Avian Orthopedics

R. Avery Bennett, DVM, MS, Diplomate ACVS

Fractures

Avian bones are commonly described as thin and brittle with a large medullary canal. They have a high calcium content compared with bones of mammals and are more prone to shattering upon impact. Many bones (most notably the humerus and femur) are pneumatic and involved in respiration and humidification of air. In most locations, soft tissues are not strongly adhered to bones and in the distal extremities there is little soft tissue coverage. These factors contribute to the high incidence of open, comminuted fractures and make iatrogenic fracture during repair attempts a significant concern.

Bone healing in birds is not well understood but the rate of fracture healing appears to depend on the integrity of the blood supply, the presence of infection, the amount of displacement, and the degree of motion at the fracture site. It is likely that under conditions of rigid immobilization, primary bone healing occurs similar to that observed in mammals. When bone callus is involved in fracture healing, endosteal and periosteal callus contribute to stabilizing the fracture. Endosteal callus, even in pneumatic bones, contributes more to healing than periosteal callus. Clinically, avian bones seem to heal faster than mammalian bones with well aligned, stable fractures requiring about 3 wks.[1]

Autogenous bone grafts are beneficial in avian fracture management. In birds with pneumatic humerus and femur, they are not viable sources of cancellous bone. More distal bones of the extremities are often small and narrow making them poor donor sites. In large birds and terrestrial birds, the tibiotarsus may provide adequate cancellous bone for grafting. More commonly, corticocancellous grafts are used in birds. These may be used for onlay grafting or cut into fragments and used around the fracture site and packed into cortical defects. The sternum and ribs are good sources of corticocancellous bone. To harvest bone graft from the keel, the pectoral muscles are elevated bilaterally exposing the carina sterni. A central portion is removed leaving a bucket handle remnant to which the pectoral muscles are reattached. When harvesting ribs, preserving the inner periosteum will preserve the thoracic air sacs and prevent subcutaneous emphysema.

Bandaging Techniques

Many fractures in birds are amenable to repair using external coaptation. External coaptation is most appropriately used if the bird is too small for internal fixation, if there is minimal fracture displacement, if there are factors which make anesthesia and surgery especially risky, or if the fracture is highly comminuted making primary repair impractical. It is an inexpensive, simple method for immobilizing fractures requiring little time and a short anesthesia. However, the outcome is usually acceptable only if good limb function is not required.

Birds with fractures treated with external coaptation generally heal, but with little functional improvement over those treated with cage rest only. Malalignment, joint ankylosis, limb shortening, and tendon contractures or entrapment within excessive callus frequently occur with external coaptation and result in poor limb function. In order to minimize the effects of fracture disease, it is best to remove external coaptation as early as possible. External coaptation should immobilize the joints proximal and distal to the fracture. With all slings and splints, care must be taken to avoid obstructing the vent and compressing the sternum which interferes with respiration.

Masking tape, drafting tape, paper tape, and self-adhesive tape are often used for external coaptation. Adhesive tape can be used especially if the bandage will be left on a week or more. Adhesive tape can stick to tightly and damage skin, however, when it is left on for several days, the tape comes off more easily with desquamated epithelial cells. Soft, conforming cast padding and conforming gauze work well for padding and as a base wrap for slings, bandages, and splints. External coaptation may be reinforced with wood applicator sticks, tongue depressors, aluminum rods, light weight casting material or other substances that will add bending stability to the coaptation. Veterinary Thermoplastic (VTP, IMEX Veterinary, Inc, Longview, TX), Orthoplast (Johnson & Johnson Products, Inc., New Brunswick, NJ 08903) and Hexcelite (Hexcel Medical, 6700 Sierra Lane, Dublin, CA 94566) are especially useful. These materials are firm at room temperature but when heated become malleable and can be molded to conform closely to the shape of the limb.

External coaptation of the humerus is generally considered ineffective in supporting open, comminuted fractures. The muscle pull generally results in severe overriding of the fragments which then heal in malunion. Proximal humerus fractures are amenable to treatment with external coaptation if the surrounding muscle mass provides adequate stability and prevents displacement. With fractures of the humerus, the entire wing should be wrapped to the body. A figure 8 bandage is applied to the wing as described below, then the wing is wrapped to the body. This type of external coaptation is commonly used to treat nondisplaced fractures of the pectoral girdle. The 3 methods described above for immobilization of the humerus may be utilized to treat such fractures.

