SMALL ANIMALS/ AVIAN

External skeletal fixator intramedullary pin tie-in for the repair of tibiotarsal fractures in raptors: 37 cases (1995–2011)

Irene Bueno, DVM, MPH; Patrick T. Redig, DVM, PhD; Aaron K. Rendahl, PhD

Objective—To evaluate the outcome of the application of an external skeletal fixator intramedullary pin tie-in (TIF) to tibiotarsal fractures in raptors.

Design—Retrospective case series.

Animals—Thirty-four raptors with 37 tibiotarsal fractures.

Procedures—Medical records and radiographs for raptors with tibiotarsal fractures that were treated at The Raptor Center at the University of Minnesota between 1995 and 2011 were reviewed. Descriptive statistics were generated and univariate logistic regression analyses were used to assess whether age, sex, body weight, location and nature of the fracture, and type of surgical reduction were significantly associated with whether the fracture healed following surgical reduction and TIF application.

Results—31 of 37 (84%) tibiotarsal fractures successfully healed following surgical reduction and TIF application. The mean healing time was 38 days (range, 15 to 70 days). None of the variables assessed were significantly associated with whether the tibiotarsal fracture healed. Twenty of the 34 (59%) raptors were eventually rehabilitated and released.

Conclusions and Clinical Relevance—Results indicated that most tibiotarsal fractures were successfully managed by surgical reduction and stabilization with a TIF. However, other comorbidities (eg, systemic infections and visual deficits) negatively affected the rehabilitation of raptors and sometimes resulted in euthanasia despite the fact that the tibiotarsal fracture had healed, and those comorbidities, along with the variables evaluated (eg, age, sex, and nature of the fracture), should be used as triage criteria and prognostic indicators. (*J Am Vet Med Assoc* 2015;247:1154–1160)

Trauma such as blunt contact with moving or stationary objects is the main reason raptors are admitted to rehabilitation centers[1] such as The Raptor Center at the University of Minnesota. Fractures are a common consequence of trauma. The TIF was introduced at The Raptor Center in 1995 for management of avian fractures.[2,3] As the name suggests, use of a TIF involves fracture reduction by implantation of an IM pin in conjunction with ESF pins that are connected, or tied together, by an acrylic or stainless steel bar.

Advantages of the TIF are the low cost (generally < $15) of required materials and its adaptability to a wide range of patient sizes, ease of application without specialized equipment or materials, and ease of removal when the fracture has healed (ie, the TIF is completely removed). A TIF also allows patients to use the fractured limb unencumbered during the healing process. The design of the TIF inherently opposes all the forces such as bending, rotation, compression, and sheer that may adversely affect the healing fracture.[2]

Multiple surgical techniques for repairing tibiotarsal fractures in birds have been described. The most commonly described technique involves the use of external skeletal fixation, typically in a type II construct.[4–6] Other methods include the use of interlocking nails,[7,8] titanium microplates,[9] and a TIF that uses a tubular fixation device.[10] However, to our knowledge, few comprehensive studies[11,12] have been conducted to evaluate the outcome following the use of a TIF to repair fractures involving a specific bone, and none of the described methods have been subjected to biomechanical analysis.

The main objective of the study reported here was to evaluate the outcome of surgical reduction and TIF application to tibiotarsal fractures in raptors. The TIF is the principal method used to stabilize and manage tibiotarsal fractures in raptors at The Raptor Center. We hypothesized that predictive variables such as age, body weight, location and nature of the fracture, and type of surgical reduction would affect the healing of tibiotarsal fractures managed with a TIF. We chose those variables because they were deemed to be the most objective variables likely to affect fracture healing; variables that were deemed to be more subjective such as surgeon experience were not evaluated.

Abbreviations

ESF	External skeletal fixator
IM	Intramedullary
TIF	External skeletal fixator intramedullary pin tie-in

From The Raptor Center, College of Veterinary Medicine, University of Minnesota, Saint Paul, MN 55108 (Bueno, Redig); and the School of Statistics, University of Minnesota, Minneapolis, MN 55455 (Rendahl). Dr. Bueno's present address is Department of Veterinary Population Medicine, College of Veterinary Medicine, University of Minnesota, Saint Paul, MN 55108.

