ANATOMY

BONY ANATOMY IN THE MATURE DOG

The radius is formed proximally by the oval and concave radial head, which articulates with the humeral capitellum. The metaphyseal area tapers slightly to become the flattened radial diaphysis. The diaphysis is of uniform shape, flattened cranial-caudally, and curves slightly as it moves from a lateral position at the elbow to a medial position at the carpus. Distally the metaphysis enlarges and enters the epiphysis. The distal epiphysis has a concave articular surface that sits upon the radial carpal bone. A medial pointed prominence, the styloid process serves as proximal attachment of the medial collateral ligament.

The proximal ulna is formed by a large bony process, the olecranon, which serves as the insertion of the triceps muscles. The articular surface, termed the trochlear notch or semilunar notch, articulates with the humeral trochlea of the medial condyle. The proximal trochlear notch is formed by the anconeal process, while the distal trochlear notch ends in the coronoid process. The ulna tapers below the articular surface and curves cranially, and the diaphysis continues to taper along its length, which begins medially at the elbow and ends laterally at the carpus. The distal process, the styloid process, is the proximal attachment of the lateral collateral ligament of the carpus.

The medullary canal of the radius is usually uniform in size and much wider medial-laterally than cranial-caudally. The ulnar medullary cavity is wide proximally and tapered along its entire length. In some small dogs it may be very small or nonexistent (Figs. 24-1 and 24-2).

FIG. 24-1 Line drawings representing two views of a mature normal radius and ulna in a German shepherd (A), a dachshund (B), and a domestic short-haired cat (C) Figures illustrate comparative anatomy and are not drawn to the same scale.

FIG. 24-2 Cranial-caudal (A) and medial-lateral (B) radiographic views of a normal radius and ulna from a Great Dane.
BONY ANATOMY IN THE MATURE CAT
The normal radial and ulnar anatomy of the cat mimics that of the dog. However, the following differences are worth noting: the proximal radius has a more pronounced tapering immediately ventral to the radial head; a prominence termed the radial tuberosity projects caudally immediately distal to the radial neck; the olecranon process is slightly smaller and, in fact, its caudal surface curves cranially, whereas in the dog it curves caudally. The only other difference relates to the contour of the caudal ulnar surface. Whereas in the dog the surface is concave in its entirety, in the cat the surface is convex to midshaft, then concave from midshaft to the styloid process (Fig. 24-1, C).

BONY ANATOMY IN THE IMMATURE CAT AND DOG
The ulna possesses four epiphyses of significance: the olecranon, the anconeal process, the coronoid process, and the distal ulnar epiphysis.

The olecranon epiphysis is a triangular piece of bone that sits on the caudal proximal extent of the olecranon. The associated growth plate is responsible for approximately 15% of the ulnar lengthening. Premature closure may lead to ulnar shortening and elbow joint deformity.

The anconeal process is a triangular or "beak"-shaped process that is responsible for forming the proximal extent of the trochlear notch. Its interface with the ulna is vertical, and it is easily fractured.

The coronoid process is a small epiphysis that helps for the distal extent of the trochlear notch. Its growth plate is vertical. Fracture or lack of growth plate fusion may lead to joint instability.

The distal ulnar epiphysis is a large bony process forming the ulnar styloid process. The associated growth plate is responsible for approximately 85% of ulnar length. This growth plate is shaped like an inverted cone; the epiphysis forms the concave portion and the metaphysis the convex surface. Premature closure of this growth plate may lead to ulnar shortening, ulnar bowing, or proximal ulnar subluxation.

The radius has two epiphyses and associated growth plates of significance: the proximal and the distal. The proximal epiphysis forms the radial head. The contact surface between the epiphysis and metaphysis is slightly convex on the metaphysis and slightly concave on the epiphysis. This growth plate is responsible for approximately 30% of radial length. Premature growth plate closure may lead to a shortened radius or radial head ventral subluxation.

The distal radial epiphysis forms the distal articular surface and the radial styloid process. The surface between the metaphysis and epiphysis is convex on the metaphyseal side and concave on the epiphyseal side. This growth plate is responsible for approximately 70% of radial length. Premature closure of the growth plate may lead to radial shortening, radial bowing, or radial head ventral subluxation. Asymmetric closure of this growth plate can occur and results in radial shortening and bowing toward the side of closure.

