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)

In dogs, the manus and pes are sites in which disease frequently develops, and common pathological conditions of the foot include trauma, infection, and neoplasia.1–5 Because surgical exploration is required for many of these conditions, identification of the precise location of the affected tissues is of critical importance. This is especially true in the case of penetrating foreign objects because the foreign body may migrate and result in development of a draining tract distant from the original site of insertion. In a study6 of 23 dogs and 2 cats, the mean number of surgical procedures for treatment of a draining tract that patients underwent prior to evaluation at a referral hospital was 2. It has been reported that the mean duration of clinical signs in dogs with draining tracts prior to referral is approximately 10 months,6 and the mean period of retention of a foreign body in a human hand is 7 months.7 In general, accurate localization of pathological changes contributes to minimization of patient morbidity; to detect diseases of the manus in small animals, several imaging modalities have been used. With the increasing availability of cross-sectional imaging techniques (eg, CT and MR imaging) in veterinary medicine, their use in diagnosis and treatment of dogs with injury or disease of the manus is becoming more widespread.

To effectively use CT and MR imaging for detection of pathological changes in the manus of dogs, one must have a thorough understanding of the CT and MR imaging appearance of the soft tissue and osseous structures of this region in limbs without disease. However, to the authors’ knowledge, there is only 1 publica-
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 extending from the base of the proximal phalan
ges 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 struc
tures 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 correspond-
ing 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 correspond-
ing anatomic section (Figure 10). Features in these CT
and MR images that corresponded to clinically impor-
tant anatomic structures in tissue sections were also
identified.

Most osseous structures were easily identified in
both CT and MR images. All bones, including the ses-
amoid bones, were visible in CT images as markedly
hyperattenuating structures, compared with surround-
ing soft tissues. Cortical bone in MR images was iden-
tified 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 abduc-
tor pollicis longus tendon were also identified in MR
images. However, the dorsal sesamoid bones were dis-
tinctly visible only in sagittal planar images and were
not identified in the transverse planar images.

The interosseous muscles II through V, abductor
digiti V muscle, and special muscles of the first digit
were identified by use of CT and MR imaging. How-
ever, definitive fascial boundaries between these mus-
cles were generally not seen in images obtained by use
of either technique. The adductor digitii II and adduc-
tor 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 su-
perficial digital flexor, deep digital flexor, common digi-

Figure 2—Representative transverse CT (A [obtained by use of a soft tissue window] and B [obtained by use of a bone window]) and
T1-weighted MR (C) images and photograph of the corresponding anatomic section (D) of the right manus obtained at level 2 in Figure 1.
In these transverse images, the lateral aspect of the limb is to the left and the dorsal aspect of the limb is at the
top of the image. Notice that the trilobed structure of the metacarpal pad (29) is not apparent in panel D because the section was cut in a slightly more distal position through the pad relative to the image levels in panels A through C. See Appendix for identification of
anatomic structures.
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.
talar 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

![Figure 9](image1.png)  ![Figure 10](image2.png)

Figure 9—Representative sagittal CT and MR images and anatomic section of the right manus of a cadaveric dog. In these sagittal images, the dorsal aspect of the limb is to the left and the proximal portion is at the top of the image. See Figure 2 and Appendix for key.

Figure 10—Representative dorsal T1-weighted MR image (A) and photograph of the corresponding anatomic section (B) of the right manus of a cadaveric dog. In these dorsal images, the lateral aspect of the limb is to the left and the proximal portion is at the top of the image. See Appendix for key.
MR imaging can be used to evaluate the extent of a mass, 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, cross-sectional depictions of those features have been limited in their scope.

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. 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, 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.

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


