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Computed Tomography and Cross-sectional Anatomy of the Normal Dromedary Camel Tarsus (One Humped Camel)

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Summary

The purpose of this study was to provide a detailed computed tomographic (CT) anatomic reference for the dromedary camel tarsus. Six cadaver pelvic limbs, obtained from three clinically and radiographically sound dromedary camels, were scanned in both soft tissue and bone windows starting from the calcaneal tuber towards the proximal metatarsus. Limbs were frozen at −20°C and sectioned transversely via an electric bone saw. The CT images were evaluated and correlated with their corresponding cryosections. The resulting images provided detailed anatomic features for bones, joints and soft tissue components of the tarsus and are intended to serve as a basic reference for the CT scanning of the dromedary camel tarsal pathology.

Introduction

The tarsus is an anatomically complex region with many joints, ligaments and tendons (Smuts and Bezuidenhout, 1987) and is considered an important source of hind limb lameness (Ehlert et al., 2011; Raes et al., 2011). A satisfactory diagnosis of most orthopaedic problems can usually be achieved with the combination of a standardized lameness examination and a judicious choice of radiography and ultrasonography (O’Callaghan, 1991). Inconclusive or incomplete findings on radiography or ultrasonography require the use of additional imaging modalities that may be useful in defining the anatomic origin of lameness, which is clinically localized at the tarsus (Van der Vekens et al., 2011). In those instances, computed tomography (CT) can be a valuable complement (Peterson and Bowman, 1988; Hanson et al., 1996; Whitton et al., 1998; Puchalski, 2007). Computed tomography allows cross-sectional imaging without bone and soft tissue overlap. Furthermore, three-dimensional rendering of the area of interest and multiplanar reformatting can yield better anatomic orientation of the area of interest and provide for more sensitive detection and characterization of disease extension (Tucker and Sande, 2001; Bienert and Stadler, 2006). Computed tomography has proved to be useful in the evaluation of stress-induced bone remodel-

Materials and Methods

Six cadaver pelvic limbs were obtained from three adult dromedary camels euthanized for reasons unrelated to musculoskeletal disorders. Camels were one male and two females. Their age was four, eight and fourteen years,
respectively. Limbs were disarticulated at the stifle joint and wrapped at their stumps with plastic sheath to prevent contamination of the working area. Tarsi of each camel were radiographically evaluated in dorsoplantar 0°, lateromedial 90°, dorsolateral-plantaromedial oblique 45° and plantarolateral-dorsomedial oblique 135° views prior to examination to ensure that no radiographic abnormalities were present.

The CT examination of the tarsal joint was performed within 4 h after camels were euthanatized. The limbs were extended and placed within the CT scanner (Philips Mx8000 IDT 16 CT Scanner; Philips, GmbH, Hamburg, Germany). A scout image (120 kV and 50 mA) was obtained for use in planning image acquisitions to ensure symmetry in positioning and inclusion of the entire region of interest. The limbs were scanned in helical fashion in a proximal to distal direction (starting at a level proximal to the calcanean tuber and continuing distally into the proximal metatarsus). The acquisition settings were for soft tissue (window width = 350, level = 60), bone (width = 2000, level = 500), slice thickness of 1 mm and matrix size of 512. Slices were reviewed for normal anatomic features, including bones, joints and various soft tissue components of the tarsus. Afterwards, tarsi were frozen at −20°C and sectioned transversely by means of an electric bone saw. Sections began strictly following the imaging protocol (beginning from the calcaneal tuber towards the proximal metatarsus). Each slice was rinsed with water, numbered and photographed. The anatomic structures were identified on the cadaver sections and subsequently correlated to the analogous structures on the corresponding CT slices.

Results

In this study, the reference CT images were selected as being representative for the main anatomic structures in conjunction with their corresponding anatomic sections. The images were formatted as labelled sequential triples of two CT images, that is, soft tissue window (a) and bone window (b) and their corresponding cryosection (c). Each image incorporated a directional compass indicating the image orientation and a reconstructed scout image representing the level of the transverse slice (Figs 1–10).

By use of the bone window settings, all bone structures including tibial cochlea, calcaneus, talus with its trochlear ridges, central tarsal bone, fourth tarsal bone, first tarsal bone, fused second and third tarsal bone and the proximal extremity of the metatarsus were seen on the transverse CT images (Figs 1–10). The tarsal bones had smooth outline and homogenous contours. The trochlear ridges of the talus, the intermediate ridge of the tibia, malleolar bone, articular cartilage and the inter-tarsal transverse bone relations could be evaluated throughout the bone window images. The entire images had excellent delineation between the cortex and medulla of the bones, and the trabecular pattern of the cancellous bone was clearly depicted.

