Correlation of ultrasonographic observations with anatomic features and radiography of the elbow joint in dogs

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Objective—To define the ultrasonographic appearance of the elbow joint of dogs and to develop an ultrasonographic imaging protocol to reliably accomplish complete evaluation of that joint.

Animals—11 clinically normal mixed-breed dogs.

Procedure—Ultrasonographic observations (by use of a 5 to 10 MHz linear array probe) were made of 22 elbow joints in cadaveric forelimbs from clinically normal dogs. Images in standard anatomic planes were recorded with a multi-image camera, on videotape, or onto a computer. The anatomic plane of the ultrasonographic beam and position of the ultrasonographic probe were also recorded. Dissection of each elbow joint was performed, and anatomic features were correlated with ultrasonographic images.

Results—Structures clearly identified ultrasonographically included the lateral and medial humeral epicondyles, the humeroradial and humeroulnar joints, anconeal process, medial coronoid process, hyaline cartilage covering the proximal articular surface of the radius, collateral ligaments, tendons of triceps brachii and supinator muscles, and the supinator tendon and sesamoid in the supinator cartilage. An ultrasonographic imaging protocol for examination of the elbow joint was developed.

Conclusions and Clinical Relevance—Precise correlations were established between the gross anatomic appearance of the elbow joint and the ultrasonographic images of its component structures. The ultrasonographic imaging protocol will enable complete examination of all regions of the joint for detection of pathologic lesions. (Am J Vet Res 2003;64:721–726)

The gross anatomic features of the elbow joint of dogs and their radiographic appearance have been well described. Diseases of the elbow joint are clinically important, especially in young dogs, as they frequently cause lameness of the forelimb. Common diseases of the elbow joint include fractures; ununited medial epicondyle; congenital elbow luxation; and miscellaneous diseases, such as incomplete ossification of the humeral condyle, patella cubiti, and elbow incongruity (distractio cubiti in chondrodystrophoid breeds).

The elbow joint of dogs has been investigated via computed tomography and magnetic resonance imaging but to the authors’ knowledge, there is only 1 report in which its normal ultrasonographic appearance is described; few reports describe the clinical application of ultrasonography for examination of the elbow joint in dogs. The purpose of the study presented here was to define the normal ultrasonographic appearance of the elbow joint of dogs and to establish an ultrasonographic imaging protocol to reliably and routinely accomplish complete evaluation of all regions of that joint.

Materials and Methods

The study was approved by the University of Pennsylvania Institutional Animal Care and Use Committee. Eleven clinically normal, mature, mixed-breed dogs (3 males and 8 females) weighing 12 to 17 kg were selected for use in the study. The dogs were used in student surgery laboratories, after completion of which dogs were immediately euthanatized by administration of pentobarbital (11 mg/kg, IV). Each forelimb was removed from the cadavers, the hair was clipped from each elbow region, and the skin was cleaned of any dirt or debris. All observations of the elbow joints were made within 4 hours of euthanasia of the dogs. Each joint was radiographed; extended mediolateral (the elbow joint at a cranial concave angulation of approximately 110°), flexed mediolateral, craniodorsolateral-caudomedial 75° oblique (Cd75M-CrLO), craniodorsolateral-caudomedial 15° (Cr15L-CdMO), and craniodorsolateral-caudomedial 45° oblique (Cr45L-CdMO) radiographic views were obtained by use of screen film and rare-earth intensifying screens. The extended mediolateral elbow joint angle was determined by means of a protractor. To obtain the oblique radiographic views, the forearm was supported at the correct angle with a radioluent foam wedge.

Ultrasonographic gel was applied to each of the 22 elbow regions, and ultrasonographic observations were made with a high frequency compact linear array probe. The ultrasonographic images, in standard anatomic planes, were recorded with a multi-image camera on single-emulsion ultrasound film, on videotape (at 60 images/s), or in a digital format on a computer. Anatomic features were identified and examined with reference to the known ultrasonographic appearances of bone surfaces, joint spaces, tendons, ligaments, and muscles.

Arthrography was performed on 7 elbow joints. With ultrasonographic guidance, a 22-gauge needle was inserted into the caudolateral part of the humeroulnar joint, and 2 to 4 mL of iohexol contrast medium (120 or 240 mg of iodine/mL) was injected. Additional mediolateral and craniodorsal radiographic views of each elbow joint held in extension were obtained to verify the successful intra-articular inject...
tion of the radiographic contrast agent. Via the same technique, ≤ 6 mL of physiologic saline (0.9% NaCl) solution was injected into the humeroulnar joint of 2 other forelimbs. Ultrasonographic examination of each of the 9 elbow joints was repeated to assess whether fluid in the cubital joint enhanced the ultrasonographic visualization of any structures.

