalization for maladaptation to captivity. A single bird, a snowy owl amputated at the level of the proximal humerus, was euthanized due to repeated trauma to the amputation site during the immediate postoperative period. Two birds had wound dehiscence requiring further care, but their wounds eventually healed.

Out of 30 birds included in the study, 10 birds were less than a year old at the time of admission (HY or N), 16 birds were more than a year old, and 4 birds were of undetermined age. One of the 10 juvenile birds (less than a year old) died 1 day after amputation and 1 developed a minor complication requiring further care during the postoperative period. Out of 10 birds less than a year old, 9 birds were placed into captive environments.

Twenty birds were placed in captivity following complete recovery, and 3 additional birds were discharged to their owners, which were falconers. Survival times of the 23 birds maintained under human care with an amputated wing were compared with the survival times of 404 non-amputated birds housed at the Union québécoise de rehabilitation des oiseaux de proie's educational facility Chouette à voir!. Survival times of the 23 birds with an amputated wing (median: 1070 days, range: 68 days to 13 years and 1 month) were significantly ($P = .02$) longer than the survival times of the 404 non-amputated birds (median: 696 days, range 37 days to 27 years and 3 months). For captive birds that underwent a surgical wing amputation (n=21), survival times ranged from 68 days to 13 years and 1 month, with a median survival of 995 days. For captive birds that underwent surgical amputation at the proximal third of the humerus (n=15), survival times ranged from 68 days to 12 years, with a median survival of 849 days. Birds remaining in captivity that presented with a traumatic amputation or frostbite, and hence did not require surgical intervention (n=9), had survival times ranging from 305 days to 16 years and 8 months, with a median survival of 1643 days. Out of the 23 birds placed in captivity with an amputated wing, 22% (5/23) were eventually found deceased, 26% (6/23) were euthanized for medical problems unrelated to the amputation site, 9% (2/23) died or were euthanized for complications related to amputation site trauma, 22% (5/23) of the deaths were undiagnosed, and 22% (5/23) were still alive at the time of this study. Post-mortem examinations of the birds found deceased did not identify the wing amputation as a cause of death. In addition to the 2 birds euthanized due to amputation site related complications, 1 bird developed minor complications. The bird with a minor complication developed ingrown feathers at the amputation site. Major complications that required euthanasia included an American kestrel (*Falco sparverius*) with a traumatic antebrachium amputation that was euthanized 517 days into captivity after repeated trauma to the amputation site, and a snowy owl with a proximal antebrachium amputation injury that was repeatedly traumatized and died 470 days after being placed in captivity during a second surgical procedure to amputate at the level of the proximal humerus. None of the birds placed in captivity with a proximal humerus amputation presented with repeated trauma of the amputation site. Of note, one female Harris hawk (*Parabuteo unicinctus*) successfully bred despite a wing amputation at the level of the scapulohumeral joint. Prevalences for the different complications encompassing both the recovery period and time spent in captivity are presented in Table 2. Overall, 9% (2/23) of birds with partial or complete, surgical or traumatic wing amputations developed life-threatening complications once placed in an educational facility.

DISCUSSION

This study documents the outcomes and complications associated with partial or complete, surgical or traumatic, wing amputations in raptor species. This current study demonstrated that birds with wing amputations can survive and be used for

Table 1. Information and outcome of birds of prey having undergone wing amputation at the Clinique des oiseaux de proie of the Université de Montréal.