By use of the soft tissue window settings, the soft tissue structures could be evaluated and showed variable shades of grey, the synovial fluid being the lowest attenuated structure. The tendons of fibularis tertius, long digital extensor and cranial tibial muscles were recognized as more or less oval hyperattenuated tendinous structures dorsal to the distal aspect of tibia (Figs 1–4), talus (Figs
5–7) and central and fourth tarsal bones (Fig. 8). The tendons of fibularis longus and lateral digital extensor muscles appeared as well-defined ovoid structures lateral to the distal aspect of the tibia (Fig. 1–4). The common tendon of the caudal tibial and lateral digital flexor muscles and the medial digital flexor tendon were evaluated on the medioplantar aspect of the tarsus as oval hyperattenuated tendinous structures (Figs 1–7) until they united at the distal third of the tarsus (Fig. 8) to form the deep digital flexor tendon (Figs 9 and 10). At the level of the calcanean tuber, the distal portion of the gastrocnemius muscle tendons (tendons of lateral and medial heads) was seen as a heterogeneous structure surrounded by the superficial digital flexor tendon (SDFT) with its lateral and medial retinaculum (Fig. 1). The SDFT was evident as a well-defined linear structure just under the skin and plantar to the calcaneus (Figs 2–4). At the middle third of the tarsus, the SDFT was recognized as a well-defined ovoid structure with rounded edges (Figs 5 and 6). At the distal third of the tarsus, it was seen as an oval structure enclosed by the medial limb of the long plantar ligament (Figs 7 and 8) and encircled by the tarsal sheath at the level of the tarsometatarsal joint (Figs 9 and 10). Each of the tarsal tendons was surrounded by a hypoattenuated rim representing its tendon sheath. The lateral and medial limbs of the long plantar ligament were seen on the plantar aspect of the tarsus and dorsal to the SDFT. The lateral limb of the plantar ligament was oval in shape while
the medial limb appeared as a crescent to enclose the SDFT (Figs 7 and 8). The tarsal collateral ligaments consisted of short and long lateral collateral ligaments and short and long medial collateral ligaments. The tarsal collateral ligaments as well as the inter- and intratarsal ligaments were recognized as hyperattenuated structures. The tarsal fascia, synovial fluid, subtendinous bursae and bone marrow were evident as hypoattenuated structures. The blood vessels and nerves were well recognized throughout the soft tissue window images.

**Discussion**

Since its introduction, computed tomography (CT) has revolutionized veterinary medicine and currently plays a prominent role in the diagnosis and evaluation of many orthopaedic diseases (Ohlerth and Scharf, 2007), as CT scanners are now routinely used in veterinary schools and in some private veterinary practices. In addition, an ever-increasing number of clinical reports involving CT assessment of animal diseases is appearing in the literature (Smallwood et al., 2002; Puchalski, 2007).

In the present study, images were obtained with multislice CT scanner that has high-contrast spatial resolution and consequently better conspicuity of small structures. This high-quality images are attributed to the thin collimator (16 simultaneous slices at sub-millimetre collimator), high speed, decrease in noise and huge number of images generated at the same scanning time.

Computed tomography of the equine tarsal joint has shown promise as a clinically useful technique for the diagnosis of the joint injuries (Hanson et al., 1996;
Before computed tomography can reach its full potential as a diagnostic modality, a normal species-specific anatomic reference is needed (Smallwood et al., 2002). Therefore, the study presented here provided the first anatomic description of the dromedary camel tarsal joint via computed tomography in which the bony structures were clearly identified, as were the most clinically important soft tissue structures.

In the current study with window settings adjusted for bone, the entire images had excellent delineation between the cortex and medulla of the bones and the trabecular pattern of the cancellous bone was clearly depicted. All bone structures, including tibial cochlea, calcaneus, talus with its trochlear ridges, central tarsal bone, fourth tarsal bone, first tarsal bone, fused second and third tarsal bone and the proximal extremity of the metatarsus, were seen on the transverse CT images. The soft tissue window allowed identification of the most clinically important soft tissue structures including various tendons, ligaments and the joint capsules in the tarsal region. Similar findings were reported in equine (Vanderperren et al., 2008; Raes et al., 2011; Van der Vekens et al., 2011), bovine (Schwarze, 1998) and canine (Gielen et al., 2001).

