Successful resection of an osteoma in a great horned owl (Bubo virginianus) with subsequent lack of regional feather regrowth

Lorraine Barbosa,1 Duane Tom,1 Sushan Han2

SUMMARY
A free-living adult great horned owl (Bubo virginianus) was presented to a wildlife rehabilitation centre in Southern California with a firm, pedunculated mass arising from the caudal-dorsal border of the left ulna. Two secondary covert feathers were incorporated into the mass and multiple secondary flight and covert feathers adjacent to the mass were broken. Radiographs revealed a calcified mass with no cortical involvement. The mass was surgically removed. Histopathology was consistent with a diagnosis of osteoma. Despite tumour removal, the owl sustained a significant flight impairment resulting from lack of regional feather regrowth. Waiting for a natural moult to take place would likely require 9–12 months. An attempt was made at inducing moult by manually pulling feathers but was not successful. As the rehabilitation facility was space limited and the bird was behaviourally a poor candidate for long-term rehabilitation, humane euthanasia was elected.

BACKGROUND
Osteoma is a benign, slow-growing tumour that arises from mature bone (central osteoma), periostea (periosteal osteoma) or soft tissues (hetero-plastic osteoma) and is composed of coalescing trabeculae of lamellar, mineralised bone with mature osteocytes and interspersed with loose vascularised collagen.1 This tumour has been observed infrequently in birds, that is, osteomas on the axial skeleton of three budgerigars (Melopsittacus undulatus) and one chicken (Gallus gallus domesticus)2–4; the appendicular skeleton of a budgerigar,5 two chickens6 and a domestic duck (Anas platyrhynchos domesticus);7 the foot pad of a domestic duck; the nostril of a blue-fronted Amazon parrot (Amazona aestiva);7 the soft tissues of the proximal wing of a canary (Serinus canaria)8 and one tumour ensheathing the kidney of a chicken.6 A suspected osteoma was found on the sternum of an eclectus parrot (Eclectus roratus).9 The only published report of an osteoma-like tumour in a raptor is a barred owl (Strix varia), which had a radial bone tumour that was histologically distinct from true osteoma and for which no treatment was attempted.10 Here we discuss the clinical presentation, diagnosis and follow-up management of an osteoma in a great horned owl (GHOW) (Bubo virginianus) with failure of feather regrowth following tumour removal. This case is a unique and important addition to the existing literature as this tumour type has not previously been reported in any raptor and because it underscores that failed regrowth of flight feathers is a significant complication that needs to be addressed when considering surgical repair of benign tumours in rehabilitating birds.

CASE PRESENTATION
In September 2016, an adult, 1060 g, unknown sex, free-living GHOW (B virginianus) was brought to a wildlife rehabilitation centre in Southern California. On physical examination, the owl was alert, moderately thin, mildly hypothermic (T=38.3°C) and mildly dehydrated. The bird had a severe left wing droop and a firm, 5×4.5×3.5 cm, pedunculated mass attached superficially along the caudal-dorsal border of the left ulna at the level of the mid-diaphysis (figure 1A,B). The overlying integument was moderately ulcerated and included several contour feathers. The mass disrupted secondary flight feathers (S) and completely effaced covert feathers overlying S5–S11 with incorporation of two covert feather follicles with remnant calami 1 cm long. Adjacent S2–S7 were ragged, but calami were intact. S8 had a visible follicle but the calamus was broken and frayed at the skin edge. The calami of S9 and S10 were ragged and broken off 2 cm from the skin surface (figure 1B), and S11 had a visible follicle, but was also missing most of the calamus.

The day after admission, the patient was placed under general anaesthesia for further examination. The owl was masked down with isoflurane (Henry Schein, Melville, New York, USA) at 5%, intubated and maintained on isoflurane at 1.25% delivered in oxygen at 1 L/min. Manual positive pressure ventilation was provided throughout the anaesthetic procedure. Radiographs revealed a pedunculated and multilobulated, calcified and fibrotic mass loosely attached to the superficial periostea and soft tissues of the left wing at the level of the mid-diaphysis of the ulna with no obvious cortical involvement (figure 2A,B).