Address correspondence to Dr. Bueno (bueno004@umn.edu).

Materials and Methods

Case selection—The computerized database for The Raptor Center at the University of Minnesota was searched to identify medical records for raptors with tibiotarsal fractures that were examined and treated between 1995 and 2011. Raptors in which the fracture was surgically stabilized with a TIF and that survived > 3 weeks after surgery (on the basis of our clinical experience, it takes a minimum of 3 weeks for tibiotarsal fractures in raptors to heal) were enrolled in the study. Raptors with tibiotarsal fractures that were euthanized following initial physical examination, did not survive > 3 weeks after surgical fracture repair, or in which the fracture was managed with coaptation or surgically stabilized by a method other than a TIF were excluded from the study.

Medical records review—For each raptor enrolled in the study, information extracted from the medical record included signalment, date of surgery, whether the surgery involved open (fracture fragments were exposed during surgery) or closed (fracture fragments were not exposed during surgery) fracture reduction, fracture outcome, patient outcome, time to full recovery, and complications. Fractures were described on the basis of severity (load sharing [transverse or simple fracture] or non–load sharing [oblique or comminuted fracture]), whether they were open or closed, and location on the tibiotarsal bone (proximal [from the tibial plateau to the most distal portion of the cnemial crests], midshaft [from the most distal portion of the cnemial crests to a point proximal to the extensor canal {approx 2 bone diameters in length proximal to the distal end of the tibiotarsus}], or distal [from the extensor canal to the distal aspect of the tibiotarsal condyles]).

Application of the TIF—For each raptor, the tibiotarsal fracture was reduced in either an open or closed manner. Typically, closed reduction was the preferred method, but open reduction was performed when closed reduction was unsuccessful or the surgeon decided that an open reduction was most appropriate on the basis of physical examination and radiographic findings. A conventional Steinmann IM pin[a] was used to stabilize the fracture and was either introduced at the fracture site and passed retrograde to the tibial plateau or inserted at the tibial plateau from the medial aspect of the femorotibial joint and passed normograde, depending on the surgeon's preference. Regardless of the method of IM pin insertion, the patellar tendon was deflected laterally to prevent it from being penetrated by the pin. The size of the IM pin used was selected such that the pin could be easily passed through the medullary canal and varied from 0.035-inch K-wire used for an Eastern screech owl (*Megascops asio*) to 3/16-inch IM pins used in several bald eagles (*Haliaeetus leucocephalus*). Following fracture reduction, the pin was gently advanced into the distal fracture fragment until it reached a point just proximal to the extensor canal and supratendinal ridge (**Figure 1**). Then, from the lateral aspect of the tibiotarsus, 2 positive-profile-threaded interface ESF pins[a] were inserted proximal and distal to the fracture site perpendicular to the long axis of the bone. For each raptor, the diameter of the ESF pins selected was approximately 20% of the diameter of the tibiotarsus.[13] The size of the ESF pins ranged from 0.035 inches used in 2 raptors that weighed < 200 g to 1/8-inch pins used in several bald eagles. The proximal pin was inserted at the level of the cnemial crests anterior to the fibula and driven in a slightly caudomedial direction until both cortices of the bone were engaged by the threads. The distal pin was inserted at a point proximal to the supratendinal ridge (ie, about the length of 2 bone diameters proximal to the tibiotarsal condyles) and driven in a lateromedial direction parallel to the pin placed proximal to the fracture. The exterior portion of the IM pin was then bent 90° to the long axis of the bone, rotated to align with the ESF pins, and connected to them with an acrylic bar. A Penrose drain with a diameter equal to or slightly larger than the diameter of the tibiotarsus was used as a mold for the acrylic bar, which was made with methyl methacrylate.[b] The raptor's feet were rotationally aligned and held in a slight valgus position while the acrylic cured.

