Radiographic anatomy and technique for arthrography of the cubital joint in clinically normal dogs

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Summary: A technique for arthrography of the cubital joint in clinically normal large-breed dogs was developed with the objective of improving visualization of the articular margin of the medial coronoid process. A lateral approach to the cubital joint for injection of contrast medium was selected. Arthrography of 24 cubital joints was performed by using 14 dogs. Twelve combinations of iodinated contrast medium, consisting of various concentrations (3) and volumes (4), were used. Two sets of arthrograms for each of the 12 combinations of contrast medium were obtained. Five radiographic views were used for each set.

All arthrograms were examined by 3 evaluators, and each articular surface received a numerical rating for how well it could be seen in each view. Results of the evaluation indicated that low volumes of contrast medium were preferable to high volumes, with 2 ml providing the best visualization. Concentration of iodine seemed less important than did volume.

The numerical ratings also indicated that the articular margin of the coronoid process was clearly observed a maximum of only 24% of the time on a slightly supinated mediolateral projection. The articular margins of the head of the radius, trochlea humeri, and trochlear notch were well visualized > 90% of the time.

Arthrography of the cubital joint was technically easy to perform, and complications were not encountered, but arthrographic anatomy of the cubital joint is complex. Potential uses for arthrography of the cubital joint include diagnosis of osteochondrosis, intra-articular fragments, and joint capsule ruptures.

Lameness referable to the cubital joint is a common finding among young large- to giant-

breed dogs. Atraumatic causes of lameness are grouped under the term elbow dysplasia, which includes any developmental abnormality of the cubital joint. Three common manifestations of elbow dysplasia are ununited anconeal process, osteochondrosis of the medial aspect of the humeral condyle, and fragmented medial coronoid process. 1 Although the first 2 of these conditions may be diagnosed via radiographic studies, fragmented medial coronoid process usually is not radiographically apparent. Therefore, signs of early degenerative joint disease, seen on initial or subsequent radiographs, are used to make a presumptive diagnosis. 1

Arthrography is a technique for visualization of synovial and cartilage surfaces of joints. Positive and negative contrast media, or a combination of the 2, are introduced into the joint, and a series of radiographs are obtained. The technique has been commonly used in human beings, especially for diagnosing meniscal tears and cruciate ligament injuries in the knee. 2 Other indications include localization of intra-articular cartilaginous and osseous fragments and the diagnosis of osteochondritis dissecans, cartilage erosions, proliferative synovitis, joint capsule rupture, and collateral ligament tears. 3-6

We wanted to determine whether articular surfaces within the cubital joint could be adequately outlined with arthrography, so that the technique could be used for detection of fragmented medial coronoid process and other abnormalities not easily identified on survey radiographs. The purposes of the study reported here were to develop a technique for arthrography of the cubital joint in dogs, to determine what combination of contrast concentration and volume gave the best results, and to determine the effectiveness of arthrography in delineating the articular surfaces of the cubital joint.

Materials and Methods

Preliminary tests—Arthrography of cubital joints was performed to gain information about arthographic positioning, timing, and potential injection sites. Various radiographic views were examined, and it was determined that the articular
surfaces were best represented by 5 views: mediolateral with the cubital joint extended, mediolateral with the joint flexed, mediolateral with the joint extended and slightly supinated,^7^ cranio-caudal with the joint extended, and cranio-caudal with the joint slightly supinated.

The time available for completion of the series of radiographic views prior to degradation attributable to decreasing intra-articular contrast was assessed, using 2 cubital joints. Mediolateral views were obtained at 2-minute intervals for 20 minutes, beginning immediately after injection of contrast medium. These 2 sequences of arthrograms were then evaluated.

To assist in understanding the anatomy of the cubital joint, 2 casts of clinically normal joints were made. For 1 cast, approximately 12 ml of 3 parts red latex to 1 part neutral-buffered 10% formalin was injected into the cubital joint until distention of the joint capsule was palpable. For the second cast, approximately 8 ml of silicone was injected into the joint, after which no more material could manually be injected. These casts were allowed to harden in a cooler for 48 hours. The specimens were then dissected to remove most of the soft tissues, including joint capsule, from around the cast, and photographs were obtained. These casts and bone specimens from other sources were used as aids for identification of articular surfaces to be evaluated by use of arthrography.

**Arthrographic technique**—For determination of the best combination of contrast medium concentration and volume for arthrography of the cubital joint in clinically normal dogs, arthrography was performed by use of 3 various concentrations and 4 various volumes of an ionic triiodinated combination of sodium and meglumine diatrizoate. Iodine concentrations of 250, 300, and 370 mg/ml were used in volumes of 1, 2, 3, and 4 ml, resulting in 12 various combinations. Each combination was repeated so that 2 sets of each combination were obtained, for a total of 24 arthrograms.