DIFFERENTIAL DIAGNOSES
► Metastatic neoplasia
► Benign neoplasia
► Granuloma
► Abscess
► Cyst
Figure 1  A firm, smooth and mostly featherless, pedunculated mass attached superficially along the caudal-dorsal border of the left ulna of a great horned owl (Bubo virginianus) (A). Adjacent to the mass, secondary flight feathers S2–S7 are ragged with intact calami, S8 has a visible follicle with a calamus broken at the skin edge (not visible in photo) and S9–10 are ragged with calami broken off 2 cm from the skin surface (B).

TREATMENT
An excisional biopsy surgery was performed. The skin was closed with 5–0 Biosyn, a synthetic polyester absorbable suture made from Glycomer 631 (Covidien-Medtronic, Minneapolis, Minnesota, USA) in a simple-continuous suture pattern. The surgical site was treated topically with silver sulfadiazine cream, USP 1% (Ascend Laboratories, Parsippany, New Jersey, USA) and a Telfa pad (Covidien-Medtronic) and a figure-8 wing wrap made of Vetrap (3M, St. Paul, Minnesota, USA) were applied. Anaesthetic recovery was uneventful. The bird was started on 100 mg of Clindamycin (orally once daily for 7 days; Henry Schein), 2 mg of butorphanol (orally twice daily for 3 days, 1 mg Torbutrol tablets; Zoetis) and 1 mg of meloxicam (orally once daily for 5 days, 1.5 mg/ml Metacam; Boehringer Ingelheim Laboratories). Nutritional and thermal support were provided postoperatively.

The excised mass was placed in 10% neutral buffered formalin and sent to Colorado State University Diagnostic Medicine Center. Histopathological examination revealed thick trabeculae of lamellar and woven bone arising from the superficial perios- teum, interspersed by small, mature osteocytes and supported by abundant loose fibrovascular stroma, interspersed with small amounts of mucin (figure 3A). Bony trabeculae were bordered by small numbers of non-reactive, spindloid osteoblasts with minimal remodelling and rare multinucleated osteoclasts. These findings were consistent with a diagnosis of osteoma. The neoplasm was circumscribed by a thin layer of periosteum and ulcerated and non-feathered squamous epithelium. Two covert feather follicles containing degenerated lamellar keratin debris and lined by attenuated and crushed barbules with a thin outer follicular sheath of squamous epithelium were incorpo- rated within the base of the neoplasm at the surgical margin (figure 3B).

Two days postsurgery, the surgical site was intact with moderate bruising of the skin (figure 4). On day 4 postsurgery, the wing wrap was removed. The surgical site bruising had improved and the bird no longer had a wing droop. Sixteen days postsurgery, the surgical site had healed and the patient was moved to an outdoor aviary to allow exercise and for flight assessment. The enclosure was a large flight pen (approximately 480 sq ft and 12.5 ft high) with natural ground covering, several perches staged at differing heights (up to 9 ft high), a hiding box, a central elevated stand for feeding, and a water dish. Within 2 weeks, the patient was able to take short flights with lifts to approximately 4–5 ft. However, increased effort and noise during flight were noted, likely due to secondary flight feather damage and missing secondary covert feathers resulting in several 2–5 cm gaps through which air passed (figure 4).

Seventy-one days postsurgery, the patient underwent anaes- thesia for imping (replacement of damaged feathers with donor feathers). A dead GHOW of a similar weight and size was used as a feather donor. Imping of the feathers entailed removal of the tattered feathers from the patient (recipient) by cutting the calamus approximately 2 cm from the skin edge using a heated scalpel blade. This was followed by application of the donor feathers using Loctite epoxy resin (epoxy resin/polymercaptan hardener; Henkel Corporation, Westlake, Ohio, USA) and a small wooden dowel fashioned to fit semi-snugly into both the calamus of the donor feather and the calamus of the recip- ient bird’s feather. S2–S7 of the left wing were imped due to being excessively tattered/ragged. S8 had a visible follicle but the calamus was broken and frayed at the skin edge and was not amenable to imping. S9 had moulted on its own and a new approximately 7 cm blood feather was growing in. S10 included a retained broken and highly frayed 2 cm calamus and S11 had a visible follicle, but was also missing most of the calamus, and neither would facilitate imping.