Following surgery, raptors were administered antimicrobials and analgesics as necessary, maintained on a deep bed of shredded paper in small, quiet hospital enclosures, and provided prescribed amounts of food ad libitum. For the first 1 to 3 days after surgery, wound treatment was con-

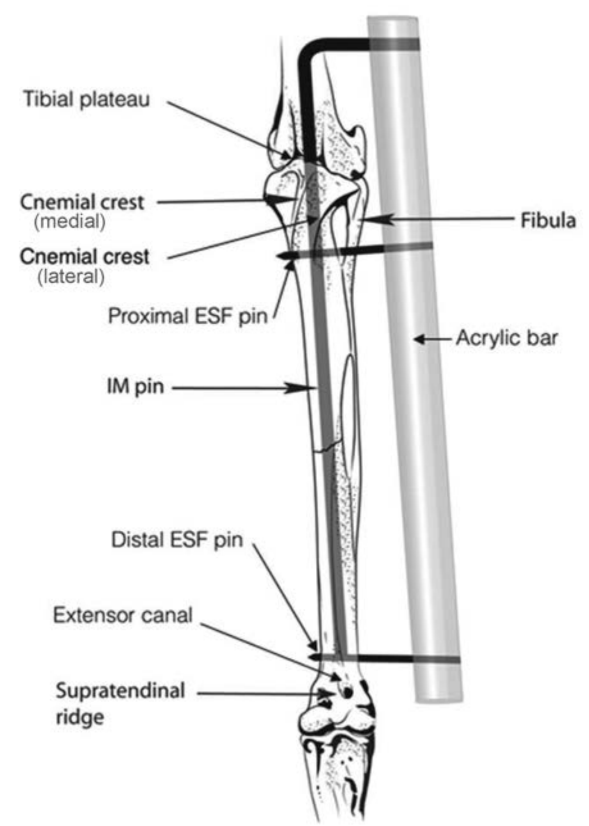

Figure 1—Diagram of the cranial aspect of the tibiotarsal region of the left pelvic limb of a bird with a tibiotarsal fracture that illustrates the application of a TIF. Notice that the acrylic bar is placed on the lateral aspect of the bone, and the leg is extended in this diagram; thus, the tibial plateau is not depicted in its entirety. (Adapted from Redig P, Cruz L. Fractures. In: Samour J, ed. *Avian medicine*. 2nd ed. Philadelphia: Elsevier, 2008;241. Reprinted with permission.)

ducted as necessary with the patient anesthetized. Passive range-of-motion physical therapy was initiated 72 hours after surgery and was performed with the patient anesthetized with inhalation anesthesia twice weekly until the TIF was completely removed. Physical therapy consisted of gentle manipulation of the affected leg and foot, alternately extending and flexing the stifle and intertarsal (hock) joints as well as the foot and toes for a few minutes.

Radiographs of the affected limb were obtained at various times after surgery and coincided with the gradual destabilization of the TIF. At 10 days after surgery, the link between the IM pin and the acrylic bar was cut. When the radiographic images revealed that sufficient callus had developed to maintain fracture immobilization (generally 2 to 3 weeks after surgery), the IM pin was removed. When the radiographic images revealed continued callus development and fracture stabilization and the bird was bearing weight on the affected limb (generally 4 to 5 weeks after surgery), the ESF pins and acrylic bar were removed. The affected limb was radiographically evaluated again before the bird was moved from a cage to a larger housing enclosure at approximately 7 weeks after surgery and during the prerelease examination.

Fracture healing was assessed by palpation of the limb and visual inspection of craniocaudal and lateromedial radiographs. Palpable healing was defined as lack of bone movement at the fracture site when gentle pressure was applied and transmittal of rotational forces from the hock joint to the stifle joint when twisting forces were applied. Radiographic healing was defined as cortical continuity in both craniocaudal and lateromedial imaging planes. Removal of all TIF elements was not completed until there was radiographic evidence of fracture healing.

After the TIF was completely removed, recovery of the patient typically required another 1 to 3 months. A patient was not deemed fit for release or return to its former status until it regained full use of the affected limb including the ability to bear weight and use its foot normally for perching and hunting.[14]

Statistical analysis—The main outcome of interest was whether the tibiotarsal fracture healed, which was objectively determined on the basis of serial radiographic evaluation of the affected limb. This outcome allowed us to assess the usefulness of the TIF as a tibiotarsal fracture repair option. Another outcome of interest was the patient outcome; ultimately, the goal of raptor rehabilitation is to return the birds to their former status (eg, released into the wild or returned to a falconer or educational center).