In this study on the CT images, it was possible to identify and evaluate the common tendon of the caudal tibial and lateral digital flexor muscles and the medial digital flexor tendon during their course on the medial aspect of the tarsal joint, until they united in the distal third of the tarsal region forming the deep digital flexor tendon.
Fig. 8. Transverse CT images at the level indicated in the scout film. a, soft tissue window; b, bone window; c, corresponding cryosection; L, lateral; M, medial; D, dorsal; P, plantar.

Fig. 9. Transverse CT images at the level indicated in the scout film. a, soft tissue window; b, bone window; c, corresponding cryosection; L, lateral; M, medial; D, dorsal; P, plantar.

Fig. 10. Transverse CT images at the level indicated in the scout film. a, soft tissue window; b, bone window; c, corresponding cryosection; L, lateral; M, medial; D, dorsal; P, plantar.
The ligaments of the tarsal joint included short and long parts of the medial and lateral collateral ligaments, inter-osseous ligaments and the medial and lateral limbs of the long plantar ligament (Smuts and Bezuidenhout, 1987). Some parts of the collateral ligaments (particularly the long parts) and the long plantar ligament could be evaluated in horses via ultrasonography, but differentiation between the long and short parts of the collateral ligaments as well as the inter-osseous ligaments could not be evaluated via this technique (Dik, 1993; Whitcomb, 2006; Vilar et al., 2008). In our study, the subdivisions of the collateral ligaments as well as the inter-osseous ligaments were visible as reported in horse (Raes et al., 2011).

The tarsus is an anatomically complex region with numerous bony and soft tissue structures (Smuts and Bezuidenhout, 1987) so that it is highly susceptible to orthopaedic problems. Correct identification of the lesion is necessary to initiate an appropriate management. Multiple imaging modalities are often required to accurately identify these lesions especially in complex joints such as the tarsus. Radiography and/or ultrasonography are the first imaging modalities of choice when a bony or soft tissue injury is suspected (Raes et al., 2011). However, radiography provides little information on soft tissue structures and is hampered by the possibility of superimposition of many multifaceted bones, and the acute skeletal abnormalities may not be radiographically visible (Stover et al., 1986). Ultrasonography of the tarsus can be a valuable adjunct to radiography for evaluation of the surrounding soft tissues but it is limited to the bone surface and a small field of view (Whitcomb, 2006).

Compared with conventional radiography and ultrasonography, the main advantages of CT are the superior definition of anatomic structures, the detailed simultaneous bone and soft tissue visualization and the absence of superimposition, which permit a direct evaluation of small lesions inside a volume (Tucker and Sande, 2001). Computed tomography has provided early diagnosis of pathological changes that were not detected by conventional radiography and proved that CT is a good complementary imaging modality, as it enabled the identification of both the extent and exact location of the lesion that are the paramount factors for prognosis (Gielen et al., 2001; Raes et al., 2011). CT presents extreme ability to detect variations of bone density such as sclerosis and lysis of the subchondral bone as well as cancellous bone and the detection of subchondral bone cysts, stress fractures, enthesophytes and periosteal proliferative lesions (Tucker and Sande, 2001). The major disadvantages of CT are the need for general anaesthesia, the need for a dedicated table and the high purchase and maintenance costs (Kraft and Gavin, 2001).

In the current study, computed tomography allowed a full assessment of the dromedary camel tarsus and proved that CT is a valuable imaging technique for evaluation of both soft and bony structures. The images provided in this study can serve as a CT reference for the dromedary camel tarsus.

References


**Appendix**

1 Tendon of fibularis tertius muscle.

1’ Tendon of fibularis tertius muscle, medial part.

2 Tendon of long digital extensor muscle.

3 Tendon of cranial tibial muscle.

4 Tendon of long fibularis [peroneus] muscle.

5 Tendon of lateral digital extensor muscle.

6 Common tendon of lateral digital flexor muscle and caudal tibial muscle.

7 Tendon of medial digital flexor muscle.

8 Gastrocnemius muscle, tendon of lateral head.

8’ Gastrocnemius muscle, tendon of medial head.

9 Tendon of superficial digital flexor muscle.

9’ Superficial digital flexor tendon, lateral and medial insertion at calcanean tuber.

