Computed tomographic, magnetic resonance imaging, and cross-sectional anatomic features of the manus in cadavers of dogs without forelimb disease

Christopher P. Ober, DVM, PhD, and Larry E. Freeman, DVM, MS

Objective—To provide a detailed description of cross-sectional anatomic structures of the manus in canine cadavers in association with corresponding features in computed tomographic (CT) and magnetic resonance (MR) images.

Sample Population—7 cadavers of adult large-breed-type dogs (weight range, 25 to 30 kg) without forelimb disease.

Procedures—Forelimbs were removed from the cadavers within 4 hours after euthanasia and frozen. The right forelimbs of 3 cadavers were cut into 4-mm sections by use of a bandsaw; 1 limb each was sectioned in the transverse, dorsal, or sagittal plane. Sections were cleaned and then photographed. After thawing, transverse CT images of the right forelimbs of 3 additional cadavers were obtained, and the right forelimb of a seventh cadaver underwent MR imaging in the transverse, sagittal, and dorsal planes. The evaluated regions extended from the digits to the carpus. Features in CT and MR images that corresponded to clinically important anatomic structures in tissue sections were identified.

Results—For most of the anatomic structures evident in tissue sections, corresponding CT and MR imaging features were identified. Osseous and musculotendinous structures of the manus were readily detected in CT and MR images, whereas vascular structures were only rarely identified by use of the imaging techniques.

Conclusions and Clinical Relevance—Results of the detailed assessment of anatomic structures of the canine manus in association with corresponding features in CT and MR images will facilitate detection of pathological conditions and be beneficial in planning surgical procedures for diseases of the manus in dogs. (Am J Vet Res 2009;70:1450–1458)
tion in which cross-sectional anatomic features of the canine manus in CT and MR imaging are described and the primary focus is placed on the osseous structures. The purpose of the study of this report was to provide a detailed description of cross-sectional anatomic structures of the manus in cadavers of dogs without forelimb disease and to associate those structures with corresponding features in CT and MR images.

Materials and Methods

Seven cadavers of apparently healthy adult large-breed-type dogs (cadaver weight range, 25 to 30 kg) without forelimb disease were used in the study. Six dogs were sedated with xylazine hydrochloride and ketamine hydrochloride (administered IM) and euthanized via IV administration of pentobarbital sodium at a local animal shelter; both forelimbs of each dog were amputated. All limbs were harvested within 4 hours after euthanasia and were frozen in a walk-in freezer immediately following amputation. The limbs remained frozen for variable amounts of time before use.

Right forelimbs from 3 of the 6 cadavers were used for preparation of anatomic sections. The right forelimbs were sectioned at 4-mm intervals from the digits to the level of the distal radius while frozen by use of a band saw; 1 limb each was sectioned in the transverse, dorsal, or sagittal plane. The tissue sections were then cleaned and photographed. The left forelimbs from these cadavers were not used in the study.

The right forelimbs from each of the other 3 cadavers were allowed to thaw and underwent CT. Computed tomography was performed with a single-slice helical scanner. Each limb was placed in the gantry with the palmar surface on the scanner table. Transverse images of each manus from the digits to the distal radius were obtained at 1.5-mm slice thickness and 0.5-mm index (CT couch movement interval) by use of a modified extremities protocol (200 mA; 120 kVp; image size, 180 mm; matrix, 512 × 512; small focal spot; and standard reconstruction algorithm). Sagittal planar reconstructions of the regions of interest were also performed by use of a dedicated CT workstation. Computed tomographic images were evaluated in both a soft tissue window (window level, 40 HUs; window width, 350 HUs) and a bone window (window level, 480 HUs; window width, 2,500 HUs). The CT images were evaluated and matched to the corresponding anatomic sections. Features in the CT images that corresponded to clinically important anatomic structures in tissue sections were identified.

A seventh dog that was euthanatized for reasons unrelated to disease of the forelimbs was donated to the Virginia-Maryland Regional College of Veterinary Medicine and subsequently used in the study. The right forelimb was amputated during necropsy. Magnetic resonance imaging of this limb was performed with a 0.2-T magnet. The manus was placed in an extremity coil with the palmar surface closest to the table, and T1-weighted spin-echo images (2.5-mm slice thickness; 0.2-mm spacing; TE, 16 milliseconds; TR, 1,720 milliseconds; NEX, 3). The field of view for all MR images was 140 mm, and a 256 × 192 matrix was used in all sequences. The MR images were evaluated and matched to the corresponding anatomic sections. Features in the T1-weighted and gradient-echo MR images that corresponded to clinically important anatomic structures in tissue sections were identified.

Results

For purposes of the study, anatomic sections were obtained from 3 right forelimbs harvested from 3 canine cadavers; from an additional 4 cadavers, CT images of 3 right forelimbs and MR images of 1 right forelimb were obtained. Transverse CT and MR images of the right manus in a dog are shown in Figure 1.
manus extending from the base of the proximal phalanges of digits III and IV to the distal carpal bones were matched with corresponding anatomic sections (Figure 1). Features in the transverse CT and MR images that corresponded to clinically important anatomic structures in tissue sections were identified (Figures 2–8).