The number of days required for healing was calculated by subtracting the date that the final TIF element was removed from the date that surgery was performed. Descriptive statistics were created. Variables assessed as predictors for successful healing of a tibiotarsal fracture following TIF application included age, sex, whether the fracture was open or closed, severity of the fracture (load sharing, non–load sharing, or unknown), location of the fracture (proximal, midshaft, or distal aspect of the tibiotarsus), and whether the fracture reduction method was open or closed. Univariate logistic regression was used to determine whether any of those factors were associated with the successful healing of a tibiotarsal fracture following fracture stabilization by a TIF. For analysis purposes, age was dichotomized as either adult or hatch year (a hatch-year bird is a bird that was hatched during the calendar year in which it was examined) because the number of nestling (young birds that are not yet able to fly) and second-year birds (birds that were hatched during the calendar year preceding the one in which it was examined) evaluated was small, and weight was categorized as < 1 kg (2.2

Table 1—Descriptive statistics for 37 tibiotarsal fractures in 34 raptors that were examined and treated by surgical reduction and application of a TIF at The Raptor Center at the University of Minnesota between 1995 and 2011.

Variable	No. of fractures	No. of fractures that healed
Species		
American kestrel	1	1
Bald eagle	11	9
Barred owl	1	0
Broad-winged hawk	2	2
Eastern screech owl	1	1
Great gray owl	2	2
Great horned owl	6	6
Harris hawk	1	1
Osprey	1	0
Peregrine falcon	3	3
Red-tailed hawk	7	5
Turkey vulture	1	1
Age*		
Nestling	2	2
Hatch year	20	17
Second year	2	2
Adult	13	11
Sex		
Male	11	8
Female	8	7
Unknown	18	16
Body weight		
< 1 kg	13	10
1–3 kg	14	13
> 3 kg	10	8
Fracture type		
Open	2	1
Closed	35	30
Fracture severity†		
Load sharing	16	15
Non–load sharing	20	15
Unknown	1	1
Fracture location‡		
Proximal	8	5
Midshaft	21	19
Distal	7	6
Unknown	1	1
Type of fracture reduction		
Open	27	22
Closed	10	9

*Nestling refers to a bird that is not yet able to fly. A hatch-year bird was hatched during the calendar year in which it was examined. A second-year bird was hatched during the calendar year preceding the one in which it was examined. Birds older than second-year birds were considered adults. †Load sharing refers to a transverse or simple fracture; non–load sharing refers to an oblique or comminuted fracture. ‡The proximal aspect of the tibiotarsus was defined as the tibial plateau to the most distal portion of the cnemial crests, the midshaft aspect was defined as the most distal portion of the cnemial crests to a point just proximal to the extensor canal (approx 2 bone diameters in length proximal to the distal end of the tibiotarsus), and the distal aspect was defined as the extensor canal to the distal aspect of the tibiotarsal condyles.

lb), 1 to 3 kg (2.2 to 6.6 lb), and > 3 kg. All analyses were performed with statistical software,[c] and values of $P < 0.05$ were considered significant.

Results

Birds—From 1995 to 2011, 3,852 long bone (humerus, ulna, radius, metacarpus, femur, tibiotarsus, and tarsometatarsus) fractures were assessed at The Raptor Center, of which 254 (6.6%) were tibiotarsal fractures. Of the 254 tibiotarsal fractures evaluated, 217 were excluded from the present study; 105 were in birds euthanized after initial examination, 69 were in birds that did not survive > 3 weeks following TIF application, and 43 were stabilized by coaptation or a surgical method other than TIF. Thus, the present study consisted of 34 raptors with 37 tibiotarsal fractures. Species represented included bald eagle (*Haliaeetus leucocephalus*; n = 11),

Figure 2—Representative radiographic images of a fractured right tibiotarsus in a red-tailed hawk (*Buteo jamaicensis*) immediately before (A) and at various times after surgical fracture reduction and application of a TIF (B through G). A—Craniocaudal image of a displaced oblique fracture of the tibiotarsus at the midshaft region prior to surgical reduction and TIF application. B—Craniocaudal image of the fractured limb obtained during surgery following ESF placement and before attachment of the acrylic bar. C—Lateromedial image of the fractured limb obtained at the same time as the image in B. D—Craniocaudal image of the fractured limb 10 days after surgical application of the TIF immediately before the link between the acrylic bar and IM pin was cut. E—Lateromedial image obtained at the same time as the image in D; notice callus has already bridged the fracture site. F—Craniocaudal image of the fractured limb obtained during the prerelease examination (approx 15 weeks after surgery). G—Lateromedial image of the fractured limb obtained at the same time as the image in F; notice that the fracture has completely healed (ie, the bone cortices are intact).

