Radiography, ultrasonography and computed tomography of the dromedary camel tarsus
(One humped camel)

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This work is financially supported by the Arab Republic of Egypt
For my parents and my family
Contents

Contents ....................................................................................................................................... I

List of Abbreviations............................................................................................................... II

1 Introduction and literature ................................................................................................. 1

2 Results
   2.1 Publication 1: Computed tomography and cross-sectional anatomy of the normal dromedary camel tarsus (One humped camel) ................................................................. 7
   
   2.2 Publication 2: Normal radiographic and ultrasonographic appearance of the adult dromedary camel tarsus (One humped camel) ................................................................. 17

3 Discussion ............................................................................................................................... 47

4 Summary ................................................................................................................................. 52

5 Zusammenfassung ................................................................................................................. 53

6 References ............................................................................................................................... 55

7 Acknowledgement .................................................................................................................. 63
**List of Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>Computed Tomography</td>
</tr>
<tr>
<td>DDFT</td>
<td>Deep Digital Flexor Tendon</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<tr>
<td>SDFT</td>
<td>Superficial Digital Flexor Tendon</td>
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<td>US</td>
<td>Ultrasonography</td>
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1 Introduction and Literature

The camel is an even-toed ungulate within the genus Camelus, bearing distinctive fatty deposits known as humps on its back. Camelids, in comparison to other domestic and farm animals, were little scientifically studied. However, recently scientific working groups increasingly begun to recognize and intensely be aware of the importance of these species (FINKE 2005).

The camelids, in zoological taxonomy, are classified in the suborder Tylopoda (pad footed animals) that represents with the suborders Suiformes (pig-like) and Ruminantia (ruminants) and the order Artiodactyla (even-toed ungulates). Thus, camelids (family Camelidae) as ruminating animals are classified in proximity to ruminants but developed in parallel and are not part of the suborder Ruminantia. Some differences as foot anatomy, stomach system and the absence of horns underline this fact (FOWLER 1998; SCHWARTZ and DIOLI 1992).

The family Camelidae is divided into two genera; the old world camels (genus Camelus) and the new world camels (genus Lama) (WILSON and REEDER 2005). Two domesticated species of old world camels exist, the dromedary or one humped camel (Camelus dromedarius), known as Arabic camel, that has its distribution in the hot deserts of Africa and Asia and the Bactrian or two-humped camel (Camelus bactrianus) that can be found in the cold deserts and dry steppes of Asia (SCHWARTZ and DIOLI 1992; TEKA 1991; WILSON and REEDER 2005; WILSON 1984).

Camels play an important socio-economic role within the pastoral and agricultural system in dry and semi dry zones of Asia and Africa. The camel possesses unique qualities which make it superior to other domesticated animals in the hot and arid desert ecosystems (SCHWARTZ and DIOLI 1992). Camels can graze on low productive pastures on which the production of milk is possible and economically profitable. For this reason, camels may reduce the dependence of pastoralists on other livestock that is usually much more vulnerable to drought than camels (FARAH et al. 2004). His adaptation to the hot and dry desert climate led to intensive use by nomadic Bedouins to transport, as a
source of food and companion animals. The camel milk is one of the most valuable food resources for nomads in arid regions and increases the income of pastoralists. Camel milk possesses superior storage life in comparison to cow milk due to its high content of proteins having inhibitory effect on bacteria (FARAH et al. 2004). It was confirmed that camel milk has special medicinal properties, especially for dropsy, jaundice and conditions affecting the lungs and spleen (SEIFUA 2007).

Besides milk, meat is one of the most important products of camels. It compares favorably with other livestock in yield and quality of the carcasses but camels are still not systemically bred for meat production in many regions as camels are considered too valuable for this production type. Other important products are the camel wool and leather. The camel wool is one of the world’s most expensive natural animal fibers (WERNERY 2003) while, the camel leather industry was better valorized in relationship with the touristic activities (FOWLER 1998; KURTU 2004; SALTIN and ROSE 1994; SCHWARTZ and DIOLI 1992; TEKA 1991; WERNERY 2003; WERNERY and WERNERY 2000; YAQOOB and NAWAZ 2007).

The Camel today finds its distribution in the arid and semiarid desert and steppe regions of the world. According to an estimate of the FAO in 2005, the total population of camels in the world accounts for approximately 21.1 million. Of these, more than 90% are dromedaries, with approximately 15.4 million animals having their highest penetration rates in Africa. Other areas of distribution of the humped camels are the Middle East, parts of Central Asia, and Australia (GERLACH 2008).

In the Gulf region the economic value of the dromedary camel has increased due to the use of camels in sports and competition (WERNERY and KAADEN 1995). Today, camel races and beauty shows are held regularly in the Gulf region where camels worth a fortune especially for the winning camels. Due to the high economic value of camels in such regions, efforts are exerted to increase their productivity through proper management and medical care. Lameness of the camel hind limb is most frequently encountered in the tarsal region due to the nature of the laying behavior of the camel (KASSAB 2008). Also, the use of camels in races played an important role in increasing the chances of musculoskeletal disorders of the camel locomotor system and especially the tarsal joint due to its complex
anatomical nature. The camel tarsus is a composite joint consists of numerous multifaceted bones, different joints, multiple ligaments, tendons and bursae (SMUTS and BEZUIDENHOUT 1987) and therefore imaging this region can be a challenge.

Diagnostic imaging is a fundamental part of the evaluation of the lame patient. The indications for diagnostic imaging include the confirmation or refute of a clinically suspected lesion, to suggest or document the site of a suspected lesion, to characterize the nature and extent of a known or suspected lesion, to follow the progression of disease or healing, to aid in establishing prognosis, to plan or evaluate surgical therapies, to suggest or guide additional diagnostic procedures, and to screen for diseases with obscure clinical signs (SUTER 1984). Diagnostic imaging is not, however, intended to serve as a shortcut to diagnosis or to take precedence over a thorough physical examination. Imaging provides the basis for establishing diagnosis from which the final diagnosis can be determined with discrimination. Radiography and ultrasonography are the most common techniques used for diagnosing equine tarsal injuries (VANDERPERREN et al. 2009a).