BLOOD SUPPLY TO THE RADIAL AND ULNAR DIAPHyses
In the mature dog or cat the major diaphyseal arteries enter the radius through the nutrient foramen on its caudal surface in the proximal one-third of the diaphysis. A separate nutrient artery enters the ulna on its cranial surface in the proximal one-third of the diaphysis. Both nutrient arteries are branches of the palmar interosseous artery. The immature dog or cat may have diaphyseal blood supply from vessels in the pronator quadratus muscle originating between the radius and ulna on their medial surfaces.

FRACTURES OF THE RADIUS AND ULNA
Fractures of the proximal radius and ulna associated with the elbow joint have been discussed in Chapter 23. Shaft fractures of the radius and ulna occur at all levels; however, fractures of the distal one-third of the radius and ulna are the most common. Fractures may be complete or incomplete and may include one or both bones. The level of the fracture site may be the same in both bones or may be widely separated. Fractures of the distal one-third of the radius and ulna are associated with a higher incidence of delayed union or nonunion, which has been related to the precarious blood supply of this area in small breed dogs. (2,10) It is these fractures of the radius and ulna that will be the most troublesome. Most animals that have radial
and ulnar fractures will present non-weight-bearing on the affected limb, but occasionally animals with greenstick fractures or nondisplaced epiphyseal injuries may present weight-bearing (Fig. 24-3). Most forelimb fractures, however, are displaced and unstable at the time of presentation. A physical examination is necessary to determine the level of the fracture and to ascertain if the fracture is open or closed. The small muscle mass surrounding the radius and ulna on the forelimb, especially in the distal forelimb, allows open fractures to occur commonly. Biplane radiographic techniques are used to establish the extent of the fracture and for assessing treatment and prognosis.

The age of the patient is significant in choosing fixation techniques as well as in determining prognosis. Likewise the size of the animal seems to be very important in the prognosis. The smaller the dog, the more difficult it may be to achieve healing, probably as a result of diminished surface contact. Small dogs need good reductions with adequate stability if they are to progress toward satisfactory union. The larger the dog, the less need there is to have a perfect anatomical reduction of the fracture. In dogs over 30 lb, reduction of the shaft to greater than one half the diameter of the bone is usually sufficient to progress to satisfactory union. The stability that can be achieved in larger dogs with this amount of bone contact is usually sufficient to provide adequate callus and union. In small breed dogs this amount of reduction would provide very little stability, which in turn may lead to loss of reduction, with delayed union or nonunion. Fractures in dogs with open physes may heal more completely than those in dogs with closed physes, especially if a gap exists at the fracture line. Experimentally, dogs with open physes have evidenced healing of large defects that would produce nonunions in dogs with closed physes. Thus the combination of age and size makes the determination of treatment modality for a radial and ulnar fracture dependent upon the individual animal. Treatment regimes may vary markedly yet produce equally good results.