red-tailed hawk (*Buteo jamaicensis*; 6), great horned owl (*Bubo virginianus*; 5), Peregrine falcon (*Falco peregrinus*; 3), broad-winged hawk (*Buteo platypterus*; 2), great gray owl (*Strix nebulosa*; 1), American kestrel (*Falco sparverius*; 1), barred owl (*Strix varia*; 1), Eastern screech owl (*Megascops asio*; 1), Harris hawk (*Parabuteo unicinctus*; 1), osprey (*Pandion haliaetus*; 1), and turkey vulture (*Cathartes aura*; 1). A red-tailed hawk, great horned owl, and great gray owl each had bilateral tibiotarsal fractures. Each fracture was considered an independent event for all analyses except patient outcome, and results are presented accordingly.

Tibiotarsal fracture outcome—The tibiotarsal fractures occurred most commonly in hatch-year birds (n = 20), followed by adults (13) and nestling and second-year birds (2 each; **Table 1**). Sex was not determined for most raptors, except in instances where strong dimorphism was present (eg, American kestrels). Although more fractures occurred in males (n = 11) than in females (8), the sex of the affected bird was unknown for 18 tibiotarsal fractures.

The majority of the tibiotarsal fractures (27/37 [73%]) were repaired by open surgical reduction. Of the 37 fractures, 31 (84%) healed and 6 (16%) did not heal. For the 31 fractures that healed **(Figure 2)**, the mean healing time (ie, time from surgery until the last element of the TIF was removed) was 38 days (range, 15 to 70 days). Of the 6 fractures that did not heal, 3 were refractured and considered unrepairable, thus necessitating euthanasia. Two of those refractures occurred in bald eagles. An osprey with a fracture at the proximal aspect of the tibiotarsus developed arthritis in the stifle joint secondary to IM pin placement and was euthanized. A red-tailed hawk with bilateral tibiotarsal fractures developed neurologic deficits secondary to the original injury in both limbs and was euthanized 6 weeks after surgical application of the TIF.

Complications associated with the TIF were few. In an American kestrel with a closed, load-sharing midshaft fracture, the distal ESF pin broke 13 days after surgery; however, the fracture continued to heal and the bird was ultimately released into the wild. The ESF pins became loose and had to be prematurely removed in 2 other birds. One was a red-tailed hawk; the ESF pins were removed 3 weeks after surgery, the fracture continued to heal, and the bird was released. The other was a great gray owl with bilateral tibiotarsal fractures that was subsequently euthanized because of severe complications associated with the fractures.

Univariate logistic regression results revealed that none of the variables assessed as predictors were significantly associated with successful healing of a tibiotarsal fracture following application of a TIF **(Table 2)**. However, the ORs provided preliminary evidence regarding the nature or direction of potential associations.

Patient outcome—Of the 34 raptors with tibiotarsal fractures, 20 birds were returned to their former status (either released into the wild [n = 18] or returned to a falconer or educational center [2]). The remaining 14 raptors, including all 3 with bilateral tibiotarsal fractures, were euthanized at various times following surgical application of the TIF. Five of those raptors were euthanized because of complications associated with fracture healing. The remaining 9 raptors were euthanized because of comorbidities, which included a visual deficit that was not detected during the initial physical examination (n = 1), presence of fractures in long bones other than the tibiotarsus that failed to heal (3), systemic infection (aspergillosis [1] and *Plasmodium* spp infection [1]), and other musculoskeletal trauma (3). Thus, although 31 of 37 (84%) tibiotarsal fractures healed following TIF stabilization, only 20 of 34 (59%) raptors were successfully rehabilitated and returned to their former status.

Table 2—Univariate logistic regression results in which the respective associations between various predictor variables and the likelihood of successful healing of tibiotarsal fractures following application of a TIF were evaluated for the raptors of Table 1.