Radiography remains the primary diagnostic imaging technique for the evaluation of the musculoskeletal disorders. After localization of lameness by means of physical examination, survey radiographs can quickly and accurately provide morphologic characterization of bone and soft tissue abnormalities which concurrently lead to formation of a definitive or differential diagnosis. It can also delineate the nature and extent of involvement and define the extent of the lesion. Imaging of the complex tarsal region is a challenge. Radiography is effective for the evaluation of bony structures, but the fact that a three-dimensional structure is projected onto a two-dimensional plate leads to the major disadvantage of a superimposition of bony structures and lack of differentiation of soft tissues (KRAFT and GAVIN 2001; LATORRE et al. 2006; PARK et al. 1987).

Ultrasonography (US) of the tarsus can be a valuable adjunct to radiography for the evaluation of the surrounding soft tissues in addition to a limited area of bone surface. When soft tissue trauma is suspected, it is the modality of choice for initial assessment of those structures (DIK 1993; KINNS and NELSON 2010; RAES et al. 2010; VILAR et al. 2008; WRIGHT und MINSHALL 2012). In addition to evaluation of tendons and ligaments, ultrasonography can be useful in evaluating the amount and nature of joint fluid
as well as the thickness of the synovium and articular cartilage and in localizing peri-articular mineralization (DENOIX 2000; EDINGER 2010; REDDING 2001; SMITH and SMITH 2008). Although ultrasonography is unable to visualize structures beyond the bone surface, it can provide an accurate evaluation of the periosteum, soft tissue tumors invading bone and, in some instances, fractures and sequestration (RASERA et al. 2007; REEF 1998; WITTOEK et al. 2010).

Inconclusive or incomplete findings on radiography or US 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 (HANSON et al. 1996; PETERSON and BOWMAN 1988; PUCHALSKI 2007; VAN DER VEKENS et al. 2011; WHITTON et al. 1998).


Skeletal computed tomography may be helpful in clinical cases in which standard radiography is negative or inconclusive and there is a high suspicion of osseous pathology.
It is highly sensitive in detecting differences in bone density, thus, osteolysis and osteogenesis could be detected very early before it could be detected by the conventional radiography (FURST et al. 2008). CT has proved to be useful in the evaluation of stress-induced bone remodeling, focal bone lesions, defining complex intra-articular fractures, subchondral bone sclerosis and other subchondral bone lesions such as osteochondritis dissecans of the talus, and preoperative planning for fracture repair (GIELEN et al. 2001). CT technology can reach its full potential as an effective diagnostic modality when a normal species specific cross-sectional anatomic reference is provided.

The selection of the appropriate diagnostic imaging study is determined by the anatomic structure to be evaluated and the type of information sought. With the advent of newer imaging modalities, anatomic and functional information about the musculoskeletal system can be determined with increasing diagnostic accuracy and anatomic resolution. The demand for advanced diagnostic imaging procedures has increased dramatically. Veterinarians seeking to improve their diagnostic capabilities and clients willing to pursue have driven this demand, resulting in the installation of advanced imaging facilities at most academic and private referral practices. Knowledge of the potential benefits of various imaging modalities allows veterinarians to optimize their use of diagnostic imaging in their own practice or in a referral practice.

The normal ultrasonographic appearance of the tarsus has been reported in equine (DIK 1993; METTENLEITER 1992; VALENTINI et al. 2005; VILAR et al. 2008; WHITCOMB 2006), bovine (FLURY 1996), and canine (CAINE et al. 2009) but has not been reported in dromedary camel yet. Computed tomographic anatomy of tarsus has been studied in horse (RAES et al. 2011; TOMLINSON et al. 2003), bovine (SCHWARZE 1998), and canine (GIELEN et al. 2001) but until now a reference for the normal transverse computed tomographic anatomy of the dromedary camel tarsus has not been described. Therefore, the objective of this study was:

1- To provide a detailed CT reference of the dromedary camel tarsal joint via comparison of computed tomographic images with gross specimens (first publication).
2- To depict the radiographic and ultrasonographic anatomical appearance of the bony and soft tissue structures of the dromedary camel tarsus to develop an optimal technique for examination of these structures to serve as a reference for evaluation of tarsal pathology (second publication).
2 Results

2.1 Publication 1: Computed tomography and cross-sectional anatomy of the normal dromedary camel tarsus (One humped camel)

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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 remodeling, focal bone lesions, defining complex intra-articular fractures, subchondral bone sclerosis and other subchondral bone lesions such as osteochondritis dissecans of the talus and preoperative planning for fracture repair (Gielen et al., 2001).

CT technology can reach its full potential as an effective diagnostic modality when a normal species-specific cross-sectional anatomic reference is provided. CT anatomy of tarsus has been studied in horse (Tomlinson et al., 2003; Raes et al., 2011), bovine (Schwarze, 1998) and canine (Gielen et al., 2001), and recently, CT and cross-sectional anatomy of the metatarsus and digits of the dromedary camel have been documented in detail (El-Shafey and Kassab, 2012), but until now a reference for the normal transverse CT anatomy of the dromedary camel tarsus has not been reported. Therefore, the objective of this study was to provide a detailed CT reference of the dromedary camel tarsal joint via comparison of CT images with gross specimens.

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 calcanean 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 (SDFT) (Figs 9 and 10). At the level of the calcaneal 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 plan- tar aspect of the tarsus and dorsal to the SDFT. The lateral limb of the plantar ligament was oval in shape while

Fig. 2. 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. 3. 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 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 periostal 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


8 Computed Tomography Anatomy Camel Tarsus

Appendix

1 Tendon of fibularis tertius muscle.

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 calcaneal tuber.

10 Deep bursa of calcaneal 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 plantar ligament.

20’ Long plantar ligament, lateral part.

20” Long plantar 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, tibiocalcaneal 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 tarsocruroal joint.