Radius, ulna, and carpometacarpus fractures may be stabilized using a figure 8 bandage utilizing the primary flight feathers as a splint. The tape crosses on the lateral surface of the wing and encircle the carpus cranially and the elbow and flight feathers caudally. It is not necessary to immobilize the wing against the body since the elbow and carpus will be immobilized. With fractures of the radius or ulna but not both, external coaptation generally results in good fracture healing with a functional outcome.

A braile sling may also be used to treat fractures of the radius, ulna, and carpometacarpus. It consists of a strip of gauze, cloth or soft leather with a longitudinal slit at the midpoint. The slit is placed over the folded carpus and the strips are then either crossed or tied medial to the humerus then wrapped around the elbow and flight feathers and tied again. The sling may be modified to prevent injury to the carpus which may occur if the wing hits the walls of the cage.

As with humerus fractures, it is difficult to adequately immobilize femur fractures with good anatomic alignment using external coaptation. Spica splints may be used in birds to immobilize the femur including the hip and stifle joints. The abdomen and affected leg are padded and the splint material is molded to curve over the dorsum and down the leg to the level of the tibiotarsus or tarsometatarsus with the joints at normal, standing angles. It is then secured with tape. A spica splint is generally considered inadequate for anatomic repair of femur fractures because it does not overcome the overriding resulting from the pull of the muscles. However, it is a useful adjunct to IM pinning of the femur. The splint should be applied with the limb in a normal, standing postion to allow weight bearing during the recovery phase. Femur fractures may also be treated using an encircling bandage. The tape should pass over the dorsum at the synsacrum lateral to the flexed leg and over the open foot, then across the abdomen and around. Because of the potential for femur fractures to override, this technique works best if there is minimal displacement or as an adjunct to IM pinning.

A lateral splint may be used to immobilize fractures of the tibiotarsus. The tibiotarsus is easier to anatomically reduce because there is less muscle pull and the splint will immobilize the joints proximal and distal to the fracture. The splint is applied with the joints in normal, standing angles. If properly supplied the bird should be able to bear weight with the splinted leg.

A modified Ehmer sling can be used to immobilize nondisplaced fractures of the tibiotarsus and tarsometatarsus. The tibiotarsus and tarsometatarsus are bandaged together using one to support a fracture of the other. The leg is then wrapped to the body with the tape lateral to the leg, over the synsacrum, and around the abdomen.

Schroeder-Thomas (ST) splints may be used to treat fractures of the tibiotarsus or tarsometatarsus. They may also be used as an adjunct to internal fixation of the tibiotarsus by preventing rotation and allowing weight bearing. The ST splint is a traction splint modified by adjusting the configuration to conform to the shape of the limb and the location of the fracture. Thus, the configuration of the ST splint will vary with the location of the fracture. It should not be applied to maintain all joints in hyperextension and traction which will predispose the limb to severe fracture disease. It should be applied with the limb in a functional position with tensions applied to separate the joints at each end of the bone. Proper application of the ST splint requires tension on the joints proximal and distal to the fracture in the correct direction to allow the fracture fragments to be separated and aligned.

Internal Fixation

The principles of fracture treatment in birds are similar to those established for mammals - rigid fixation, anatomic alignment, and minimal disruption of soft tissues and callus formation. Early return to function is critical to prevent ankylosis. This is especially important when normal limb function is required as for wild birds intended for release. Practical considerations in fracture management include cost of the materials, ease of application, required limb function, patient's temperament, availability of equipment, and the surgeon's level of expertise with various fixation devices. In avian orthopedics, internal fixation is often used in combination with external coaptation. This should be avoided as the negative aspects of both may be manifest. The surgical approaches to long bones of birds have been described.[2,3] When closing the surgical wound, the muscles may be loosely apposed to cover the fractured bone unless there is concern that this might restrict joint function. In these situations it is only necessary to close the skin.

Application of IM pins and orthopedic wires is familiar to most veterinarians and requires little specialized equipment. They are inexpensive, provide axial alignment and bending stability, and require minimal tissue exposure for insertion. They do not stabilize fractures against rotation and shear forces. For proper flight, rotational alignment is critical. External coaptation is frequently utilized in conjunction with IM pins to stabilize fractures against rotation and shear forces. This can result in impaired function from fracture disease. More appropriately stack pinning, cerclage or hemicerclage wires, interfragmentary figure 8 wires, or external skeletal fixation (ESF) are used to counter these forces. Orthopedic wires may be used as cerclage, hemicerclage, or interfragmentary wires to provide stability to the fracture. The most significant concern when using IM pins in avian patients is the potential for damage to articular and periarticular structures. Even pins placed near a joint may stimulate production of sufficient scar tissue to inhibit normal joint function. If possible, pins are inserted so they do not enter or exit through or near a joint. If a pin must be placed through a joint, it is removed as soon possible. Cross pin and Rush pin techniques are used to stabilize metaphyseal fractures. Rush technique achieves a dynamic 3 point fixation which will counter all major forces.