Over the following months, the bird’s flight strength improved some but flapping and gliding remained noisy. The owl was able
to make several flights across the full length of the enclosure; however, it would then land on the ground and cease flight attempts. At 126 days postsurgery, the bird was reassessed. The covert feathers overlying the distal secondary feathers (S1–S4) were broken mid-shaft, and as such, they were pulled to stimulate regrowth. Coverts along S5–S11 remained absent altogether with no regrowth noted. Continued lack of regrowth of S8, S10 and S11 was also noted. The bird was again assessed at 164 days postsurgery. A flight test revealed good lift and symmetry. However, increased flight noise and a persistent lack of physical endurance were noted. The bird landed on the ground after the second round-trip flight across the aviary and was easily caught. No regrowth of coverts was noted along the left distal secondaries where the feathers had been pulled, and there was continued lack of regrowth of S8, S10 and S11. Additionally, the bird had developed bilateral carpal wounds due to self-inflicted trauma in the enclosure, creating significant concerns for continued captive care. Together with the increasing space limitations at the rehabilitation facility, these factors led to the decision for humane euthanasia. Following euthanasia, the bird’s left ulna was submitted for histopathology to assess for tumour regrowth as well as to assess the feather follicles for potential causes of impaired regrowth.

OUTCOME AND FOLLOW-UP

Postmortem histopathology of the left ulna revealed no tumour regrowth at the surgical site and no abnormalities of the radius or ulna. Secondary flight feather follicles and soft tissues at the surgical site were evaluated to investigate lack of feather regrowth. Grossly abnormal feather follicles were characterised by retained broken and frayed calami without inflammation or folliculogenesis (figure 5A), by complete feather loss with marked distortion of the infundibulum, mild inflammation and no developing feather follicle (figure 5B), or by a developing follicle with distortion of the dermal papilla (figure 5C). Grossly normal feather follicles were intact and mature (figure 5D). Few, large, intracytoplasmic protozoal cysts filled with tightly packed zoites of *Sarcocystis* species were observed in the muscle surrounding the surgical site and considered an incidental finding.

DISCUSSION

This GHOW represents a case of an uncommonly reported neoplasm in birds that was appropriately treated but that resulted in a lack of regrowth of secondary covert and flight feathers and a loss of flight ability. Osteomas are discrete and

Figure 3  Photomicrographs of an excised ulnar mass consisting of mature, anastomosing trabeculae of woven bone and loose fibrovascular stroma consistent with benign osteoma (A), incorporating few secondary covert feather follicles within the neoplasm (B).

Figure 4  Dorsal view of the left wing of a great horned owl (*Bubo virginianus*) 2 days following surgery to remove a large pedunculated mass at the mid-diaphysis of the caudal-dorsal border of the left ulna. Bruising can be seen at the surgical site of the mass removal. Note the large gaps created by ragged secondary flight feathers S2–S5, missing secondary feathers S8 and S11 (not visible in photo), broken secondary feathers S9–S10 and the lack of secondary covert feathers in the region of the mass resection.

Figure 5  Secondary flight feather follicles of the left ulna revealing fragments of retained calami (arrows), with no inflammation and no folliculogenesis (A); marked distortion of the follicle with remnants of the epidermal collar (*), complete feather loss, mild lymphoplasmacytic inflammation and no folliculogenesis (B) and a developing feather follicle with distortion of the dermal papilla (C); in contrast to a normal feather follicle (D).
Osteomas are rare in animals and have been reported infrequently in birds. A single case report of an osteoma-like tumour arising from the proximal radius in a barred owl is published; however, the histological description of the lesion is not consistent with a classical osteoma, and the bird was euthanised due to the extent of the lesion with no attempt at surgery or rehabilitation. The authors could not find reports of an osteoma in a free-living bird or in any raptor species.

In most mammals, osteomas typically arise from the skull, especially the oral cavity and nasal and paranasal sinuses, while in humans, these tumours usually arise from the appendicular skeleton. In birds, the proportion of tumours arising from the appendicular skeleton is approximately 36% of known cases. As these tumours appear to occur sporadically, it remains unclear why they would have a propensity for affecting the extremities in certain species. Trauma has been suggested as a potential underlying cause of osteomas in humans.

No signs of trauma to the left ulna, aside from feather damage, were noted in this individual. However, as the substantial size of this slow-growing tumour indicates a chronic process, it is possible that the bird underwent a traumatic injury in the left ulna that subsequently healed prior to presentation.

Surgical excision is the treatment of choice for osteomas in birds, especially those causing clinical signs, and successful surgery may be curative. In a blue-fronted Amazon parrot, an osteoma located at the left nostril was surgically excised and no tumour regrowth was noted. In an eclectus parrot, a suspected osteoma was removed from the sternum and no regrowth was noted 6 months later. In our individual, no regrowth of the tumour was noted 5.5 months postsurgery.