36 Tarsal sheath.

37 Dorsal recess of tarsocruroal joint.

38 Dorsolateral recess of tarsocruroal 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.
2.2 Publication 2: Normal radiographic and ultrasonographic appearance of the adult dromedary camel tarsus (One humped camel)

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Normal Radiographic and Ultrasonographic Appearance of the Adult Dromedary Camel Tarsus (One Humped Camel)

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With 15 figures

Summary

Six cadaver pelvic limbs were obtained from clinically sound dromedary camels and examined radiographically and ultrasonographically using a 7.5 MHz convex transducer. Radiographic examination was performed in dorsoplantar, lateromedial, dorsolateral-plantaromedial oblique and plantarolateral-dorsomedial oblique projections and the bony structures and articulations of the tarsal joint were outlined. The tarsus was ultrasonographically investigated in four planes (dorsal, medial, lateral and plantar) and each plane was scrutinized in four levels (calcaneal tuber, tibial malleoli, base of calcaneus and proximal end of metatarsus) in both transverse and longitudinal views. Limbs were examined grossly, frozen at -20°C and sectioned. Radiographic and ultrasonographic findings correlated well with the gross anatomy and frozen sections. The normal appearance of bony and soft structures of the tarsus described in this study provided basic reference data for ultrasonographic and radiographic investigations of tarsal disorders in the dromedary camel.
Introduction

The dromedary camel population all over the world is approximately 14 million live animals distributed mainly in the Horn of Africa, Middle East and South Asia (Al Haj and Al Kanhal, 2010). The camel plays a pivotal role in the life of the pastoral people, browse scanty vegetation and produce where other livestock species cannot survive (Schwarz, 1992). The camel has been used for milk and meat production as well as for draught and riding purposes. Today, camel races and beauty shows are held regularly in the Gulf region where camels may be worth a fortune which is especially the case for the winning camels.

The camel tarsus is a composite joint consisting of multiple articulations involving numerous soft and bony structures (Smuts and Bezuidenhout, 1987) and, similar to the equine tarsus (Raes et al., 2010), it is susceptible to a considerable incidence of pathology. Radiography and ultrasonography are the most common techniques used for diagnosing equine tarsal injuries (Vanderperren et al., 2009). Radiography remains the mainstay of equine musculoskeletal imaging due to its low cost, ready accessibility and global evaluation of bony structures. It is typically the first imaging modality employed when traumatic lesion of the tarsus is suspected (Kinns and Nelson, 2010).

Ultrasonography is the most cost effective imaging modality for evaluation of soft tissue injuries (Vanderperren et al., 2009), bone surface (Raes et al., 2010) as well as the articular cartilage of the equine tarsus (Tomlinson et al., 2000). It represents an excellent complementary technique to radiography in equine practice. On multiple joints it allows a good representation of ligaments, joint capsule, synovial membrane, synovial fluid, articular cartilage and subchondral bone (Denoix, 2009).

Lameness of the camel hind limb is common and most frequently encountered in the tarsal region due to the nature of the laying behavior in camel (Kassab, 2008). The aim of this study was to depict the radiographic and ultrasonographic anatomical appearance of the bony and soft structures of the dromedary camel tarsus to develop an optimal technique for
examination of these structures to serve as a reference for evaluation of tarsal pathology. This paper complements recently reported data on the use of cross-sectional anatomy of limb regions of domesticated camelids and bovines as a reference for identifying structures that can be visualized by novel medical imaging techniques (Ehlert et al., 2011; El-Shafey and Kassab, 2012; Hagag et al., 2012).

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. The limbs were disarticulated at the stifle joint and wrapped at their stumps with plastic sheets to prevent contamination of the working area.

The tarsal joints were radiographed in four projections, dorsoplantar 0º, lateromedial 90º, dorsolateral-plantaromedial oblique 45º and plantarolateral-dorsomedial oblique 145º views using a digital X-ray machine (Philips Digital X-ray Unit; Philips GmbH, Hamburg, Germany).

Prior to ultrasonographic examination, the hair was clipped from mid-tibia till the middle of the metatarsus with # 40 blades, the skin was washed with soap and water, saturated with alcohol, and acoustic coupling gel was applied. Echographic examination was performed with a real time ultrasound machine (Aloka, Pie Medical Equipment, Maastricht, Netherlands) equipped with a 7.5 MHz convex transducer.

The tarsus was ultrasonographically investigated in four planes (dorsal, medial, lateral and plantar) and each plane was scrutinized in four levels (calcaneal tuber, tibial malleoli, base of calcaneus and proximal end of metatarsus) in both transverse and longitudinal views. The position, echogenicity and degree of demarcation of the tendons and ligaments and the
appearance of the joint recesses were determined. On the dorsal plane of the tarsus, the fibularis tertius tendon, cranial tibial tendon (cunean tendon), long digital extensor tendon and the tarsocural (i.e. tibiotalar) joint capsule were evaluated. On the lateral aspect of the tarsus, the lateral digital extensor tendon, fibularis longus tendon and the lateral collateral ligaments were examined. The medial aspect of the tarsus included the medial digital flexor tendon, the tendon of the fused lateral digital flexor and caudal tibial muscle tendons, the medial collateral ligaments, and the cranial tibial muscle tendon (cunean tendon). The plantar aspect of the tarsus involved the superficial digital flexor tendon, the long plantar ligament, and the deep digital flexor tendon.