Intramedullary polymer rods (polyvinylidine fluoride and polypropylene) have been used as an alternative to steel IM pins.[4] They are inserted using a shuttle technique which does not damage articular structures and requires minimal surgical exposure. These pins are not as resistant to bending as steel and are frequently used in combination with transverse pins, ESF, or intramedullary polymethylmethacrylate (IM PMM) to add shear and rotational stability. A modification of this technique involves the use of threaded Steinmann pins which may be cut to an appropriate length and placed IM using a shuttle technique. These pins are stiffer and, when used with IM PMM, provide a cohesive surface bond with the PMM. These IM devices are not removed after fracture healing as they are completely within the bone.

Polymethylmethacrylate (Surgical Simplex-P, Howmedica, Inc., Rutherford, NJ 07070; LVC Bone Cement, Zimmer, P.O. Box 708, Warsaw, IN 46580) is a nontoxic bone cement that produces a cohesive, mechanical friction bond with the interstices of the bone. Once the liquid monomer is mixed with the powered polymer, the reaction is exothermic, producing temperatures of >100^{o} C. This results in osteocyte death but appears to be of little clinical significance. PMM may be used in pneumatic or marrow containing bones, as well as to incorporate fracture fragments into the repair of comminuted fractures. IM PMM has been used as a sole means of fracture support by injecting the cement into the medullary canal of both fracture fragments. While the cement is curing, the fracture is held in reduction. IM PMM is brittle and prone to breaking at the fracture site. It is most commonly used in conjunction with some other means of support such as a shuttled threaded Steinmann pin, polypropylene rod, or with a bone plate.

Bone plate fixation of avian fractures has historically been discouraged. It was believed that the thin, brittle cortices would not provide adequate screw purchase. There are no studies on the screw holding strength of avian bones. Recently, bone plates have been used successfully in birds with or without IM PMM. Veterinary cuttable plates (#243.99 and 242.99, Synthes, 1690 Russel Road, Paoli, PA 19301) are well suited for treatment of avian fractures. These plates may be used with either 1.5 mm or 2.0 mm (243.99) or 2.0 mm or 2.7 mm (242.99) screws. They are lightweight, small, strong, have closely placed screw holes, and may be cut to an appropriate length. They can be stacked for added strength. Special care must be taken when inserting screws into avian bones. The drill bit must be straight and sharp, proper drill guides must be used so that screws are placed in the correct location within the hole of the plate, threads must be tapped carefully clearing the flutes frequently, and the drill and tap should be cleaned between screws. Screws must be inserted delicately to prevent iatrogenic fractures and stripping the threads.

The Kirschner-Ehmer splint is only one type of external skeletal fixation device. Because of the expense and weight of this type of fixator, they are rarely used in avian fracture management. Biphasic fixators utilize steel fixation pins and acrylic compounds to connect the fixation pins external to the body surface. ESF devices do not damage articular and periarticular structures. They require minimal surgical exposure and are light weight allowing early return to function. Their strength is a function of configuration and fixation pin placement. Depending upon the size of the patient, small Steinmann pins, Kirschner wires, injection needles, or spinal needles may be used as fixation pins. Positive profile pins with a rough pin shaft for improving the PMM bond are available in a variety of sizes either with the threads centrally located (Centerface Pins) or with threads located at the tip (Interface Pins) (Centerface Pins, Interface Pins, and Threaded Pins for

Acrylic Fixators; IMEX Veterinary, Inc. Longview, TX 75604). Nonsterile PMM (Technovit, Jorgensen Labs, Loveland, CO 80537), 5 min epoxy glue, Hexcelite (Hexcel Medical, 6700 Sierra Lane, Dublin, CA 94566) cast material, Veterinary Thermoplastic (VTP; IMEX Veterinary, Inc.) and dental acrylics have been used for the connecting bar of biphasic fixation splints. With the exception of VTP and Hexcelite, these materials may be injected into flexible tubing which has been placed over the fixation pins. Placing the tubing over pins which are placed at different angles can be challenging. Alternatively, cement can be mixed to a dough consistency, then molded around the fixation pins while the fracture is maintained in reduction. To improve the bond between the pins and the cement, the pins should be notched with a pin cutter or bent over and incorporated into the connecting system. Hexcelite and VTP are casting materials that becomes soft and malleable when immersed in hot water and become rigid when cool. For use with ESF, the material is softened and molded onto the fixations pins. Once cool, the material becomes a rigid connecting system. ESF has gained a prominent role in avian fracture management because of the severe consequences of fracture disease in birds.