Sagittal CT reconstructions and MR images of the manus were obtained at a level through metacarpal bone II and digit II; these images included the entire portion of the forelimb distal to the middle carpal joint. The sagittal images were matched with a corresponding anatomic section (Figure 9). A dorsal MR image of each manus was obtained at a level through the middle portion of the manus; these images included the entire portion of the forelimb distal to the middle carpal joint. The dorsal image was matched with a corresponding anatomic section (Figure 10). Features in these CT and MR images that corresponded to clinically important anatomic structures in tissue sections were also identified.

Most osseous structures were easily identified in both CT and MR images. All bones, including the sesamoid bones, were visible in CT images as markedly hyperattenuating structures, compared with surrounding soft tissues. Cortical bone in MR images was identified as a structure with minimal to no signal. The carpal bones, metacarpal bones, and phalanges were easily identified by use of MR imaging. The proximal sesamoid bones and the sesamoid bone in the abductor pollicis longus tendon were also identified in MR images. However, the dorsal sesamoid bones were distinctly visible only in sagittal planar images and were not identified in the transverse planar images.

The interosseous muscles II through V, abductor digitii V muscle, and special muscles of the first digit were identified by use of CT and MR imaging. However, definitive fascial boundaries between these muscles were generally not seen in images obtained by use of either technique. The adductor digitii II and adductor digitii V muscles were difficult to detect because of their close proximity to the interosseous muscles, but were visible in CT images (Figures 6 and 7) when they were surrounded by less attenuating tissue (likely fat). The other, smaller muscles of the manus, including the interflexorii, flexor digitorum brevis, lumbricales, and flexor digitii V muscles, were not identified by use of either technique because of their small size and the limited spatial resolution of the imaging techniques. Likewise, the individual muscle bellies of the 3 special muscles of digit I could not be resolved in images.

On examination of CT and MR images, the superficial digital flexor, deep digital flexor, common digi-
Figure 3—Representative transverse CT and MR images and anatomic section of the right manus of a cadaveric dog obtained at level 3 in Figure 1. Note that the deep digital flexor tendons (12) are superficial to the superficial digital flexor tendons (44) distal to the manica flexoria (22). See Figure 2 and Appendix for key.

Figure 4—Representative transverse CT and MR images and anatomic section of the right manus of a cadaveric dog obtained at level 4 in Figure 1. See Figure 2 and Appendix for key.
Figure 5—Representative transverse CT and MR images and anatomic section of the right manus of a cadaveric dog obtained at level 5 in Figure 1. See Figure 2 and Appendix for key.

Figure 6—Representative transverse CT and MR images and anatomic section of the right manus of a cadaveric dog obtained at level 6 in Figure 1. See Figure 2 and Appendix for key.
Figure 7—Representative transverse CT and MR images and anatomic section of the right manus of a cadaveric dog obtained at level 7 in Figure 1. See Figure 2 and Appendix for key.

Figure 8—Representative transverse CT and MR images and anatomic section of the right manus of a cadaveric dog obtained at level 8 in Figure 1. See Figure 2 and Appendix for key.
tal extensor, and lateral digital extensor tendons were identified throughout most of their length in the manus. These structures appeared as ovoid structures that were slightly hyperattenuating, compared with the surrounding soft tissues in CT images, and markedly hypointense, compared with the surrounding soft tissues on MR images.

Few vessels were visible in images obtained by use of either imaging technique. Palmar common digital artery III was identified in the distal portion of the manus at the level of the metacarpal pad with both CT and MR imaging, where it is surrounded by sufficient fat to provide contrast. Although other palmar common digital arteries, the palmar interosseous artery, and the median artery were identified in more proximal anatomic sections, these were not visible by use of CT or MR imaging.

Visibility of structures was similar on T1-weighted spin-echo images and gradient-echo images. Gradient-echo images produced sharper margins of many structures, which in some instances helped differentiate these structures from the background tissues. However, this mild increase in visibility was generally offset by the apparent increase in anatomic complexity caused by the increased number of margins (eg, fascial boundaries) seen in gradient-echo images.

Discussion

Lameness, swelling, or signs of pain that are localized to the manus in dogs can be attributed to trauma, infection or inflammation, foreign body retention, or neoplasia. Radiography of the manus is generally indicated initially when disease is suspected, but is often of limited use because of the superimposition of multiple osseous structures and the minimal information that can be obtained regarding the soft tissues. Additionally, foreign bodies embedded in the distal limbs are commonly composed of plant material and are generally not visible radiographically. For this reason, further evaluation of the manus with other imaging techniques such as CT is indicated when an embedded foreign object is suspected.