The radiographic examination of the camel tarsus was performed in approximately ten minutes, while the ultrasonographic investigation was completed in about twenty minutes. After examination two limbs were freshly dissected and examined macroscopically to define and recognize the location and relations of tendons, ligaments and joint capsules in the tarsal region. Another two limbs were frozen and sectioned in transverse and longitudinal anatomic sections of one centimeter thickness to be compared with the resulting images. The anatomical nomenclature is based on the Nomina Anatomica Veterinaria (Nomina Anatomica Veterinaria, 2005)

Results

Radiographic Examination:-

The bony structure of the tarsal region consisted of the distal extremity of the tibia, the tarsal bones (calcaneus, talus, central tarsal, first, fourth and fused second and third tarsal bones) and the proximal extremity of the fused third and fourth metatarsal bones. The radiographic examination was performed in the four classical projections.
Lateromedial view (LM, 90°)

In the normal LM view the plantar border of the fourth tarsal bone was projected slightly behind the central and first tarsal bones. The medial and lateral borders of the talus were smoothly curved and slightly flattened in the distal part of the talus. The joint spaces between the various articulations of the tarsal joint (tarsocrural, talocalcaneal, intratarsal and tarsometatarsal joints) could be assessed. The internal structures of the tarsal bones were uniform from dorsal to plantar with bone trabeculae perpendicular to the joint spaces (Fig. 1).

Dorsoplantar view (DP, 0°)

In the DP view, the articulation between the cochlea tibiae and the trochlea of the talus was best seen on this view (specially the articulation between the intermediate ridge of the cochlea and the trochlea of talus) and appeared smooth and sharply demarcated. The lateral malleolar bone (distal portion of fibula) projected slightly further than the lateral malleolus of the distal tibia and articulated proximally with the tibia, medially with the talus and distally with the calcaneus. The joint spaces between the tarsal bones could be clearly visualized (Fig. 2).

Dorsolateral - plantaromedial view (45°)

In this view, the 4th tarsal, central and fused 2nd and 3rd tarsal bones were outlined. The dorsomedial part of the intratarsal joint spaces, the medial trochlear ridge, the distomedial tuberosity of the talus and the distal intermediate ridge of the tibial cochlea as well as the medial malleolus could be evaluated (Fig. 3).

Plantarolateral – dorsomedial view (135°)
In this view the plantar aspect of the sustentaculum tali, the lateral trochlea of the talus, the dorsomedial aspects of the intratarsal joints and the 4th tarsal bone were outlined (Fig. 4).

**Ultrasonographic Examination:**

The levels of the ultrasonographic images of this study are shown in Fig. 5. The ultrasonographic images were selected as being representative for the main anatomic structures in conjunction with their corresponding anatomic sections. Each ultrasonographic image incorporated a directional compass indicating the orientation of both the ultrasonographic image and its corresponding cryosection.

**Dorsal approach:**

Structures evaluated dorsally included the fibularis tertius tendon, long digital extensor tendon, cranial tibial tendon (cunean tendon) and the tarsocrural (i.e. tibiotarsal) joint capsule. Other intratarsal and tarsometatarsal joint capsules could be evaluated with difficulty.

*Fibularis tertius muscle tendons*

The fibularis tertius tendon was a quite large, clearly defined, oval and homogenous echogenic structure with a parallel fiber pattern that appeared as long white echoes in the longitudinal view (Fig. 6) and as a uniform distribution of pin-point white echoes in the transverse view (Fig. 7). It extended over the dorsal aspect of the hock and bifurcated at the level of the tarsocrural joint into two primary tendons of insertion, i.e. dorsal and lateral branches. The former was thick and attached to the metatarsal tuberosity while the latter was thinner and crossed the tendon of the extensor digitorum longus muscle to attach to the fused second and third tarsal bone.

23
Long digital extensor muscle tendon

The long digital extensor tendon was dorsolaterally located and extended throughout the tarsal region. It could be identified by its oval shape and hyperechoic texture situated lateral to the fibularis tertius muscle tendon in transverse view (Fig. 7) and by its linear fiber pattern in longitudinal view (Fig. 8).

Cranial tibial muscle tendon

The cranial tibial tendon appeared as a more or less rounded echogenic structure in the transverse view (Fig. 9a) on the tarsal dorsum just proximal and medial to the bifurcation of the fibularis tertius tendon. The linear fibers of the tendon could be easily seen deeper to the skin surface in the longitudinal view (Fig. 9b). It passed medially to be inserted on the plantar aspect of first and fused second and third tarsal bones.

Tarsocrural joint

The tarsocrural joint capsule was easily imaged over the dorsomedial compartment of the tarsocrural joint (dorsomedial recess) just below the medial malleolus of the tibia and the synovial fluid was anechoic (Fig. 7). A little synovial fluid was detected in the plantaromedial and plantarolateral recesses of the tarsocrural joint. The articular cartilage of the medial and lateral trochlear ridges of the talus appeared as a hypoechoic band overlying the hyperechoic subchondral bone. The bone surfaces elsewhere in the tarsocrural joint and other intratarsal joints were seen as hyperechoic reflections beneath the soft tissue structures, with the occasional presence of anechoic synovial fluid.

Lateral approach
The lateral structures included the lateral digital extensor tendon, fibularis longus tendon and the lateral collateral ligaments.

Lateral digital extensor muscle tendon

The lateral digital extensor tendon passed in the groove of the lateral malleolus of the tibia together with the fibularis longus tendon continued on the lateral aspect of the tarsus and then passed to the dorsal surface of the metatarsus. It could be recognized as an elliptical echogenic structure in the transverse view (Fig. 10a) and by its linear echogenic fibers in the longitudinal view (Fig. 10b).

Fibularis longus muscle tendon

The fibularis longus tendon was oval and hypoechoic in the transverse view and had a linear fiber pattern in the longitudinal view (Fig. 11). It covered and crossed the tendon of the lateral digital extensor muscle in the groove on the lateral tibial malleolus, then coursed distally and plantarly in a groove on the fourth tarsal bone under cover of the lateral collateral ligament of the tarsal joint, and inserted on the first tarsal bone.

Lateral collateral ligaments

The lateral collateral ligaments included a superficial long and a deep short collateral ligament. The long superficial collateral ligament was an echogenic structure with densely packed coarse echogenic linear fibers in the longitudinal view (Fig. 12b). It could be evaluated from its origin from the caudolateral aspect of the lateral tibial malleolus and along its course till it inserted at the proximal end of the metatarsal bone. The short ligament consisted of two parts. Only one part of the short ligament which connected the
calcaneus and metatarsus was seen at its origin from the calcaneus (Fig. 12a); the other part connecting the tibia and calcaneus couldn’t be recognized.