The 24 arthrograms were obtained from 14 dogs with no evidence of lameness and normal survey radiographs of both cubital joints. Ten male and 4 female young adult dogs, weighing between 22 and 33 kg, were used. Ten Greyhounds, 2 Chow Chow types, 1 Labrador Retriever type, and 1 Doberman Pinscher were included. Both cubital joints were used for arthrography in 10 dogs, and 1 joint each was used in 4 dogs. For the 2 sets of each concentration/volume combination, joints from different dogs were used.

Dogs were anesthetized, and the area of the cubital joint was shaved and prepared for aseptic puncture. A 1.5-inch, 20- or 22-gauge spinal needle^b^ attached to a 3-way stopcock and 3-ml syringe was used. With the joint moderately flexed and the digits and carpus supinated, a groove was palpated between the trochlear notch of the ulna and the lateral aspect of the humeral condyle. The joint was entered at this location by directing the needle distomedially and slightly cranial. A small amount of synovia was aspirated prior to injection of contrast medium to confirm intra-articular placement of the needle.

Immediately after injection, the joint was flexed and extended several times, and a rapid series of the 5 radiographic views was obtained, using a high-detail film-screen combination. For 2 of the joints, however, the supinated cranio-caudal view was replaced with a pronated cranio-caudal view, and for 3 joints, the supinated mediolateral view was omitted.

Dogs were used for teaching purposes while still under anesthesia, and then they were euthanatized. Eighteen of 24 joints were examined at necropsy for gross signs of joint abnormalities and injury secondary to arthrocentesis.

**Evaluation**—The arthrograms obtained were assigned a random number from 1 to 24 and were separated by view into 5 groups. These groups were then examined by 3 evaluators working separately and having no knowledge of the contrast medium combinations used. Criteria for assessment of the diagnostic quality of each arthrographic view included the sharpness of delineation of articular cartilage margins in 7 areas, including the medial coronoid process of the ulna, the lateral coronoid process of the ulna, the head of the radius, the medial aspect of the trochlea humeri, the groove of the trochlea humeri, the capitulum humeri, and the cranial margin of the trochlear notch of the ulna.

A numerical value from 1 to 4 was assigned to each evaluated articular surface. A rating of 1 represented the judgment that 100% of the articular margin could be seen. A rating of 2 represented that > 50%, but < 100%, of the articular margin could be seen. A rating of 3 represented that some portion, but < 50%, of the articular margin could be seen, and a rating of 4 was assigned if none of the articular margin could be seen.

When < 100% of the articular margin was visualized, evaluators also recorded their impression as to why. Reasons that could be chosen included too much contrast, too little contrast (whether in volume or concentration), air bubbles obscuring the surface, inappropriate view for seeing the margin, and indistinctness for unknown reasons. The number of times that each reason was chosen was totalled for the 12 contrast medium combinations. Percentages were then calculated for each reason for all 12 combinations by dividing the total for each reason by the maximal number of times it

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^a^Angiost 370, Berlex Laboratories Inc, Wayne, NJ.
^b^B-D Spinal needle, Becton, Dickinson & Co, Rutherford, NJ.

^Kodak Lanex fine screen 100 and T-Mat I film, Eastman Kodak Co, Rochester, NY.

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could have been selected. These percentages were then tabulated.

From the numerical ratings of all 3 evaluators, combined scores for the visualization of all 7 cartilage surfaces on all available views were totaled and ranked from lowest to highest to derive the combination of iodine concentration and volume that resulted in the best quality arthrogram. To include the 3 arthograms that lacked a supinated mediolateral view in the ranking of the total scores for the arthograms, a mean score was assigned to this view. This was calculated separately for each evaluator by use of means of their scores for the same view on the other 21 arthograms evaluated.

To evaluate how well each articular surface could be seen in the various radiographic views, the 8 arthograms composing the 4 top-ranked combinations of contrast medium volume and iodine concentration were used. Scores for each articular surface were evaluated separately. A percentage was calculated by tallying the total number of times each evaluator gave a rating of 1 or 2, indicating 50 to 100% visibility of the articular surface, and dividing this by the total number of times the articular surface was rated. This was calculated for each of the radiographic views. For the medial coronoid process, a second percentage was calculated for how often its articular surface was seen, even if poorly.

*Statistical analysis*—Nonparametric statistics were used to assess the validity of our qualitative data. The Kruskal-Wallis test was used to determine whether there was a significant difference among the medians of the scores for the 3 evaluators. The Mann-Whitney U test was used to determine whether the median scores between the 2 sets of contrast medium combinations were significantly different.

**Results**

*Preliminary tests*—Evaluation of the 2 serial sets of arthographic views revealed that good diagnostic quality remained for 5 to 7 minutes. Crispness of definition of the articular surfaces decreased rapidly beyond 7 minutes after injection, and by 15 to 17 minutes, arthograms were considered of poor diagnostic quality.