CLOSED REDUCTION AND EXTERNAL FIXATION

The closed reduction of closed fractures and immobilization in casts or splints is very useful in treating fractures of the radius and ulna.(3) Most fractures are handled in this manner (Fig. 24-4). The older the dog or the smaller the dog, the greater attention is spent in achieving a form-fitting splint that will impart stability to the fracture site. In large breed puppies fractures may heal very successfully in a ready-made metasplint, while in the Italian greyhound the same fixation device might produce a nonunion. When treating closed fractures with closed reduction, it is important that the animal be heavily sedated or anesthetized so that the manipulation can be performed without causing the patient pain. When doing closed manipulation of a closed fracture, care has to be taken not to create an open fracture. Since any radial and ulnar fracture has the potential of becoming an open fracture, it is important to surgically prep the area of the fracture site prior to reduction and to use aseptic technique while reducing the fracture if manipulation is necessary. If, in fact, the fracture then becomes open through manipulation, the chance of contamination and infection will be greatly reduced. Clipping the hair around the fracture also aids in determining whether the fracture is indeed a closed fracture and gives the surgeon a better assessment of skin viability. The best fixation can be achieved with casting materials that are molded to the particular animal. The use of ready-made splints may work in certain animals, but the incidence of delayed union or nonunion can be greatly reduced by a properly fitting splint or cast. The type of cast usually used for front legs is a total encircling plaster cast or a double half cast of plaster. (See Chapter 15.) The total encircling cast is best for the large breed dogs because it is the strongest cast that can be applied. The dog's fracture should have a good reduction, and the foot position should be such that the carpus is in slight flexion and slight medial deviation with no external rotation. When applying the cast it is important that the animal's injured leg be in the down position, thereby preventing placement of the leg in a valgus position at the time of casting and, thus, during the time of healing. The double half cast, although not as strong as the total encircling cast, can be used when swelling is present or the soft tissues are such that frequent examination may be necessary. This cast is already split in half and can have one section removed to examine the leg while maintaining stability of the fracture reduction. As the swelling subsides the cast may be adjusted so that it is firmly in place to control fracture movement.
OPEN REDUCTION AND EXTERNAL FIXATION
Occasionally closed reduction of closed fractures is not possible because of delay in attempting the reduction or because of interposed soft tissue. Sometimes open reduction of closed fractures may be performed without internal fixation, especially in fractures that are relatively transverse. The animal is positioned with his injured leg down, and the foot is elevated and held by a stirrup to an IV stand or ring. The leg is completely clipped and surgically prepared. The foot is draped, as is the rest of the body, and aseptic technique is used while making a small incision over the fracture site. The fracture fragments are levered back into position with a small bone elevator. Following perfect anatomical reduction of the fracture, the skin wound in closed and an encircling or double half cast is applied to the fracture. Healing in these animals occurs satisfactorily as it would in an animal with a good reduction of a closed fracture by closed means. The technique is simple and often the time involved is less than that required for closed manipulation.

OPEN REDUCTION AND INTERNAL FIXATION
Open reduction and internal fixation of closed fractures is usually performed when the leg is inherently unstable, as with comminuted fractures or long oblique fractures, or when closed reduction is not possible or a simple open reduction is unstable (Fig. 24-5). The internal fixation device that seems to have the highest degree of success, especially in small breed dogs, is the plate and screws. (1,2,10) The plate is applied to the cranial surface of the radius, and no attempt is made to stabilize the ulna. If the radius heals and the ulna is in contact, the ulna will heal. Occasionally in small breed dogs atrophy of the ulna may occur, and the distal ulna may disappear entirely. This does not seem to adversely affect function or fracture healing of the radius. Most complications of radial and ulnar fractures appear to occur when intramedullary pins are used, especially in small breed dogs.(2,10) These pins seem to interact in an area of poor vascularity in such a way that the stability achieved is not complete and a fibrous nonunion will ensue. The literature does report success using these techniques,(4,5,8) but based on personal experience we do not recommend the use of radial intramedullary pins for fractures of the distal radius and ulna in small breed dogs.

Occasionally in large breed dogs an intramedullary pin is used in the ulna to reduce fractures of the distal radius and ulna, which are then stabilized through the use of a cast or splint (Fig. 24-6). In this way the radius will be given a chance to heal and the ulnar pin may be removed at a later date following fracture healing of the radius. The use of an ulnar pin and a radial plate is very successful in large dogs (Fig. 24-7).

FIG. 24-4 This midshaft comminuted fracture of the radius and ulna (A) was treated with a plaster cast (B). The healed fracture shows good bone consolidation and remodeling (C). (Courtesy of Dr. R.B. Hohn)

FIG. 24-5 This distal one-third transverse fracture of the radius and ulna (A) was treated with open reduction and internal fixation using a plate and screws (B). This type of fracture could also be treated with open reduction and external fixation if treated soon after the injury. This particular animal presented 2 weeks after the injury (which had been treated) in a cast without reduction.

Occasionally in large breed dogs an intramedullary pin is used in the ulna to reduce fractures of the distal radius and ulna, which are then stabilized through the use of a cast or splint (Fig. 24-6). In this way the radius will be given a chance to heal and the ulnar pin may be removed at a later date following fracture healing of the radius. The use of an ulnar pin and a radial plate is very successful in large dogs (Fig. 24-7).