**Medial approach**

Structures evaluated on the medial aspect of the tarsus included the medial digital flexor tendon, the tendon of the fused lateral digital flexor and caudal tibial muscle tendons, the medial collateral ligaments and the cranial tibial muscle tendon (cunean tendon).

**Medial digital flexor muscle tendon**

The tendon of insertion of the medial digital flexor muscle was imaged on the plantaromedial aspect of the distal third of the tibia and extended downward on the plantar aspect of the talus till it united with the tendon of the caudal tibial muscle at the level of the tarsometatarsal joint (Fig. 13).

**The caudal tibial muscle tendon**

The caudal tibial tendon was identified on the caudomedial aspect of the medial malleolus of tibia. It passed downward and backward till it united with the tendon of the medial digital extensor muscle at the planter aspect of the tarsometatarsal joint forming the deep digital flexor tendon. The latter passed to the plantar aspect of the metatarsus and was covered by the superficial digital flexor tendon (Fig. 13).

**The medial collateral ligaments**
The medial collateral ligaments included superficial long and deep short collateral ligaments similar to the lateral collateral counterparts. The short ligament consisted of two parts; one part connected the tibia and calcaneus, the other part connected the tibia and talus. Both parts of the short ligament were not recognized ultrasonographically. Only the long medial collateral ligament with its densely packed echogenic linear pattern was recognized (Fig. 14).

**Plantar approach**

The structures evaluated on the plantar aspect of the tarsus included the superficial digital flexor tendon, the long plantar ligament, and the deep digital flexor tendon. The superficial digital flexor tendon was the most superficial plantar structure in the tarsal region. It appeared as a moderately homogenous echogenic structure with long parallel fiber bundles that appeared as long white echoes in the longitudinal view (Fig. 15a) and as uniformly distributed pin-point white echoes in the transverse view (Fig. 15b).

The long plantar ligament was well developed and consisted of two (i.e. lateral and medial) limbs. The lateral limb originated from the calcaneal tuber, adhered to the plantar surface of the calcaneus and inserted on the fourth tarsal and metatarsal bones. The long medial limb arose also from the calcaneal tuber and passed on the plantar aspect of the lateral limb. It partly enclosed the superficial digital flexor tendon and flattened out to form a sheet which attached to medial and lateral ridges on the metatarsal bone. The deep digital flexor tendon passed between the medial and lateral limbs to reach the plantar aspect.
Discussion

Conventional radiography is the classic imaging technique for diagnosing bone lesions, while ultrasonography represents an excellent complementary diagnostic tool to radiography for determination of soft tissue structures in equine practice (Tenbrunner-Martinek et al., 2007). Both techniques are used in conjunction as basic imaging modalities in most clinical situations in field practice. The combination of these techniques has led to the re-evaluation of several well-known dogmatic pathological conditions and the identification of many new clinical entities (Vanderperren et al., 2009). In the present study, the normal digital radiography and ultrasonography of the tarsal region in the one humped camel is presented, giving basic reference data for investigation of disorders of camel tarsus.

The radiographic examination was performed in four projections as defined by Verschooten and Schramme (1994). The dorsoplantar view was optimal for evaluation of the articular surfaces and joint spaces of the tarsocrural as well as the intratarsal joints. The lateromedial view was the best for evaluation of the talocalcaneal joint, the dorsolateral-plantaromedial view for the medial aspect of the tarsocrural joint, and the plantarolateral-dorsomedial view for the plantar aspect of the sustentaculum tali and the lateral trochlea of the talus. Similar findings have been reported for the same radiographic projections of the equine tarsus (Butler et al., 2000).

The normal appearance of the soft tissue structures of the tarsus has been reported in horses (Mettenleiter, 1992; Dik, 1993; Whitcomb, 2006; Vilar et al., 2008), cattle (Flury, 1996) and dog (Caine et al., 2009). In this study, the normal ultrasonographic anatomy of the tarsal region in adult dromedary camel was described. A stand-off pad was not used because it was cumbersome and did not enhance the resolution of most structures examined, especially when a generous amount of acoustic coupling gel was applied (Tomlinson et al., 2000; Caine et al., 2009). Due to the complexity of the tarsal joint anatomy and presence of numerous structures, ultrasonographic examination of the camel
tarsus was performed in a systematic manner similar to that reported for the equine tarsus in both longitudinal and transverse planes (Dik, 1993; Whitcomb, 2006; Vilar et al., 2008). The ultrasonograms in both planes correlated well with the freshly dissected and the frozen sectioned specimens.

In the current study, tendons and ligaments of the tarsal region had an even echogenic structure in transverse and longitudinal planes. Similar findings were reported for the same region in horses (Dik, 1993; Whitcomb, 2006; Vilar et al., 2008) and cattle (Flury, 1996). Ultrasonographic examination was performed in a systematic manner as described by Whitcomb (2006) and Vilar et al. (2008), whereby the structures of the tarsus were identified via the transverse view and their orientation and morphology through the longitudinal in accordance with Vilar et al. (2008). Sonographic evaluation of the tarsocrural joint capsule was easier from the dorsomedial aspect of the tarsus between the fibularis tertius and cranial tibial tendons. The intratarsal joint capsules couldn't be evaluated due to minimal synovial fluid. Similar findings have been described in the equine tarsus (Dik, 1993; Whitcomb, 2006).

The collateral ligaments should be recognized in the longitudinal view and examined from their origin to their insertion in order to be differentiated from other structures. The long lateral collateral ligament and the short part connecting the calcaneus and metatarsal bone were identified, whereas the other part of the short lateral collateral ligament connecting the tibia and calcaneus could not be evaluated. In contrast, only the long medial collateral ligament was recognized while the two parts of the short medial collateral ligament could not be differentiated from the long ligament.