In raptors, damage or loss of feathers can result in flight impairment including decreased lift, thrust and balance. Owls, known for their unique nearly silent flight, are especially vulnerable to the consequences of feather damage. When their specialised wing morphology is compromised, flight becomes noisy, making food acquisition more difficult. In a study of 92 wild-caught and two captive GHOwS, feather moult was noted to begin in mid-late May with the entire process requiring until September or October for completion. The individual in our study presented to the rehabilitation facility in early September, near the end of the normal moulting period for this species, indicating that a natural moult for our patient would likely require 9–12 months in rehabilitative care.

Various methods have been described to attempt induction of feather regrowth prior to the next natural moult, including hormonal additives such as progesterone, thyroxine, thyroid hormone or Eltiryen (a synthetic non-apeptide analogue of gonadotropin releasing hormone); feeding beef thyroid; removal of food (for a period long enough for involution of the reproductive tract) and water (for up to 3 days); reduction in photoperiod or manipulation of dietary minerals. However, due to inconsistent results, ethical concerns and lack of extensive understanding of side effects, such techniques may not be suitable for all individuals. In one of the authors’ experience, and likewise noted by colleagues, manually pulling damaged feathers can induce feather regrowth, even outside of the normal moulting period. A study in rock pigeons reported that primary flight feathers accidentally pulled during handling typically began to regrow within 8 days.

In an attempt to accelerate the rehabilitation process, the feather-pull method of moult induction was utilised for several secondary covert feathers in the GHOW in our study but failed to stimulate regrowth. Although feather pulling often induces regeneration, it may also produce the opposite effect. When a feather is manually pulled, keratinised cells of the feather sheath are torn away from epithelial cells of the epidermal collar. If this process occurs, damage to these cells or the dermal papilla occurs, impaired or arrested folliculogenesis may ensue. Secondary flight feathers were not pulled precisely due to this possibility.

In American kestrels, when flight feathers were manually pulled from individuals outside of the moult season, only 58% of secondary feathers and 8% of primary feathers began to regrow within the following 4 months. Additionally, the pulling of the feathers induced follicular lesions in some individuals. Such lesions included incarnated (ingrown) feathers with cystic distension and follicular inflammation. In that study, none of the follicles with lesions had regrown within 4 months. The authors also noted that during the following natural moult, 53% of the secondary flight feathers that had been plucked still failed to regrow normally.

In our GHOW, one of the damaged secondary feathers, S9, did moult on its own and regenerate a new feather outside of the natural moult season. It is possible that the damage to its follicle was less severe compared with the other affected follicles, or that the damage occurred in such a way as to induce a moult. Failure of the remaining secondary flight feathers to regenerate could have been influenced by damage to the follicles. On histopathology, the secondary flight feather follicles demonstrated moderate infundibulitis and a lack of folliculogenesis. It is possible that the retained shafts and infundibulitis caused damage to the dermal papilla or the epidermal cells, preventing regrowth of new feathers or promoting growth of abnormal feathers.

Despite tumour removal and attempted induction of feather regeneration, this owl sustained a significant flight impairment, resulting from lack of feather regrowth. During the time of year that the owl was in rehabilitation, high patient numbers and space limitations required that the use of the flight conditioning enclosure space be reserved for individuals with the best release prognosis. Due to this bird’s behaviour in captivity, as well as the uncertainty of whether the remaining damaged feathers would regrow during the next natural moulting season and if incoming feathers would be normal, it was not appropriate to continue rehabilitating this individual for several additional months at the expense of rehabilitating patients with more favourable prognoses. Such constraints are important to consider when contemplating options for surgical repair of benign tumours in rehabilitating birds, especially when feather damage or loss is involved.