Predictor variable	OR (95% confidence interval)	*P* value
Fracture location	—	0.23
Proximal	0.18 (0.02–1.35)	—
Midshaft	Referent	—
Distal	0.63 (0.05–8.25)	—
Fracture severity	—	0.12
Load sharing	Referent	—
Non–load sharing	0.20 (0.02–1.92)	—
Fracture type	—	0.25
Open	0.17 (0.01–3.12)	—
Closed	Referent	—
Body weight	—	0.46
< 1 kg	Referent	—
1–3 kg	3.90 (0.35–43.37)	—
> 3 kg	1.20 (0.16–9.01)	—
Age	—	0.98
Hatch year	1.03 (0.15–7.19)	—
Adult	Referent	—
Type of fracture reduction	—	0.52
Open	0.49 (0.05–4.79)	—
Closed	Referent	—

— = Not applicable.
See Table 1 for remainder of key.

Discussion

Various surgical methods have been used to repair tibiotarsal fractures in birds, and the method chosen for each particular fracture is dependent on the nature of the fracture, the individual patient, and the preference of the surgeon. The goal of the present study was to evaluate fracture and patient outcomes following TIF application to tibiotarsal fractures only. Most studies[4,6–10] that describe the management of tibiotarsal fractures in birds are case reports that involve either a single bird or a small number of birds. To our knowledge, the success rate of various tibiotarsal fracture repair methods for a large number of birds that were managed by multiple surgeons has not been assessed. Consequently, there are no studies available for comparison with the present study. Results of the present study indicated that 31 of 37 (84%) tibiotarsal fractures in raptors were successfully managed and healed following surgical application of a TIF.

The TIF has been used to repair long bone fractures in raptors at The Raptor Center since 1995. However, TIF application to tibiotarsal fractures was not fully explored until the TIF was successfully used for treatment of pectoral limb fractures. Concerns that delayed the use of the TIF for tibiotarsal fractures were that the IM pin would have to exit the bone at either the stifle or hock joint, the fact that the proximal ESF pin would share the marrow cavity space with the IM pin, and the substantial narrowing of the marrow cavity in the distal portion of the tibiotarsus near the flexor tendon retinaculum and the extensor canal.[15] Because the stifle joint is maintained at an acute angle when a bird is perching at rest, the stifle joint was chosen as the exit site for the IM pin. The concern about the proximal ESF pin sharing the marrow cavity with the IM pin was mitigated by the fact that the marrow cavity widens in the very proximal portion of the tibiotarsus. Successful implementation of a TIF for repair of tibiotarsal fractures was ultimately achieved by the use of a slightly smaller IM pin than that generally used in other repair methods, early removal of the IM pin after surgery (2 to 3 weeks in most instances), and limiting the extent to which the IM pin is driven distally in the tibiotarsus.

Compared with other methods of fracture fixation, the TIF with an acrylic bar is inexpensive and lightweight and can be easily applied to birds of various sizes without the need for specialized equipment. Furthermore, most practitioners have received the orthopedic training necessary to apply a TIF.

Although none of the variables assessed in the present study were identified as significantly important predictors for the successful healing of tibiotarsal fractures in raptors, the ORs calculated provided some useful information about possible associations. For example, midshaft fractures may have been more likely to heal following TIF application than were fractures of the proximal or distal aspects of the tibiotarsus. Midshaft fractures of the tibiotarsus may have been easier to repair and stabilize than fractures in other portions of the tibiotarsus. Also, in the present study, there were more midshaft (n = 21) tibiotarsal fractures than fractures of the proximal (8) or distal (7) portion of the tibiotarsus, which may have biased the outcome. As expected, load-sharing tibiotarsal fractures may have been more likely to heal following TIF application than were non–load-sharing fractures. By definition, load-sharing fractures are transverse or simple fractures, which are easier to stabilize (and thereby more likely to heal) than are non–load-sharing fractures that are comminuted and complex or oblique. Closed fractures may have been more likely to heal than were open fractures, which was also expected because, compared with closed fractures, open fractures are typically accompanied by more soft tissue damage and are at greater risk of becoming infected or developing complications. Similarly, fractures managed by closed surgical reduction may have been more likely to heal than were fractures managed by open surgical reduction. Finally, tibiotarsal fractures in hatch-year birds may have been more likely to heal than were fractures in adult birds, which was consistent with the fact that young animals have greater healing potential than do adult animals.[16]