Inspection of the 2 casts of the cubital joints as well as study of bones comprising the cubital joint aided in accurate evaluation and scoring of the arthograms. The casts revealed that the joint capsule lay fairly close to adjacent bone medially and laterally, bounded by the collateral ligaments. Numerous pouches, however, extended away from the joint to rest under tendons. Medially, pouches were formed under the biceps brachii tendon and under the origins of the flexor muscles originating from the medial epicondyle (Fig 1). Laterally, similar pouches were found under the tendons of the extensor carpi radialis and the common digital ex-

tensor muscles. The cranial and caudal aspects of the joint capsule were more spacious. The cranial pouch projected around the annular ligament, traversing the head of the radius. Caudally, a large pouch extended from the supratrochlear foramen laterally.

Using the casts and bone specimens, the 7 articular surfaces to be evaluated were identified on the preliminary arthograms. Evaluation of the mediolateral views revealed that within the humeral condyle, the semicircle of cartilage having the smallest diameter represented the groove of the trochlea humeri, located almost midsagittal within the joint (Fig 2). The slightly wider diameter semicircle of cartilage was identified as the capitulum, or lateral aspect of the humeral condyle, which articulated with the head of the radius. The arc of
cartilage with the widest diameter and the least delineation was the medial aspect of the trochlea humeri, which articulated with the medial coronoid process. The medial aspect of the trochlea humeri was poorly delineated on lateral views because it sloped distally from lateral to medial. Identification of the articular margin of the medial coronoid process was made adjacent to the arc of the medial aspect of the trochlea humeri. Like the medial trochlea, the surface of the medial coronoid process sloped distally from lateral to medial, making it difficult to visualize, because the cartilage was not projected tangentially (Fig 3). The articular margin of the head of the radius had 2 projections. Toward midline, it cupped the trochlea humeri, near its groove, whereas the lateral aspect sloped distally from caudal to cranial (Fig 4). The lateral coronoid process articulated with the head of the radius. The cranial aspect of the trochlear notch of the ulna articulated with the groove of the trochlea humeri.

The articular margins of the humeral condyle were easily identified on the cranio-caudal views (Fig 5). The margin of the head of the radius also was clearly seen. Abbreviated visualization of the articular margins of the medial and lateral coronoid processes was observed, because most of their surfaces were projected en face using these views. The articular margin of the trochlear notch does not project in tangent by use of this view, and therefore was not evaluated.


diagram

Arthrographic technique—The technique chosen for arthrography of the cubital joint resulted in arthograms suitable for evaluation in all instances. Contrast medium was placed appropriately into the joint, and no leakage was seen. The 5 radiographic views were obtained within 3 minutes after injection of contrast medium.

Necropsy revealed that 2 of 18 joints used for arthrography had superficial cartilaginous defects in the area of injection. These 2 joints were among the first ones used in our study.

Evaluation—The Mann-Whitney U test indicated that median scores between the 2 repetitions of each iodine concentration and volume combination were not statistically different. The Kruskal-Wallis test indicated that the median scores for the arthograms were similar among the 3 evaluators.
Table 1—Percentages of reasons given for incomplete visualization of articular surfaces

<table>
<thead>
<tr>
<th>Rank</th>
<th>Volume (ml)</th>
<th>Concentration (mg of iodine/ml)</th>
<th>Reasons (%) *</th>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>370</td>
<td>A 11</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>250</td>
<td>B 20</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>250</td>
<td>C 47</td>
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<td>4</td>
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<td>250</td>
<td>D 27</td>
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<tr>
<td>5</td>
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<td>370</td>
<td>E 47</td>
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<td>6</td>
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<td>7</td>
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<td>300</td>
<td>B 47</td>
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<td>8</td>
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<td>C 27</td>
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<td>9</td>
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<td>10</td>
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<td>11</td>
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<tr>
<td>12</td>
<td>3</td>
<td>370</td>
<td>B 20</td>
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*A = Too little contrast, in volume or concentration; B = too much contrast; C = air bubbles obscuring articular surface; D = inappropriate view for seeing surface; E = unknown.

Ranking of the combined scores for all views for the 12 combinations of contrast concentration and volume indicated that the scores of the 2 top-ranked combinations differed from one another by 1 point. Two milliliters of 370 mg of iodine/ml and 2 ml of 250 mg of iodine/ml were equivalent in the quality of arthrograms produced. Of the top-ranked 6 combinations, volumes used were low. Of the 4 lowest ranking combinations, volumes were high, with 3 of 4 being from the 4-ml volume category. The milligrams of iodine used per milliliter in the contrast solution seemed to have less bearing on the ranked results, because these values were distributed throughout the ranking order. Body weight, within the narrow range used in our study, appeared to have no relation to the rankings of the concentration/volume combinations.