Contributors LB and DT made the clinical decisions regarding care and treatment of the great horned owl patient in this report. SH performed the histopathological assessment and interpretation of the tumour and feather follicles. LB prepared the initial and subsequent drafts of the manuscript with substantial input on intellectual content from both SH and DT. All authors agree to the final version of the document submitted for publication.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is
REFERENCES

1 Moteen DJ. Tumors in domestic animals. 5th edn. Iowa: Wiley Blackwell, 2017.
2 Arnall LR. Further experiences with cagebirds. Vet Rec 1961;73:1146–54.
3 Reece RL. Observations on naturally occurring neoplasms in birds in the state of Victoria, Australia. Avian Pathol 1992;21:3–32.
4 Reece RL. Some observations on naturally occurring neoplasms of domestic fowls in the state of Victoria, Australia (1977–78). Avian Pathol 1996;25:407–47.
5 Frost C. Experiences with PET budgerigars. Vet Rec 1961;73:621–6.
6 Campbell IG, Appleby EC. Tumours in young chickens bred for rapid body growth (broiler chickens): a study of 351 cases. J Pathol Bacteriol 1966;92:77–90.
7 Cardoso JFR, Lev Y, Liparisi F, et al. Osteoma in a blue-fronted Amazon parrot (Amazona aestiva). J Avian Med Surg 2013;7:2718–21.
8 Javadu M, Hashemnia M, Nikousefat Z, et al. Oral osteoma in 6 dogs. Vet Rec Case Rep 2017;8:265–8.
9 Cowan ML, Yang P-J, Monks DJ, et al. Some observations on naturally occurring neoplasms of domestic fowls in the state of Victoria, Australia (1977–78). Avian Pathol 1996;25:407–47.
10 Hallberg OE, Begley JW. Origin and treatment of osteomas of the paranasal sinuses. Arch Otolaryngol 1950;51:750–60.
11 Sakhivel P, Yogal R, Sikka K, et al. Mastoid Osteoma — Is "Trauma" A Possible Etiologic Factor? J Nepal Med Assoc 2017;56:367–70.
12 Kim SH, Lim DS, Lee DH, et al. Post-Traumatic peripheral giant osteoma in the frontal bone. Arch Craniofac Surg 2017;8:273–6.
13 Weller MW. Bursa regression, gonad cycle and Molt of the Great-horned owl. Bird-Banding 1965;36:102–12.
14 Young JC. The effect of progesterone on the Molt of a peregrine falcon. Hawk Chalk 1958;1:24–7.
15 Li QJ, LB Li, McNabb AFM, et al. The role of thyroxine on the production of plumage in the American kestrel (Falco sparverius). J Raptor Res 2005;39:84–8.
16 Perez JH, Meddle SL, Wingfield JC, et al. Effects of thyroid hormone manipulation on pre-nuptial molt, luteinizing hormone and testicular growth in male white-crowned sparrows (Zonotrichia leucophrys gambelii). Gen Comp Endocrinol 2018;255:12–18.
17 Watson GE. The mechanism of feather replacement during natural Molt. Auk 1963;80:486–95.
18 Webster RKS, Aguilar RE, Argandona-Gonzalez A-K, et al. Forced Molt in four juvenile yellow-eyed penguins (MEGADYPTES antipodes). J Wildl Dis 2016:52:809–16.
19 Parks JE. Use of beef thyroid to induce molting in a male red-tailed hawk. Hawk Chalk 1980;19:33–4.
20 Berry W. The physiology of induced molting. Poult Sci 2003:82:971–80.
21 Wolford JH. Induced molting in laying fowls. Worlds Poult Sci J 1984:40:66–73.
22 Youssif M, CHAUDHRY AS. History, changing scenarios and future strategies to induce molting in laying hens. Worlds Poult Sci J 2008:64:65–75.
23 Hedenstrom A, Sunada S, Siquiera RS, et al. Successful subtotal orbitectomy in a cat with osteoma. J Feline Med Surg 2015:17:281–5.
24 Pope JP, donnell RL. Spontaneous neoplasms in captive Virginia opossums (Didelphis virginiana): a retrospective case series (1989–2014) and review of the literature. J Vet Diagn Invest 2017;29:331–7.
25 Kindblom LG. Bone Tumors: Epidemiology, Classification, Pathology. In: Davies AM, Sundaram M, James SLJ, eds. Imaging of bone tumors and tumor-like lesions. Springer-Verlag: Berlin Heidelberg, 2009:39.
26 Hedenstrom A, Sunada S. On the aerodynamics of moult gaps in birds. J Exp Biol 1999;202:67–76.
27 King AS, McLelland I. Integument. In: King AS, McLelland J, eds. Birds: their structure and function. Philadelphia: Bailliere Tindall, 1984:28–42.
28 Delnatte P, Lair S, Beauchamp G, et al. Osteoma of paranasal sinuses in a horse with inspiratory dyspnoea. Vet Pathol 2014;51:750–60.
29 Vett Record Case Reports