FIG. 24-6 This comminuted midshaft fracture of the radius and ulna (A) was treated with an intramedullary pin in the ulna (B). Since the pin provides alignment and only some stability to the ulna, a cast or splint is usually added to help immobilize the radius. (C) The fracture 5 weeks later following bony union. (Courtesy of Dr. R.B. Hohn)
Radial intramedullary pins have been used with good results in giant breed dogs, but the problem with this technique is related to the position of the end of the pin. Any pin that is large enough to control motion within the cortices must exit through a joint. The exit of the pin will, in fact, help destroy the antebrachial joint and will usually leave the joint somewhat compromised even following pin removal. Therefore, intramedullary pinning of the radius is not performed in our clinic. Small cross pins, combinations of cross pins, and figure-of-eight wires have been used successfully in fractures of the radius and ulna. Also use of intramedullary pins that are inserted at the fracture site and toggled into position by a technique similar to that of the Leighton shuttle pin has been reported in the veterinary literature. The disadvantage of this technique is difficulty in removing an intramedullary pin that has not exited the medullary cavity if such removal should become necessary.

Occasionally small breed dogs in whom plates and screws have been inserted will experience some discomfort, especially in cold weather, even after the fracture has healed. This appears to be related to heat transfer associated with the environment and the "massive" metal device. Removal of this device will usually eliminate the problem. It must be remembered that bony remodeling occurs when an implant is removed, and the bone will not regain its strength for some time after removal. While the implant is in place, the bone adjacent to the fracture site will never regain its normal strength, and the return of strength following implant removal is related to bone remodeling. In the dog the bone will probably require 8 weeks to remodel properly such that full weight-bearing effort can be exerted on it without refractured Most radial and ulnar plates in our clinic are not removed. It is not uncommon to have a fracture occur if adequate immobilization is not accomplished after plate removal.

External skeletal fixation is a popular method of treating fractures of the radius and ulna. The technique lends itself to such fractures because of the ease of bone palpation and pin insertion. External skeletal fixation works best when little or no muscle is traversed by the pins as can occur in radial and ulnar fractures.

FRACTURES OF THE DISTAL RADIUS AND ULNA
EPHYSEAL FRACTURES

Epiphyseal fractures of the distal radius and ulna are common in immature dogs. The epiphyses are usually displaced into a lateral position (Fig. 24-8). Closed manipulative reduction and external fixation is the treatment of choice. Because immature animals lay down callus rapidly, reduction must be prompt or the lateral deviation will be permanent. Premature closure of the ulnar physis or the radial physis may occur subsequent to this fracture (Fig. 24-9).

FIG. 24-7 (A) Cranial-caudal radiograph of a distal transverse radial and segmental ulnar fracture in a German shepherd. (B) Lateral radiograph demonstrates fixation using an ulnar Steinmann pin and a radial bone plate. (C) The fracture 10 weeks later following bony union.

FIG. 24-8 (A) Cranial-caudal radiograph of an Irish setter pup with complete fracture of the distal radial and ulnar epiphyses. Note the lateral deviation. (B) Gross photo of the pup demonstrates the valgus deformity typically associated with this fracture.

FIG. 24-9 This physeal fracture occurred in a 4-month-old German shepherd puppy. Incomplete reduction (no reduction) resulted in deformity that necessitated a corrective osteotomy several months later.
ULNAR STYLOID FRACTURE
Distal ulnar styloid fractures are not usually intra-articular and, if incomplete, are treated in a cast or splint. The short ulnar collateral ligament attached to the ulnar styloid process is necessary for lateral stability, and the palmar ulnocarpal ligament is responsible for palmar stability. These functions must be preserved, hence the importance of immobilizing these seemingly inconsequential fractures to ensure a positive outcome.

Complete Fractures of the ulnar styloid require internal fixation. A tension band wire is the treatment of choice.(1)

RADIAL STYLOID FRACTURE Radial styloid fractures are usually intra-articular and require perfect anatomical alignment and internal fixation. The short radial collateral ligament attached to the radial styloid process is necessary for medial stability of the antebrachio-carpal joint. This function must be preserved, hence the importance of fixation of the fracture. Following open reduction the styloid process can be immobilized using a tension band wire or one or more interfragmentary bone screws.(1)

REFERENCES

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