Species	Sex	Age	Anatomic location	Type of amputation	Outcome	Relatedness of death/euthanasia to amputation	Survival time after placement in captivity (days)
American kestrel (*Falco sparverius*)	F	AHY	Proximal third of carpometacarpus	Traumatic amputation	C→ D	U	2960
American kestrel (*Falco sparverius*)	M	HY	Distal third radius-ulna	Traumatic amputation	C→ E	R	517
Bald eagle (*Haliaeetus leucocephalus*)	M	HY	Proximal third of carpometacarpus	Surgical amputation due to talon injury to wing	C→ E	I	3650
Bald eagle (*Haliaeetus leucocephalus*)	M	ASY	Proximal third of carpometacarpus	Traumatic amputation	C	NA	2131
Bald eagle (*Haliaeetus leucocephalus*)	M	N	Proximal third humerus	Surgical amputation due to failed external fixator	C→ E	U	2089
Broad-winged hawk (*Buteo platypterus*)	M	SY	Proximal third humerus	Surgical amputation due to partial traumatic amputation	C→ E	U	366
Cooper's hawk (*Accipiter cooperii*)	M	ASY	Proximal carpometacarpus	Traumatic amputation	E	R	NA
Harris hawk (*Parabuteo unicinctus*)	F	ATY	Proximal third carpometacarpus bilaterally	Suspect bilateral frostbite leading to necrosis	C→ D	U	305
Harris hawk (*Parabuteo unicinctus*)	F	ATY	Second digit bilaterally	Suspect bilateral frostbite leading to necrosis	C	NA	1643
Harris hawk (*Parabuteo unicinctus*)	F	ASY	Scapulohumeral disarticulation	Surgical amputation following failed orthopedic surgery	C	NA	4798
Osprey (*Pandion haliaetus*)	F	AHY	Second digit, phalanx II	Traumatic amputation	E	R	NA
Turkey vulture (*Cathartes aura*)	UN	AHY	Proximal third carpometacarpus	Surgical amputation due to tendon necrosis and chronic wound	E	U	NA
Peregrine falcon (*Falco peregrinus*)	F	HY	Proximal third humerus	Surgical amputation due to peripheral neurologic deficits	C→ D	I	3259
Peregrine falcon (*Falco peregrinus*)	M	HY	Scapulohumeral disarticulation	Surgical amputation due to failed orthopedic surgery	D	R	NA
Peregrine falcon (*Falco peregrinus*)	F	ASY	Proximal third humerus	Surgical amputation due to an open comminuted fracture	C→ D	U	282
Great grey owl (*Strix nebulosa*)	F	AHY	Proximal third humerus	Surgical amputation due to repeated fracture	C→ D	I	4515
Great grey owl (*Strix nebulosa*)	M	ASY	Proximal third humerus	Surgical amputation due to open fracture with bone necrosis	C→ D	U	920
Great grey owl (*Strix nebulosa*)	UN	HY	Proximal third humerus	Surgical amputation due to soft tissue necrosis	C→ D	I	128
Saw-whet owl (*Aegolius acadicus*)	UN	AHY	Proximal third humerus	Surgical amputation due to brachial plexus avulsion	C	NA	4363
Saw-whet owl (*Aegolius acadicus*)	F	ASY	Proximal third carpometacarpus	Traumatic amputation	C→ D	I	657
Short-eared owl (*Asio flammeus*)	F	HY	Proximal third humerus	Surgical amputation due to failed orthopedic surgery	C→ D	U	849
Short-eared owl (*Asio flammeus*)	M	HY	Proximal third humerus	Surgical amputation due to open fracture with bone necrosis	C→ D	I	68
Snowy owl (*Bubo scandiacus*)	F	UN	Proximal third radius-ulna	Surgical amputation due to open fracture	C→ D	R	489
Snowy owl (*Bubo scandiacus*)	M	HY	Proximal third carpometacarpus	Surgical amputation due to failed orthopedic surgery	C	NA	2357
Snowy owl (*Bubo scandiacus*)	UN	UN	Second digit	Traumatic amputation	C	NA	6118
Snowy owl (*Bubo scandiacus*)	F	AHY	Proximal third humerus	Surgical amputation due to partial traumatic amputation	D	R	NA

Table 1. Continued.