Typically, raptors admitted to The Raptor Center are severely injured, with multiple problems that require triage and prolong their recovery. In the present study, only 20 of 34 (59%) raptors were eventually returned to their former status despite the fact that 31 of 37 (84%) tibiotarsal fractures healed successfully. This highlights the vagaries associated with maintaining wild birds in captivity for extended periods while they recover from fractures and other injuries. At The Raptor Center, injured raptors must be able to function normally and be indistinguishable from an uninjured bird before they are released back into the wild. Although that is a high standard, it is required to assure that the raptor has a reasonable chance of survival following release. Raptors that do not achieve that status are euthanized regardless of the effort expended to rehabilitate them.

The TIF was generally well tolerated by the raptors. The design of the TIF is inherently resistant to any efforts a bird might make to dismantle or remove it. This is in contrast to an IM pin alone, which can be dislodged rather easily. Moreover, in the few instances in which elements of the TIF had to be prematurely removed, the fractures typically continued to heal.

Only 1 of the 34 raptors of the present study developed inflammatory pododermatitis (bumblefoot) in the foot of the nonfractured limb because of prolonged asymmetric weight bearing, which compromised the epithelium of the metatarsal pad and resulted in secondary infection.[17] The fact that none of the other study raptors developed bumblefoot suggested that the TIF and other ancillary management practices implemented allowed the birds to bear at least some weight on the affected limb, which prevented damage to the contralateral foot. Those ancillary management practices included prophylactic bandages (interdigital or ball bandages or polypropylene shoes) on the contralateral foot, weight management, housing on deep, soft bedding materials such as shredded paper, and close monitoring of the contralateral foot for loss of epithelial integrity. In general, the development of bumblefoot secondary to leg fractures in raptors rehabilitated at The Raptor Center was fairly rare.

Limitations of the present study aside from its retrospective nature included the lack of a control group, a fairly small sample size, and some incomplete medical records, which resulted in the results being primarily descriptive in nature. Further clinical experience will facilitate evaluation of the TIF and allow its effectiveness to be compared with other surgical methods for fracture stabilization such as microplates and interlocking nails. However, the results of the present study suggested that the use of a TIF to surgically stabilize tibiotarsal fractures in raptors and appropriate patient management after surgery generally resulted in successful fracture healing. Cost-benefit analyses to compare surgical application of a TIF with other methods of tibiotarsal fracture repair need to be evaluated, as does the usefulness of TIF for fracture stabilization in general avian practice.

a. IMEX Veterinary Inc, Longview, Tex.
b. Technovit Horse Hoof repair acrylic, Jorgensen Laboratories Inc, Loveland, Colo.
c. R, version 3.0.1, R Foundation for Statistical Computing, Vienna, Austria.

References

1. Wendell MD, Sleeman JM, Kratz G. Retrospective study of morbidity and mortality of raptors admitted to Colorado State University Veterinary Teaching Hospital during 1995 to 1998. *J Wildl Dis* 2002;38:101–106.