Computed tomography and MR imaging can also be beneficial for more detailed evaluation of disease processes that may be detectable radiographically. In dogs and cats, injuries to the feet are relatively common, and surgical planning requires an understanding of the extent of disease, including bone, ligament, and tendon involvement. Although fractures and soft tissue swelling can be identified by use of radiography, sectional imaging allows a more thorough assessment of osseous and soft tissue structures and can also be used to identify sites of infection. Imaging of the distal portion of a limb is also indicated in dogs with a digit mass; in 1 study of 117 dogs, 76 of 124 (61%) digit masses were malignant neoplasms. Both CT and
MR imaging can be used to evaluate the extent of a mass,10,17 which is necessary for planning a surgical approach. Because the use of cross-sectional imaging for complete evaluation of the manus in dogs is expanding, it is critical to understand the complex anatomic structures within the canine manus in multiple planes. However, although detailed descriptions of the general anatomic features of the canine manus are available,18 cross-sectional depictions of those features have been limited in their scope.8

Computed tomography or MR imaging can be used to eliminate the diagnostic difficulties associated with superimposition of tissues in radiographic views. Although the spatial resolution achieved by use of CT or MR imaging is inferior to that of radiography, the contrast resolution of either cross-sectional imaging technique is superior to that of radiography.19 This is especially true with regard to the soft tissue contrast resolution associated with MR imaging. In the present study, details of osseous structures were more easily identified by use of CT, especially when viewed in an appropriate bone window. Cortical bone has low to no signal on MR imaging,20 so subtle structural abnormalities can be more difficult to detect. However, compared with the use of CT, soft tissue structures were more readily differentiated by use of MR imaging. For example, the low-signal tendons were more easily distinguished from the higher-intensity muscle bellies in MR images, whereas all of those structures were highly similar in their attenuation characteristics in CT images. The improved soft tissue contrast resolution of MR imaging relative to that achieved by use of CT is also important in disease detection and management because characterization and extent of pathological changes in soft tissues are often more readily determined by use of MR imaging than by use of CT.14,16,17,21

In the present study, the difficulties in identifying the dorsal sesamoid bones in the transverse MR images of the manus were related in part to the spatial resolution and slice thickness used with this technique. Because improving the spatial resolution of MR imaging leads to a more apparent decrease in signal-to-noise ratio than is identified with spatial resolution improvements in CT,19 a smaller matrix and thicker slices were used for MR imaging, compared with settings for CT. Because of this, the ability to resolve smaller structures such as the sesamoid bones by use of MR imaging was diminished because the signal characteristics of small structures were more likely to be averaged with those of adjacent tissues (ie, partial volume averaging artifact). Additionally, tendons and cortical bone have very low signal intensities in MR images20; thus, there is minimal contrast between sesamoid bones and the tendons that contain them.

The difficulty in identifying vessels with CT and MR imaging was likely a function of both spatial resolution and contrast resolution. In CT images, the vessels have attenuation characteristics similar to that of muscle; hence, in the present study, the palmar common digital artery III was visible only when it was surrounded by fat. Additionally, the vessels in the manus are small, and the matrix size chosen in our CT protocols may not have been sufficient to allow differentiation of most vascular structures from the surrounding tissues.

Results of the present study indicated that both CT and MR imaging are useful for thorough evaluation of the manus of dogs; most clinically important structures in the canine manus can be detected by use of either imaging technique. It is anticipated that the information provided in this report will be useful in clinical settings.

Appendix
Anatomic structures in the right manus of dogs and assigned numbers that correspond to structures identified in Figures 2 through 10.

1 = Abductor digitii V muscle
2 = Abductor digitii II muscle
3 = Adductor pollicis brevis, adductor pollicis, and flexor pollicis brevis muscles
4 = Adductor pollicis longus tendon
5 = Adductor digitii V muscle
6 = Carpal bone I
7 = Carpal bone II
8 = Carpal bone III
9 = Carpal bone IV
10 = Carpal pad
11 = Common digital extensor tendon
12 = Deep digital flexor tendon
13 = Digital pad
14 = Distal interphalangeal joint
15 = Distal phalanx I
16 = Distal phalanx II
17 = Dorsal sesamoid bone
18 = Extensor carpi radialis tendon
19 = Interosseous muscle
20 = Intertendinous ligament
21 = Lateral digital extensor tendon
22 = Manica flexoria
23 = Median artery
24 = Metacarpal I
25 = Metacarpal II
26 = Metacarpal III
27 = Metacarpal IV
28 = Metacarpal V
29 = Metacarpal pad
30 = Metacarpophalangeal joint
31 = Middle phalanx II
32 = Palmar common digital artery II
33 = Palmar common digital artery
34 = Palmar common digital artery IV
35 = Palmar (caudal) interosseous artery
36 = Proximal digital annular ligament
37 = Proximal interphalangeal joint
38 = Proximal phalanx II
39 = Proximal phalanx III
40 = Proximal phalanx IV
41 = Proximal phalanx V
42 = Proximal sesamoid bone
43 = Sesamoid in abductor pollicis longus tendon
44 = Superficial digital flexor tendon
45 = Ulnaris lateralis tendon
References