The long plantar ligament consisted of medial and lateral limbs extending through the plantar aspect of the tarsus. Similar finding were detected in the canine tarsus (Caine et al., 2009). The plantar ligament was more echogenic than the deep digital flexor tendon and both were more echogenic than the superficial digital flexor tendon. The caudal tibial and medial digital flexor tendons united and ran on the plantar aspect of the tarsus at the level of the tarsometatarsal joint, so the deep digital flexor tendon was only evaluated at the level
of the tarsometatarsal joint. In conclusion, digital radiography and ultrasonography are complementary to each other and suitable for assessment of the camel tarsus.

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References


Fig. 1. Lateromedial radiograph of the right camel tarsus. Ti, distal extremity of the tibia; CT, calcaneal tuber; Cal, calcaneus; Ta, talus; C, central tarsal bone; 2+3, fused second and third tarsal bones; 1, first tarsal bone; 4, fourth tarsal bone; Met, fused third and fourth metatarsal bones.
Fig. 2. Dorsoplantar radiograph of the right camel tarsus. Ti, distal extremity of the tibia; Lm, lateral malleolus; Mm, medial malleolus; Mb, malleolar bone; Cal, calcaneus; Ta, talus; C, central tarsal bone; 2+3, fused second and third tarsal bones; 1, first tarsal bone; 4, fourth tarsal bone; Met, fused third and fourth metatarsal bones.
Fig. 3. Dorsolateral-plantaromedial oblique radiograph of the right camel tarsus. Ti, distal extremity of the tibia; Ir, intermediate ridge of the tibial cochlea; Mm, medial malleolus; Cal, calcaneus; Ta, talus; C, central tarsal bone; 2+3, fused second and third tarsal bones; 1, first tarsal bone; 4, fourth tarsal bone; Met, fused third and fourth metatarsal bones.
Fig. 4. Plantarolateral-dorsomedial radiograph of the right camel tarsus. Ti, distal extremity of the tibia; CT, calcaneal tuber; Cal, calcaneus; Ta, talus; C, central tarsal bone; 2+3, fused second and third tarsal bones; 1, first tarsal bone; 4, fourth tarsal bone; Met, fused third and fourth metatarsal bone.
Fig. 5. Topographic anatomical position of the sonograms on the dorsal (a), and the medioplantar (b) aspects the camel tarsus.
Fig. 6. Longitudinal sonogram of the fibularis tertius muscle tendon and its tendon sheath at the level of the tarsocrural joint (a) and its corresponding cryosection (b). D, dorsal; P, plantar; Pr, proximal; Ds, distal.
Fig. 7. Transverse sonogram at the level of the tarsocrural joint (a) and its corresponding cryosection (b). LDE, long digital extensor muscle tendon; L, lateral; M, medial; D, dorsal; P, plantar.
Fig. 8. Longitudinal sonogram of the long digital extensor muscle tendon (LDE) in front of the central tarsal bone (a) and its corresponding cryosection (b). D, dorsal; P, plantar; Pr, proximal; Ds, distal.
Fig. 9. Longitudinal sonogram of the cranial tibial muscle tendon (a) and its corresponding cryosection (c) at the level of the tarsocural joint and transverse sonogram of the cranial tibial muscle and the fibularis tertius muscle tendons (b) and their corresponding cryosection (d) at the level of the medial condyle of the tibia. D, dorsal; P, plantar; Pr, proximal; Ds, distal; L, lateral; M, medial.
Fig. 10. Transverse (a) and longitudinal (b) sonograms of the lateral digital extensor muscle tendon and their corresponding cryosections (c) and (d) respectively, in front of the fourth tarsal bone. L, lateral; M, medial; D, dorsal; P, plantar; Pr, proximal; Ds, distal.
Fig. 11. Longitudinal sonogram (a) of the fibularis longus muscle tendon and its corresponding cryosection (b) at the level of the tarsocrural joint. L, lateral; M, medial; Pr, proximal; Ds, distal.
Fig. 12. Longitudinal sonogram of the origin of the short lateral collateral ligament from the calcaneus (a) and longitudinal sonogram of the long lateral collateral ligament during its course over the calcaneus (b) and their corresponding cryosections (c) and (d), respectively. L, lateral; M, medial; Pr, proximal; Ds, distal.
Fig. 13. Transverse sonogram (a) and longitudinal sonogram (b) of the caudal tibial tendon (C.T) and medial digital flexor tendon (MDF) and their Common tendon sheath (Ts) during their course over the calcaneus and their corresponding cryosections (c) and (d), respectively. L, lateral; M, medial; D, dorsal; P, plantar; Pr, proximal; Ds, distal.
Fig. 14. Longitudinal sonogram (a) of the long medial collateral ligament during its course on the fused second and third tarsal bones and the fused third and fourth metatarsal bone and its corresponding cryosection (b). L, lateral; M, medial; Pr, proximal; Ds, distal.
Fig. 15. Transverse sonogram of the medial and lateral limbs of the long plantar ligament and the superficial digital flexor tendon on the calcaneus (a) and its corresponding cryosection (c). Longitudinal sonogram of the superficial digital flexor tendon (SDFT), the deep digital flexor tendon (DDFT) and the long plantar ligament (Long pl. lig.) at the level of the tarsometatarsal joint (b) and its corresponding cryosection (d). D, dorsal; P, plantar; Pr, proximal; Ds, distal; L, lateral; M, medial.
3 Discussion

The camel tarsus is an anatomically complex region, with a sophisticated relationship between multiple bones, synovial structures, ligaments, and tendons (SMUTS and BEZUIDENHOUT 1987). Therefore, it is highly susceptible to a considerable incidence of orthopedic problems (CLEGG 2003). Tarsal pain is responsible for 80% of chronic, low-grade hind limb lameness in horses (BLAIK et al. 2000). A satisfactory diagnosis of most orthopedic problems can usually be achieved with the combination of a standardized lameness examination and the judicious choice of a diagnostic imaging tool (OCALLAGHAN 1991). The correct identification of the lesion requires a good knowledge of the normal anatomical appearance of the scrutinized region (RAES et al. 2010) as well as the different manifestations of tissue alterations (BECHT et al. 2001). The normal appearance of the dromedary camel tarsus on various imaging modalities has not been described yet. Therefore, the present investigation was carried out to characterize the normal appearance of the different anatomic structures of the dromedary camel tarsus via radiography, ultrasonography and computed tomography to serve as an imaging reference for interpretation of the dromedary camel tarsal pathology.