For each image obtained with the elbow joint of the limb flexed or extended, the anatomic plane of the ultrasonographic beam and position of the probe in the region of the elbow were recorded, and these data were used to establish an ultrasonographic imaging protocol.

Gross anatomic dissection of each elbow joint was subsequently performed to establish correlations between anatomic features and ultrasonographic images. For selected anatomic features, dimensions were measured in the dissected specimens (with a ruler graduated in millimeters) and in the ultrasonographic images on the screen of the ultrasonographic machine (by use of calipers); the ultrasonographic measurements are reported as mean ± SD, and the number of elbow joints in which the measurements were made is identified.

Results

Radiographic and anatomic examinations—Each elbow joint of each dog was normal in appearance; no abnormalities were detected in radiographs or after gross anatomic dissections. The medial coronoid process was best defined in the Cr45L-CdMO and Cr15L-CdMO radiographic projections. Precise correlations were established between the morphologic features observed in ultrasonographic images, radiographs, and elbow joints after anatomic dissections.

Ultrasonographic observations—More than 200,000 ultrasonographic images, including videofields, were recorded and analyzed. Structural details were judged superior in images obtained with the (more advanced) ATL 5000 ultrasound machine than with the ATL Ultramark 9. In the following description of our findings, unless otherwise stated, each structure was detected in the ultrasonographic images of each elbow joint. Although the distal humeral condyle was not seen, the surfaces of the lateral and medial humeral epicondyle were imaged in dorsal, transverse, and oblique transverse planes. Each appeared as an intensely hyperechoic linear echo with distal acoustic shadowing. A thin (approx 1-mm-thick) anechoic band was seen between the surface of the humeral epicondyle and the adjacent, superficial soft tissue structures. The lateral epicondyle was more rounded than the medial epicondyle. The olecranon and anconal process were identified as well-defined, hyperechoic, linear echoes with distal acoustic shadowing and were best defined when the probe was positioned halfway between the dorsal and transverse anatomic planes caudal to the medial (or lateral) humeral epicondyle (Fig 1). The outer margin of the medial coronoid process of the ulna was most easily seen by ultrasonographically following the medial epicondyle caudally to the humeroulnar joint space. The medial coronoid process was seen as a sharp echogenic projection immediately distal to the joint (Fig 2); it extended a distance of approximately 5.3 ± 0.1 mm (n = 3) into the joint, at which point it could no longer be detected ultrasonographically. Its distal part, 1 to 2 mm in length, merged with the ulnar diaphysis. The medial coronoid process was more easily seen after the intra-articular injection of saline or iohexol, as its borders were surrounded by anechoic fluid (Fig 3). The subchondral bone of the head of the radius was represented as a hyperechoic line; its hyaline cartilage covering was represented as a smooth, hypoechoic to anechoic band (thickness, 1.1 ± 0.1 mm; n = 15). The head of the radius and its hyaline cartilage were imaged with the transducer in a transverse orientation along the lateral humeral epicondyle and humeroradial joint space.

Synovial joint spaces were identified as hypoechoic regions between the hyperechoic areas of bone. The humeroradial joint space appeared as a hyperechoic line between the echogenic adjacent bones; it

Figure 1—Ultrasonographic image in the dorsal anatomic plane and diagram of the caudal aspect of the right humeroulnar joint of a male dog weighing 14.1 kg. The ultrasonographic probe was placed on the caudomedial aspect of the elbow joint. Notice the hyperechoic line that corresponds to the anconeal process (ANCON) and medial humeral epicondyle (HUMERUS). The anechoic humeroulnar joint space is evident (arrow). The scale on the right side of the image is in centimeters; the top and bottom of the image are the superficial and deep aspects of the forelimb, respectively. Black rectangle in drawing = Footprint of linear array probe. White star = Proximal aspect of probe and image.
had a width of $2.4 \pm 0.1\text{ mm (n = 4)}$. In the transverse anatomic plane, the humeroulnar joint (at the level of the medial coronoid process) was also seen as a hypoechogenic line that was $2.1 \pm 0.1\text{ mm (n = 6)}$ in width (Fig 2 and 3). It was seen immediately deep to the medial collateral ligament. At the level of the anconeus muscle, however, the humeroulnar joint space (in the dorsal anatomic plane) had a hypoechogenic, triangular shape and was $\leq 4\text{ mm in width}$ (Fig 1). The proximal radioulnar articulation was not seen. Synovial fluid in the joint was not identified. After arthrography and saline injection, however, the anechoic fluid was easily seen in the elbow articularizations; the joint capsule was also identified (Fig 3). Ultrasonographically, joints injected with saline or positive contrast iohexol appeared identical.