10 Deep bursa of calcanean tendon.

11 Short digital extensor muscle.

12 Common tendon of caudal tibial, lateral digital flexor and medial digital flexor muscles (deep digital flexor tendon).

13 Common tendon sheath of caudal tibial and lateral digital flexor tendons.

14 Tendon sheath of the adjacent muscles.

15 Subtendinous calcaneal bursa of superficial digital flexor muscle.

16 Articular cartilage.

17 Subtendinous bursa of the insertion of cranial tibial muscle.

18 Long lateral collateral tarsal ligament.

19 Long medial collateral tarsal ligament.

20 Long planter ligament.

20’ Long planter ligament, lateral part.

20” Long planter ligament, medial part.

21 Short plantar ligament connecting between the fourth tarsal bone, fused second and third tarsal bone and the metatarsal bone.

22 Short lateral collateral tarsal ligament.

22’ Short lateral collateral tarsal ligament, tibiotalar part.

22” Short lateral collateral tarsal ligament, calcaneometatarsal part.

23 Short medial collateral tarsal ligament, tibiotalar part.

23’ Short medial collateral tarsal ligament, tibiocalcanear part.

24 Short medial collateral tarsal ligament.

25 Common tendon sheath of fibularis tertius, cranial tibial and long digital extensor muscle tendons.

26 Dorsal annular ligament (dorsal part of the retinaculum extensorum crurale).

27 Common tendon sheath of long fibularis muscle tendon and the lateral digital extensor muscle tendon.

28 Oblique dorsal ligament connecting the talus, calcaneus and fourth tarsal bone.

29 Inter-muscular septum.

30 Deep crural fascia.

31 Lateral annular ligament (lateral part of the retinaculum extensorum crurale).

32 Short transverse ligament connecting the central tarsal bone with the fourth tarsal bone.

33 Intratarsal ligament.

34 Short dorsal ligament connecting between the fourth tarsal bone, fused second and third tarsal bone and the metatarsal bone.

35 Plantar recess of tarsocrural joint.

36 Tarsal sheath.

37 Dorsal recess of tarsocrural joint.

38 Dorsolateral recess of tarsocrural joint.
39 Joint capsule.
40 Cutis.
41 Subcutis.
A Tibia, compact bone.
A1 Tibia, bone marrow.
A2 Tibia, cancellous bone.
A3 Tibia, cranial end of cochlea.
A4 Cranial aspect of the intermediate ridge of tibial cochlea.
A5 Caudal aspect of the intermediate ridge of tibial cochlea.
B Calcaneus, cortical bone.
B1 Calcaneus, cancellous bone.
B2 Calcaneus, bone marrow.
B3 Apophyseal growth line of the calcaneus.
B4 Calcaneus, distal end of the medullary cavity.
B5 Calcaneal tuber.
C Talus.
C1 Talus, body.
C2 Talus, cancellous bone.
C3 Talus, sustentaculum.
C4 Talus, cortical bone.
C5 Talus, lateral trochlear ridge.
C6 Talus, medial trochlear ridge.
C7 Talus, bone marrow.
D Malleolar bone.
E Central tarsal bone, cancellous bone.
E1 Central tarsal bone, cortical bone.
F Fused second and third tarsal bone, cortical bone.
F1 Fused second and third tarsal bone, cancellous bone.
G First tarsal bone.
H Fourth tarsal bone, cancellous bone.
H1 Fourth tarsal bone, cortical bone.
H2 Fourth tarsal bone, bone marrow.
J Third metatarsal bone, cancellous bone.
J1 Third metatarsal bone, cortical bone.
K Fourth metatarsal bone, cancellous bone.
K1 Fourth metatarsal bone, cortical bone.
a Superficial fibular nerve.
b Deep fibular nerve.
c Tibial nerve.
d Lateral plantar nerve.
e Medial plantar nerve.
e' Medial plantar artery and vein.
f Caudal cutaneous sural nerve.
g Lateral saphenous vein, cranial branch.
h Cranial tibial artery and vein.
j Cranial tibial artery.
k Cranial tibial vein.
l Saphenous artery and medial saphenous vein, caudal branches.
m Caudal branch of saphenous artery, medial malleolar branches.
n Saphenous artery, calcaneal branches of caudal branch.
o Lateral saphenous vein, caudal branch.
p Medial saphenous vein, caudal branch.
q Saphenous artery, caudal branch.
r Dorsal pedal artery and vein.
s Dorsal pedal artery.
t Dorsal pedal vein.