The tabulated percentages of reasons for incomplete visualization of articular surfaces in the 12 ranked arthrograms indicated that air bubbles obscuring the articular surface were a minor problem (Table 1). An inappropriate radiographic view was judged the problem 26 to 38% of the time (mean, 33%). This small range indicated that inappropriate view was a fairly constant finding among the ranked combinations. Comparing the percentages for too little contrast with those for too much contrast revealed some trends across the ranked arthrograms. Too little contrast was strongly believed to be a problem for concentration/volume combinations ranked 3, 5, and 8. Too much contrast was a problem predominantly in the lower-ranked arthrograms, including combinations ranked 7, 9, 10, 11, and 12. Too little or too much contrast was not a predominant problem for combinations ranked 2, 4, and 6. In general, for the more highly ranked arthrograms, the reason for less than ideal visualization of articular margins was unknown, whereas for the lowest ranking arthrograms, the reason for poor quality was believed to be too much contrast.

In the 4 top-ranked contrast concentration/volume combinations, the mediolateral extended view was best for visualizing the articular margins of the head of the radius and the trochlear notch, demonstrating 50 to 100% of these surfaces in 92% of joints. The mediolateral supinated view allowed the most frequent clear visualization of the articular margin of the medial coronoid process, but 50 to 100% of its surface was seen only 24% of the time. Some visualization of the articular margin of the medial coronoid process was observed 38% of the time by use of the supinated mediolateral view. For most joints, when the articular margin of the medial coronoid process was identified on other views, it was best visualized using the supinated mediolateral view. This view projects the medial coronoid process in a plane more parallel with the film and has been recommended as the view of choice for the diagnosis of fragmented medial coronoid process by use of survey radiographs and linear tomograms.7 The mediolateral flexed view resulted in decreased visibility of most articular margins, especially the medial aspect of the trochlea. Contrast medium tended to accumulate in the cranial aspect of the joint, thus, obscuring anatomic detail.

The cranio-caudal and supinated cranio-caudal views were excellent for seeing the articular margins of the humeral condyle. Fifty to 100% of the articular margins of the medial aspect of the trochlea humeri and the capitulum were seen 100% of the time on the supinated cranio-caudal view. This same view revealed 50 to 100% of the articular margin of the groove of the trochlea humeri in 96% of joints. Visualization of the articular margins of the medial and lateral coronoid processes was limited because their surfaces are seen en face; therefore, percentages were not tabulated.

Discussion
The method for arthrography of the cubital joint described in the study reported here resulted in arthrograms well suited for interpretation, and the procedure was not technically difficult to perform. Assessment for lameness after the procedure could not be made, because in all but 2 cases, the dogs were not allowed to recover from anesthesia. In the 2 cases in which the dog recovered from anesthesia, lameness was not observed. Judging from
necropsy findings of most of the cubital joints, direct trauma from arthrocentesis was not a notable problem. Superficial scoring of articular cartilage does not induce clinically apparent problems and has not been associated with progression of cartilage damage. Although it is recommended that veterinarians practice this technique on cadaver dogs prior to performing cubital joint arthrography, the possibility of scoring the cartilage during arthrocentesis should not preclude use of this procedure.

Lameness secondary to adverse reaction to the positive contrast medium is another possible sequela to arthrography. However, compared histologic changes in the femoro-tibial joints of rabbits, resulting from injection with 4 various positive contrast media as well as 0.9% NaCl, and they failed to show any difference in the degree of synovial inflammation 1 to 7 days after injection. Adverse reaction to intra-articular positive contrast medium, although of concern, probably would be infrequently encountered.

Results from comparison of articular margin visibility for various combinations of contrast concentration and volume indicated that for normal joints, lower volumes tended to be preferable, whereas concentration seemed to be less important. In cubital joints containing effusion or synovial proliferation, the volume of contrast medium may have to be increased to adequately cover the articular surfaces. Alternatively, aspiration of joint fluid prior to injection decreases the dilution of contrast medium in the synovia and has been recommended for arthrography in human beings and dogs.

For arthrography of the cubital joint in human beings, double-contrast arthrography has been recommended, combined with positional views to take advantage of gravity for highlighting structures within the joint. Similar to other arthrographic studies in veterinary medicine, we found on initial trials that introducing air into the joint in combination with positive contrast medium produced many small air bubbles that obscured the cartilaginous surfaces. This may be attributable to the fact that the canine cubital joint is much smaller than the human cubital joint.

Clear visualization of the articular margin of the medial coronoid process was not achieved in most instances. Potential uses for cubital joint arthrography in the dog include diagnosis of osteochondrosis, intra-articular osteochondral fragments, and joint capsule and ligamentous tears.

References