The fibers of the lateral and medial collateral ligaments appeared as bands of medium echogenicity with hyperechoic parallel lines that corresponded to bundles of collagen fibers. The lateral collateral ligament (width, $3.4 \pm 0.1\text{ mm; n = 5}$), including its origin on the lateral epicondyle, was seen; its distal insertions on the radius and ulna were not identified. Similarly, the origin on the medial epicondyle of the medial collateral ligament was observed, but the divisions and distal insertions on the radius and ulna were not seen. The width of the medial collateral ligament was difficult to determine, but in 1 dog in which it could be accurately measured, it was $2\text{ mm}$ (Fig 4). The tendon of the triceps brachii muscle was imaged in dorsal and transverse planes and was best defined when the elbow joint was fully flexed. In the dorsal plane, the hyperechoic parallel lines of collagen fiber bundles within the tendon were visible (Fig 5). In the transverse plane, the collagen fiber bundles appeared as echogenic pinpoint foci. The tendon was $7.5 \pm 0.2\text{ mm (n = 5)}$ in depth and

Figure 2—Ultrasonographic image1 in the transverse anatomic plane and diagram of the left humeroulnar joint of a male dog weighing 14.1 kg. The ultrasonographic probe was placed on the medial aspect of the elbow joint. Notice the 3-mm hyperechoic edge (a) of the medial coronoid process (M) of the ulna (ULNA), which was optimally imaged when the medial humeral epicondyle (H) was included in the same anatomic plane. The width (b) of the humeroulnar joint space (arrow) was 3 mm. The scale on the right side of the image is in centimeters. See Figure 1 for remainder of key.

Figure 3—Ultrasonographic image1 in the transverse anatomic plane and diagram of the right humeroulnar joint of a male dog weighing 14.1 kg after intra-articular injection of 4 mL of physiologic saline (0.9% NaCl) solution. The ultrasonographic probe was placed on the medial aspect of the elbow joint. Notice that the hyperechoic humeroulnar joint space contains fluid (saline) and is 4 mm in width between the caliper crosses (1). The hyperechoic margin of the medial coronoid process (MCP) of the ulna (ULNA) is more distinct than the image in Figure 2. The joint capsule (arrows) is identified as an echogenic line $< 1\text{ mm in thickness}$. The medial epicondyle of the humerus (H) is evident. The scale on the right side of the image is in centimeters. See Figure 1 for remainder of key.
8.6 ± 0.1 mm (4) in width at its proximal end, at the level of the groove between the 2 cranial prominences on the tuber of the olecranon. The tendon was ultrasonographically followed proximally from its origin on the caudal margin of the olecranon; the 4 triceps brachii muscle bellies could be seen arising from the proximal end of the tendon. The tendon could be identified until it became indistinguishable from the muscle. Immediately superficial to the radius, the tendon of the supinator muscle (Fig 6) was seen as a broad, flat, echogenic structure arising from the lateral epicondyle and the ulnar collateral ligament. The muscle itself could not be distinguished from the more superficial extensor carpi radialis and long and lateral digital extensor muscles. The sesamoid cartilage in the medial aspect of the tendon of the supinator muscle was observed as a localized hypoechoic region (5 to 10 mm in length) at the proximal end of the tendon (Fig 6). In both elbow joints of 1 dog, a mineralized hyperechoic, oval sesamoid bone (1 mm in diameter) was seen within the sesamoid cartilage; there was no evidence of distal acoustic shadowing.

The muscles involved in the complex action of the elbow appeared hypoechoic with hyperechoic spindles. The associated deep fascia appeared as very hyperechoic bands that were oriented parallel to the muscle bellies.

Ultrasonographic imaging protocol—From our experience, an ultrasonographic imaging protocol that produced optimal results was determined. The ultrasonographic probe was initially placed in the dorsal anatomic plane on the medial aspect of the extended elbow joint of a female dog weighing 15.0 kg. The ultrasonographic probe was placed on the caudal aspect of the elbow joint. Notice the hyperechoic parallel lines of the collagen fiber bundles in the triceps tendon in the dorsal plane (a). The olecranon (O) is seen as a hyperechoic line. The calipers in the upper longitudinal image (a) illustrate the level at which the image (b) in the dorsal anatomic plane was made. In the dorsal plane, the collagen fiber bundles (in transverse section) appear as echogenic pinpoint foci. The tendon (as measured with the calipers) is 5.5 mm in depth and 6.2 mm in width. Magnification = 4X. See Figure 1 for remainder of key.