Species	Sex	Age	Anatomic location	Type of amputation	Outcome	Relatedness of death/euthanasia to amputation	Survival time after placement in captivity (days)
Snowy owl (*Bubo scandiacus*)	F	UN	Proximal third humerus	Surgical amputation due to open fracture with bone necrosis	E	R	NA
Snowy owl (*Bubo scandiacus*)	F	UN	Proximal third humerus	Partial traumatic amputation radius-ulna	C→ D	I	470
Snowy owl (*Bubo scandiacus*)	F	AHY	Proximal third humerus	Surgical amputation due to open articular fracture	E	R	NA
Snowy owl (*Bubo scandiacus*)	M	HY	Proximal third humerus	Partial traumatic amputation radius-ulna	C→ E	U	1070

Abbreviations: AHY, after hatching year; ASY, after second year; ATY, after third year; C, captivity; D, died; E, euthanized; F, female; HY, hatching year; I, incomplete record; M, male; N, nestling; NA, non-applicable; R, related to amputation; U, unrelated to amputation; UN, undetermined.

display birds, when selected for appropriate behavior traits. The birds with amputated wings from this study that were placed in captivity could easily move between 2 perches, bathe, conduct species specific behaviors, and eat voluntarily, which are characteristics that can be considered positive for captive placement.[12] The findings of this study should be considered by personnel at raptor rehabilitation centers when making medical decisions, as well as in the establishment of regulations regarding amputation of the wings in non-releasable raptor species.

The literature pertaining to amputation as a solution for unresolvable orthopedic conditions of the wing in raptors is limited to case reports, with a maximum follow-up duration of 3 years.[8,13] Amputation of the wing at the level of the proximal humerus was elected in a golden eagle (*Aquila chrysaetos*) due to an old humeral fracture. No complications related to the amputation were encountered up to 6 months following surgery in this golden eagle.[13] In a case series reporting a novel technique for scapulohumeral amputation, a peregrine falcon (*Falco peregrinus*) recovered from the procedure without any short-term or long-term complications during the 3 year follow-up period.[8] Both of these birds were owned by falconers and were accomodated to a captive setting.

The present study found that most complications occurred during the initial rehabilitation process. Euthanasia due to maladaptation to captivity was performed during the rehabilitation process for all birds except for two which were euthanized following placement in captivity. Once birds were placed in educational facilities, the complication rate associated with the wing amputation was reduced from 43% to 13%. Maladaptation to captivity is ill defined terminology. Assessing a bird's adjustment to captivity is largely subjective, making it difficult to define qualitatively or quantitatively. It should be acknowledged that behaviors such as fear or flight responses leading to self-harm might be modified by conditioning or other techniques (systematic desensitization, counter conditioning) in some individuals in an attempt to prevent euthanasia.[14] Behavioral interventional methods were not used for the birds placed in captivity in this study as they were all free-ranging and it was elected to not modify their behavior. Further studies should investigate the use of behavioral interventional methods in free-ranging raptors transferred to captive setting where they

Table 2. Complications in birds of prey with wing amputations presented to the Clinique des oiseaux de proie of the Université de Montréal.

Amputation site	No complications	Minor complications	Major complications	Undetermined
Scapulohumeral disarticulation	0	1	1	0
Proximal third humerus	11	1	3	0
Radius-ulna	0	0	2	0
Proximal third carpometacarpus	3	2	2	1
Second digit	2	0	1	0
Total (%)	16/30 (54%)	4/30 (13%)	9/30 (30%)	1/30 (3%)

will interact with humans. Behavioral interventional methods may be difficult to implement during the initial rehabilitation process as birds may require frequent handling to perform wound assessment and appropriate care.

The present study identified longer survival times for amputated birds compared with non-amputated birds under human care in the same captive conditions. Birds demonstrating a strong flight response to human presence and/or birds with a self-destructive temperament were almost all identified during the rehabilitation process. Overall, chronic trauma to the amputation site was a complication encountered at a low rate. Moreover, no birds with a proximal humerus amputation traumatized the amputation site. Considering that numerous birds contributed to educational programs, or in 1 case (female) bred in captivity, and that their welfare was deemed appropriate, the results of this study support the use of proximal humerus amputation in certain cases when legal approval can be obtained, and when the bird's temperament is appropriate for transfer to an educational facility.

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