Radiography remains the most common technique used for diagnosing injury of the tarsal bones. The importance of radiographs in the evaluation of lameness, as well as areas inaccessible to other modalities because of size or positioning issues, must not be trivialized or forgotten in the age of bigger and better diagnostic modalities (DENOIX 2000; VANDERPERREN et al. 2009b; WHITCOMB 2006). The bony structure of the dromedary tarsal region consisted of the distal extremity of the tibia (tibial cochlea), the malleolar bone, the tarsal bones (calcaneus, talus, central tarsal, first, fourth and fused second and third tarsal bones) and the proximal extremity of the fused third and fourth metatarsal bones. The radiographic examination of the dromedary camel tarsus was performed in the standard radiographic projections (0º and 90º) as well as two oblique directions (45º and 135º) as described by BUTLER et al. (2008). Radiography of the dromedary tarsus provided valuable information on the bony structures of the dromedary tarsal joint but with certain limitations.
The most important limitation of conventional radiography is the display of a three-dimensional object in two dimensions (PARK et al. 1987; KRAFT and GAVIN 2001). Also, 30% to 50% variation in bone density is required before it is radiographically apparent (HANSON et al. 1996; KRAFT and GAVIN 2001). In addition, problems such as summation of bony densities and superimposition of different contours can result in a failure to detect conditions such as subchondral bone cysts and small hairline fractures (HANSON et al. 1996). In common conditions such as osteoarthritis of the distal tarsal joints (bone spavin), the clinical presentation and the radiographic appearance of the area often correlate poorly (KRAFT and GAVIN 2001). However, despite these disadvantages, radiography remains essential for the diagnosis of bone lesions, such as osteochondrosis, degenerative joint disease or fractures (DENOIX 2000). In those instances, computed tomography is superior to radiography for bone representation.

Computed tomography has become an established clinical diagnostic tool in equine medicine as scanners have become more available and affordable, and equipment has improved dramatically: image resolution has increased, and slice thickness and scan times have decreased (BARBEE 1996; BIENERT and STADLER 2006). Compared with conventional radiography and ultrasonography, computed tomographic images can be selectively displayed to highlight either bone structures or soft tissues by adjusting window width and level as necessary (bone or soft tissue display windows) (TUCKER and SANDE 2001). Because of the cross-sectional characteristics of this imaging modality, superimposition or overlapping of different tissues do not occur and this allows a real isolation of the lesion directly exposed without covering layers, and therefore permits detection of small lesions inside a volume. Digital assembling of adjacent CT images allows reconstruction of new images in different anatomical planes as well as three-dimensional representation of bone and joint surfaces (BIENERT and STADLER 2006).

In the current study, with the computed tomography adjusted to bone window settings, all bony structures were seen. All images allowed excellent delineation between the cortex and medulla of the bones and the trabecular structure was clearly depicted. CT provides an exceptional imaging representation of bone and joints. It presents an extreme ability to
detect variations of bone density (MARTENS et al. 2000; OCALLAGHAN 1991; WIDMER et al. 2000), such as sclerosis and lysis of the subchondral bone, as well as cancellous bone. The sensitivity of computed tomography to subchondral bone cysts (OCALLAGHAN 1991; TUCKER and SANDE 2001) and bone stress (fatigue fractures) is now well established. Moreover, this technique can provide an excellent spatial representation of fractures (ROSE et al. 1997). Bone shape and contour are precisely imaged allowing diagnosis of enthesophytes and periosteal proliferative lesions (TUCKER and SANDE 2001).

As previously mentioned, radiography is useful for the detection of bone involvement, but it is not useful for the determination of soft tissue involvement and early diagnosis of joint inflammation (BARGAI et al. 1989). As a complementary diagnostic tool, ultrasonography examination allows excellent visualization of the soft tissue structures and bone surface (DIK 1993; PARK et al. 1987; REDDING 2001; VANDERPERREN et al. 2009a; WHITCOMB 2006).

Diagnostic ultrasonography has revolutionized the quality of medicine for the animal patient. In the last several years, ultrasound machines have become more portable as well as more affordable, and therefore they are more widely available to animal practitioners. Ultrasonography is the only modality that provides real-time evaluation of both soft tissue and, to a limited extent, bone surface. It can detect lesions not evident (or not yet evident) radiographically, allowing treatment to be instituted and/or management changes to be made which would slow or arrest lesion progression and prolong the useful life of the animal. In particular, it may identify soft tissue and cartilage defects over radiographically normal bone. It aids surgical decision-making by allowing the clinician to classify lesions more accurately and determine their extent preoperatively.

In the present study, the normal ultrasonographic anatomy of the tarsal region in adult dromedary camel was described. The position, echogenicity and degree of demarcation of the tendons and ligaments and the appearance of the joint pouches were determined. A stand-off pad was not used because it was cumbersome and did not enhance the resolution.
of most structures examined especially when a generous amount of acoustic coupling gel was applied (Caine et al. 2009; Tomlinson et al. 2003). Due to the complexity of the tarsal joint anatomy and presence of numerous structures, ultrasonographic examination of the camel tarsus was performed in a systematic manner similar to that reported for the equine tarsus in both longitudinal and transverse planes (Dik 1993; Vilar et al. 2008; Whitcomb 2006) whereby the structures of the tarsus were identified via the transverse view and their orientation and morphology through the longitudinal in accordance with (Vilar et al. 2008). The tendons and ligaments of the tarsal region had an even echogenic structure in transverse and longitudinal planes. Similar findings were reported for the same region in horses (Dik 1993; Vilar et al. 2008; Whitcomb 2006) and cattle (Flury 1996). Although most of the soft structures of the dromedary camel tarsus were evaluated via ultrasonography, it was not possible to identify neither the short lateral collateral ligament connecting the tibia and calcaneus nor the short medial collateral ligament. The plantar ligament was more echogenic than the deep digital flexor tendon (DDFT) and both were more echogenic than the superficial digital flexor tendon (SDFT). The caudal tibial and medial digital flexor tendons united and ran on the plantar aspect of the tarsus at the level of the tarsometatarsal joint, so the DDFT was only evaluated at the level of the tarsometatarsal joint.