By repositioning the ultrasonographic probe on the lateral aspect of the extended elbow joint, the lateral humeral epicondyle was visible in the dorsal anatomic plane. The humeroradial joint ligament, including its origin, was best defined in the transverse plane. With the elbow in a flexed position, repositioning the probe onto the caudomedial aspect of the lateral humeral epicondyle enabled imaging of the olecranon, anconeal process, and caudal part of the humeroulnar joint. Examination of the triceps brachii muscle and its tendon required relocation of the probe to the caudomedial aspect of the elbow joint to obtain images in the dorsal and transverse anatomic planes.
anatomic plane also revealed the head of the radius and its cartilage, the lateral collateral ligament, and supinator muscle and tendon. To complete the ultrasonographic examination, transverse images of the olecranon and anconeal process were obtained with the elbow joint in the flexed position.

Discussion

In many standard radiographic projections, the medial coronoid process is obscured by the proximal portions of the radius and ulna. Oblique projections (eg, Cd75M-CrLO and Cr15L-CdMO) have been advocated by many radiographers as most useful for imaging the medial coronoid process, although there is disagreement regarding which oblique projection is optimal. In the radiographs of elbow joints obtained in the study reported here, the Cr45L–CdMO projection was useful for examination of the medial coronoid process (a projection not previously reported). Precise correlations were established between the gross anatomic features of the elbow joint and their ultrasonographic appearance. Articular cartilage covering the head of the radius was most easily identified as a hypoechoic line. An unexpected finding was the anechoic band between the surface of the humeral epicondyles and the adjacent superficial soft tissue structures. This band was not related to articular cartilage, and it remains uncharacterized; whether it is consistently present in elbow joints in vivo was beyond the scope of this study. Of particular interest was the quality of the ultrasonographic imaging of the medial coronoid process; its observation via ultrasonography was enhanced by injection of fluid into the elbow joint. Ultrasonography has potential value for detection of fragmentation of the medial coronoid process, although results obtained with this diagnostic modality are varied.

Synovial fluid and the capsule of the elbow joint were not detected initially; the joint space and capsule were clearly seen after intra-articular injection of radiographic contrast medium or saline. The presence of effusion in the elbow joint is considered to be indicative of joint pathology. Thus, if joint effusion or a thickened joint capsule developed because of joint disease, such pathologic changes should be detectable during ultrasonographic evaluation.

The sesamoid cartilage was consistently identified in the tendon of origin of the supinator muscle. Mineralization (ie, a sesamoid bone) in the sesamoid cartilage of the supinator tendon was seen (radiographically and ultrasonographically) in 2 of 22 (9%) elbow joints, which is a lower frequency of detection than that reported from radiographic data (31%) in another study. Mineralization might have been found more frequently if radiography and ultrasonography had been performed on the dissected tendon of the muscle. In ultrasonographic images, the sesamoid bone was not associated with distal acoustic shadowing, probably because of its small size. Ultrasonographic investigation of the elbow joint during flexion and extension facilitates detection of the sesamoid bone because of its asynchronous movement with the underlying bone. This type of dynamic ultrasonographic examination has also been recommended for identification of other elbow structures.

Recently developed modes of ultrasonographic imaging (including harmonic imaging, compound scanning, and improved visibility and definition of tissue texture patterns) may lead to improvements in image resolution. Thus, with advances in technology, it may be possible to more completely delineate the insertions of the collateral ligaments and to distinguish between individual muscle bundles associated with complex actions of the elbow joint. To ensure thorough ultrasonographic examination of all regions of the elbow joint in dogs, it is important to routinely use a comprehensive imaging protocol, made in standard anatomic planes. The use of a protocol, such as that determined in the study reported here, enables definitive diagnosis of elbow joint disease to be made and clear definition of the extent and character of any pathologic changes.

Figure 6—Ultrasonographic image in the transverse anatomic plane of the left supinator muscle and tendon of a female dog weighing 16.5 kg. The ultrasonographic probe was placed on the lateral aspect of the elbow joint. Notice the surface of the tendon of the supinator muscle (arrows) that was visible as an echogenic band. Its sesamoid bone (S) is identified as a well-demarcated hyperechoic oval-shaped region positioned superficial to the head of the radius. The sesamoid cartilage (C) within the tendon is also evident, as are the fibers of the supinator muscle (M). The scale on the right side of the image is in centimeters. See Figure 1 for remainder of key.

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