Luxations[5]

There are few reports of methods for managing luxations in birds. Coxofemoral luxations are frequently the result of trauma during restraint, or the bird getting its leg caught within the cage structure or a fence. Elbow luxations occur in raptors primarily secondary to trauma which occurs during flight. In treating luxations it is crucial to reduce the luxation as early as possible to minimize the formation of periarticular fibrosis and cartilage damage. Within a period of as little as three days significant fibrosis occurs inhibiting reduction of the luxation and predisposing to joint ankylosis.

Luxation of the Shoulder

Luxations of the shoulder frequently involve avulsion of the ventral tubercle of the proximal humerus.[3] These may be treated by bandaging the wing to the body to immobilize the shoulder joint for 10-14 days. If precision flight is required an open reduction and reattachment of the ventral tubercle may be beneficial. The shoulder joint is not a very stable joint and reluxation is common.

Elbow Luxations[6]

Luxation of the elbow is usually the result of severe blunt trauma strong enough to disrupt the ligamentous support. This type of injury occurs infrequently in companion birds but has been reported to occur as frequently as in 12% of raptor patients.[6] Because of the anatomy luxation usually occurs dorsal, caudal or caudodorsal. Ventral luxation occurs only in association with fracture of the radius. The wing is generally held with the elbow extended (drooped) and externally rotated. Pain, crepitus and swelling are noted on palpation of the affected wing. The wing should be examined for concomitant soft tissue injury which may affect prognosis. The presence of open wounds and fractures has been associated with a poor prognosis for return to normal function.

Reduction is accomplished by flexing the elbow which counteracts the force of the scapulotriceps muscle pulling the ulna caudally. Maintaining flexion, the radius and ulna are internally rotated while pressure is applied to the dorsal (lateral) aspect of the radial head to force it into opposition with the dorsal (lateral) humeral condyle. As the elbow is gently extended, a pop is often palpable as reduction is completed. In cases with severe ligamentous damage, this pop may not be palpable.

If the joint is stable following reduction, it may be supported with a figure eight bandage for 7-12 days. Where there is severe ligamentous damage as evidenced by laxity following reduction, a transarticular ESF device may be applied to maintain reduction. Controlled physical therapy is initiated following removal of the support. Four of eight raptors with elbow luxations in one study were released.

Luxation of the Carpus

Luxations of the carpus are generally dorsal. The bird will hold the wing with the carpus extended and externally rotated at the carpus. Reduction is accomplished by applying traction and (dorsal) abduction of the distal extremity. The carpometacarpus is then toggled into reduction and the carpus is flexed and (ventrally) adducted. With the carpus in flexion a figure eight bandage is applied to maintain reduction for 7-12 days. With large birds or chronic luxations, open reduction may be indicated. In cases where there is significant laxity following reduction a transarticular pin or ESF device may be placed to maintain reduction. The pin is placed with the carpus in a normal degree of flexion through the main body of the carpometacarpus and into the ulna immobilizing the carpus. Controlled physical therapy is initiated after support devices are removed.

Coxofemoral Luxations[2,3,7-10]

In most psittacine birds and raptors the coxofemoral joint is not a tight fitting ball and socket joint but has a significant amount of cranial to caudal gliding motion with little abduction and adduction. It is a diarthrodial joint supported by a round ligament as well as collateral ligaments. The ventral collateral ligament and the round ligament are primarily involved in maintaining the femoral head within the acetabulum. In order to create luxation both of these structures must be disrupted. In many species the dorsal rim of the acetabulum is well developed and extends as the antitrochanter to articulate with the broad, flat femoral neck and trochanter.

Coxofemoral luxations are generally the result of traction and rotational trauma such as occurs when the leg is caught. Most luxations are craniodorsal in birds though cranioventral luxation has also been reported. Closed reduction and stabilization with slings, splints and casts have been recommended. In some cases, the luxation may be reduced and maintained using a transarticular pin. The pin is inserted through the trochanter into the head of the femur and across the acetabulum. This pin must be inserted carefully to avoid injuring the kidney which lays on the medial side of the acetabulum. The chuck should be set on the pin at a predetermined length. If inserted too deeply the pin will penetrate the kidney resulting in excessive intracoelomic hemorrhage. The limb should be supported using an off weight bearing sling or spica splint to prevent pin migration. In most cases there will be sufficient production of scar tissue by 5-7 days postoperatively that the pin may be safely removed. Long term maintenance of a transarticular pin will predispose to the development of degenerative joint disease and pin migration.