Although ultrasonographic examination of the dromedary camel tarsus yielded precious information on the soft tissue structure, bone surface and articular cartilage of the dromedary camel tarsus, it was limited to the peri-articular tissues. In this instance, computed tomography offers the ability to evaluate structures deep to gas-containing organs, as well as deep to bone, which are inherent limitations of ultrasonography (Kraft and Gavin 2001; Ross 1998). It is optimally suited to the assessment of soft tissue. Its ability to detect subtle changes in tissue attenuation, distortion of fat tissue planes, and the presence of fluid or gas collections has been well described. The superior cross-sectional anatomic detail provided by computed tomography allows localization of the alterations in the soft tissues (Beauchamp et al. 1995). In the current study, 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 (Raes et al. 2011; Van der Vekens et al. 2011;
The soft tissue structures of the dromedary camel tarsus showed variable shades of grey, the synovial fluid being the lowest attenuated structure. The tendons were recognized as hyper-attenuated structures. Each of the tarsal tendons was surrounded by a hypo-attenuated rim representing its tendon sheath. The short and long components of the tarsal collateral ligaments as well as the inter- and intra-tarsal ligaments were recognized as hyper-attenuated structures. The tarsal fascia, synovial fluid, subtendinous bursae and bone marrow were evident as hypo-attenuated structures. The blood vessels and nerves were well recognized throughout the soft tissue window images.

In the present study imaging of the dromedary camel tarsus was a challenge due to its complex anatomic structure and the presence of numerous bony and soft tissue structures. Digital radiography provided a high definition and excellent imaging representation of bones. It allowed the assessment of the tarsal joint angulation and congruency as well as assessment of the tarsal joint stability. Ultrasonography allowed a good representation of the tendons, ligaments, capsule, synovial fluid, articular cartilage and subchondral bone of the dromedary camel tarsus. Computed tomography afforded valuable information not only on bony structures but also on the clinically important soft tissue structures of the dromedary camel tarsus at the same time.
4 Summary

Usama Ismaeil Mohamed Hagag

Radiography, ultrasonography, and computed tomography of the dromedary camel tarsus (Camelus dromedarius)

Large Animal Clinic for Surgery, Faculty of Veterinary Medicine, University of Leipzig
54 Pages including copies of 2 publications, 76 references, appendix
Keywords: dromedary, camel, radiography, ultrasonography, computed tomography, tarsus.
Submitted in December 2012

The dromedary camel has a very high economic importance in the Arabic countries. Nevertheless, there is a very little background literature on the use of ultrasound (US) and computed tomography (CT) in dromedaries in comparison to other domestic and farm animal species. Therefore, the tarsal region of six cadaver limbs, obtained from three orthopedic disease free dromedary camels, was evaluated via radiography, US and CT. The limbs were frozen and sectioned transversely, sagittaly and dorsally. The anatomic structures were identified and correlated to the analogous structures on the corresponding CT slices and US images and published in two manuscripts.

Radiography was performed in both standard (0° and 90°) oblique (45° and 135°) radiographic projections. The tarsus was investigated via US in four planes (dorsal, medial, lateral and plantar) and each plane was scrutinized in four levels (calcaneal tuber, tibial malleoli, base of calcaneus and proximal head of metatarsus) in both transverse and longitudinal views.

Radiography provided a good representation of the bony structures and articulations with little information on the soft tissues of the tarsus and superimposition of the tarsal bones. Ultrasonography furnished adequate delineation of the peri-articular tissues of the tarsus and was limited to the bone surface. Computed tomography provided cross sectional imaging of the dromedary tarsus without bone and soft tissue overlap and allowed visualization and differentiation of tissues in almost every situation.

This work was undertaken to document the normal appearance of the dromedary camel tarsus via radiography, ultrasonography, and computed tomography which may be used as a resource for interpretation of dromedary tarsal pathology using various diagnostic imaging modalities.
5 Zusammenfassung

Usama Ismaeil Mohamed Hagag

Röntgenanatomie, Ultraschalluntersuchung und Computertomographie des Sprunggelenkes beim Dromedar Kamel (Camelus dromedarius)

Chirurgische Tierklinik, Veterinärmedizinische Fakultät, Universität Leipzig
54 Seiten, 2 Publikationen, 76 Literaturangaben, Anhang
Schlüsselworte: Dromedar, Kamel, Röntgen, Ultraschall, Computertomographie, Sprunggelenk.

Eingereicht im Dezember 2012


Sechs isolierte Hinterbeine gliedmaßengesunder Kamele wurden im Bereich des Tarsus untersucht. Ultraschall-, computertomographische und anatomische Schnitte wurden einander gegenübergestellt und bewertet und in zwei wissenschaftlichen Publikationen veröffentlicht.


Mit den Untersuchungen wurde nachgewiesen, dass mittels Röntgendiagnostik eine umfassende Darstellung von Knochen und Gelenken möglich ist, jedoch wenig Informationen über die Weichteile des Tarsus bietet. Die Sonographie erlaubt eine

Basierend auf einer Literaturrecherche erfolgte eine umfassende Zusammenstellung des Erkenntnisstandes zur Bildgebung im Bereich des Tarsus unter anatomischen und orthopädischen Gesichtspunkten. Die dabei zusammengetragenen Ergebnisse bilden eine entscheidende Grundlage für die Auswertung und Interpretation von Befunden der Regio tarsi des Dromedars (Camelus dromedarius) mit Hilfe der bildgebenden Diagnostik.
6 References


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61


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Usama Hagag