2. Redig PT. The use of an external skeletal fixator-intramedullary pin tie-in (ESF-IM fixator) for treatment of long bone fractures in raptors. In: Lumeij J, Poffers J, eds. *Raptor biomedicine III*. Lake Worth, Fla: Zoological Education Network, 2000;239–254.
3. Redig P, Cruz L. The avian skeleton and fracture management. In: Samour J, ed. *Avian medicine*. 2nd ed. Philadelphia: Elsevier, 2008;215–247.
4. Meij B, Hazewinkel H, Westerhof I. Treatment of fractures and angular limb deformities of the tibiotarsus in birds by type II external skeletal fixation. *J Avian Med Surg* 1996;10:153–162.
5. Hatt JM, Christen C, Sandmeier P. Clinical application of an external fixator in the repair of bone fractures in 28 birds. *Vet Rec* 2007;160:188–194.
6. De Conti J, Marcelo A, Adamas B, et al. Use of type II external skeletal fixator for tibiotarsus osteosynthesis in white Plymouth Rock chickens: an experimental model for using in wild birds. *Pesqui Vet Bras* 2007;27:199–204.
7. Hollamby S, Dejardin LM, Sikarskie JG, et al. Tibiotarsal fracture repair in a bald eagle (*Haliaeetus leucocephalus*) using an interlocking nail. *J Zoo Wildl Med* 2004;35:77–81.
8. Stejskal M, Radišić B, Pećin M, et al. Interlocking nail for tibiotarsal fracture repair in a black swan (*Cygnus atratus*)—a case report. *Vet Arhiv* 2011;81:785–791.
9. Gouvea A, Alievi M, Noriega V, et al. Titanium microplates for treatment of tibiotarsus fractures in pigeons. *Ciênc Rural* 2011;41:476–482.
10. Muller MG, Mohammed J. Use of the FixEx tubulaire type FESSA system for tibiotarsal fractures in falcons. Abu Dhabi Falcon Hospital. Available at: www.falconhospital.com/Cms_Bin/Cms/doc_manager/fractures%20tibiotarsus%20in%20falcons%20FESSA.pdf. Accessed Jan 1, 2014.
11. Van Wettere AJ, Redig PT, Wallace LJ, et al. Mechanical evaluation of external skeletal fixator–intramedullary pin tie-in configurations applied to cadaveral humeri from red-tailed hawks (*Buteo jamaicensis*). *J Avian Med Surg* 2009;23:277–285.
12. Van Wettere AJ, Wallace LJ, Redig PT, et al. Mechanical evaluation of various external skeletal fixator-intramedullary pin tie-in configurations using a tubular plastic bone model. *J Avian Med Surg* 2009;23:263–276.
13. Palmer RH, Hulse DA, Hyman WA, et al. Principles of bone healing and biomechanics of external skeletal fixation. *Vet Clin North Am Small Anim Pract* 1992;22:45–68.
14. Arent L, Goggin R. *Reconditioning raptors: a training manual for the creance technique*. Saint Paul: The Raptor Center, College of Veterinary Medicine, University of Minnesota, 2001.
15. Harcourt-Brown NH. Orthopedic conditions that affect the avian pelvic limb. *Vet Clin North Am Exot Anim Pract* 2002;5:49–81.
16. Ekeland A, Engesæter LB, Langeland N. Influence of age on mechanical properties of healing fractures and intact bones in rats. *Acta Orthop Scand* 1982;53:527–534.
17. Willette M, Ponder J, Cruz-Martinez L, et al. Management of select bacterial and parasitic conditions of raptors. *Vet Clin North Am Exot Anim Pract* 2009;12:491–517.

From this month's *AJVR*

Risk factors for carriage of antimicrobial-resistant *Salmonella* spp and *Escherichia coli* in pet dogs from volunteer households in Ontario, Canada, in 2005 and 2006

Erin K. Leonard et al

Objective—To determine pet-related management factors associated with the carriage of antimicrobial-resistant *Salmonella* spp and *Escherichia coli* in a population of pet dogs.

Sample—138 dogs from 84 households in Ontario, Canada.

Procedures—From October 2005 through May 2006, dogs and households in Ontario, Canada, were recruited to participate in a cross-sectional study. Fecal samples were submitted for culture of *Salmonella* spp and *E coli*, which provided 515 bacterial isolates for antimicrobial susceptibility testing. Multilevel logistic regression models with random effects for household and dog were created to identify pet-related management factors associated with antimicrobial resistance.

Results—Bacterial species, feeding a homemade diet or adding homemade food to the diet, feeding a raw diet or adding anything raw to the diet, feeding a homemade raw food diet, and feeding raw chicken in the past week were significant risk factors for antimicrobial resistance in this population of dogs.

Conclusions and Clinical Relevance—In this study, several potentially important pet-related risk factors for the carriage of antimicrobial-resistant *Salmonella* spp and *E coli* in pet dogs were identified. Further evaluation of risk factors for antimicrobial resistance in dogs may lead to development of evidence-based guidelines for safe and responsible dog ownership and management to protect the public, especially pet owners who are immunocompromised. (*Am J Vet Res* 2015;76:959–968)

November 2015

See the midmonth issues of *JAVMA* for the expanded table of contents for the *AJVR* or log on to avmajournals.avma.org for access to all the abstracts.