Surgical reduction and stabilization is considered the treatment of choice for acute coxofemoral luxations. A femoral head and neck excision arthroplasty is often indicated for chronic luxations. The surgical approach for both of these is the craniolateral approach which also allows for the placement of support sutures.[2,7] Other approaches including ventral[10] and caudolateral[8] have also been used.

The craniolateral approach allows access to the joint capsule which should be incised allowing enough joint capsule on each side for closure. Following reduction of the luxation, stabilization sutures are placed from the trochanter to the dorsolateral iliac crest caudal to the central axis of the femur and from the trochanter to the cranial rim of the acetabulum. The sutures are placed through the bone and while the stifle is maintained in a normal standing position, the sutures are tightened.

These sutures will prevent excessive external rotation of the leg in the recovery phase. The joint capsule is closed and the iliotrochantericus caudalis and iliofemoralis externus are reopposed. The remainder of the closure is routine.

When performing a femoral head and neck excision arthroplasty the same approach is used. The head and neck of the femur are removed with appropriate sized rongeurs being sure that no rough or sharp edges remain. Following FHNEA there is a tendency for external rotation of the limb. This can be countered using the support sutures described above. Because polydioxanone suture remains for over 4 months in birds but is absorbable, it is an appropriate choice for these antirotational sutures.

Postoperatively the limb should be supported in a spica splint or off weight bearing sling for 1-2 weeks. It is best to maintain the bird in a cage with smooth walls and a perch near the floor to discourage attempts to climb.

Luxation of the Stifle

Luxation of the stifle with damage to the collateral ligaments occurs in companion birds following traumatic episodes. Frequently there is multiple ligamentous injury to the stifle. Not only is a positive drawer sign elicited but also medial and/or lateral collateral instability exists. Surgical repair of the ligaments may be attempted especially in large birds; however, in most small companion birds the size of the ligaments precludes surgical opposition. In such cases transarticular ESF may be used to maintain the stifle in reduction allowing periarticular fibrosis to stabilize the joint. This technique has been used with positive results.

At least 2 fixation pins should be placed in the femur and in the tibiotarsus. With the limb in a normal, standing position the pin in the proximal femur is connected to the pin in the distal tibiotarsus and the distal femoral pin is connected to the proximal pin in the tibiotarsus. Alternatively, a type II fixator may be placed in a cranial to caudal plane; however, this results in more muscle trauma and decreased patient acceptance. The device is maintained for 3-6 weeks to allow scar tissue to mature stabilizing the joint.

Prognosis with avian fracture and luxation repair is somewhat dependent on the intended use of the bird. Companion birds and zoo specimens may function without the ability to fly with precision; however, with wild birds, hunting birds, and racing pigeons, anything less than perfection cannot be regarded as success. In many birds, some degree of leg dysfunction may be acceptable. In raptors, legs are important for obtaining food, in terrestrial birds they are necessary for survival, and in many species they are vital for successful reproduction.

References

1. Bennett RA, Kuzma AB. Fracture management in birds. J Zoo Wildl Med 1992 23(1):5-38.

2. Orosz SE, Ensley PK, Haynes CJ: Avian Surgical Anatomy - Thoracic and Pelvic Limbs. Philadelphia, WB Saunders Co, 1992.

3. Martin HD, Ritchie BW. Orthopedic surgical techniques. In: Ritchie BW, Harrison GJ, Harrison LR (eds). Avian Medicine: Principles and Application. Lake Worth, FL: Wingers Publishing Inc, 1994:1137-1169.

4. Redig P (ed.): Orthopedics. Seminars in Avian and Exotic Pet Medicine, April, 1994.

5. Bennett RA. Orthopedics. In: Altman RB, Clubb SL, Dorrestein GM, Quesenberry KE (eds). Avian Medicine and Surgery. Philadelphia: WB Saunders Co, *in press*.

6. Martin HD, Bruecker KA, Herrick DD, Scherpelz J. Elbow luxations in raptors: a review of eight cases. In: Redig, P.T., Cooper, J.E., Remple, J.D., and Homer, D.B. (eds). Raptor Biomedicine. Minneapolis, MN: University of Minnesota Press, 1993:199-206.

7. Martin HD, Kabler R, Sealing L. The avian coxofemoral joint. J Assoc Avian Vet 1989;1(1):22-30.

8. MacCoy DM. Excision arthroplasty for management of coxofemoral luxations in pet birds. J Am Vet Med Assoc 1989; 194(1):95-97.