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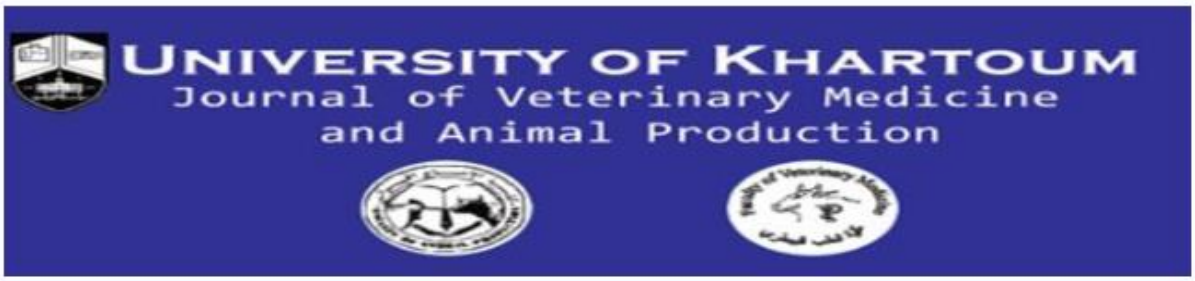

Computed Tomography of the Hind Limbs in Healthy Dromedary Camel Foot

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Abstract

The objective of this study was to provide a detailed computed tomographic (CT) reference of the normal dromedary camel foot. Six hind limbs obtained from three dromedary camel cadavers with no evidence of orthopedic disease of the foot. In all limbs, computed tomography was performed in both soft tissue and bone windows; transverse, sagittal and dorsal planes slice thickness of 1 mm and matrix size of 512x512. In computed tomography images the proximal, middle and distal phalanges, proximal and distal sesamoid bones, superficial and deep digital flexor tendons, collateral ligaments and the inter-digital ligament were clearly identified. The computed tomography images allowed excellent delineation between the cortex and medulla of bones and the trabecular bone was clearly depicted. The transverse images provided good visualization of the different bony and soft tissues and vessels of the camel foot. The sagittal images allowed a detailed evaluation of the contour of the joints while, the dorsal images allowed full assessment of the collateral ligaments of the joints. In this study, computed tomography was a useful imaging tool for identification and characterization of the osseous and soft tissue structures of the dromedary camel foot. This technique may be of value when results from other diagnostic imaging techniques are inconclusive. The images provided will serve as a computed tomography reference for the dromedary camel foot.

Keywords: computed tomographic, camel, foot

المستخلص

هدفت هذه الدراسة لتقديم صور اشعة مقطعية مرجعية مفصلة للوضع الطبيعي لقدم الجمل ذو السنام الواحد. ست اقدام خلفية تم اخذها من ثلاثة جثث لجمال ليس بها دليل على وجود مرض في القدم. اجريت الاشعة المقطعية في كل من الانسجة الرخوة والعظام في كل الاطراف بإطارات عرضية، سهمية وشرائح ظهرية بسماكة 1 ملم وبحجم مصفوفة 512 x512. عَرفت بوضوح صور الاشعة المقطعية الاصابع الدانية والوسطى والقاصية، العظام السمسمانية الدانية والقاصية، وتر العضلة قابضة الاصبع السطحي، وتر العضلة قابضة الاصبع الغائر، الاربطة الجانبية والرباط بين الاصابع. صور الاشعة المقطعية سَمحت بترسيم ممتاز بين القشرة واللب للعظام وترابيق العظم صُورت بطريقة واضحة. الصور العرضية قدمت تصور جيد للعظام والانسجة الرخوة المختلفة والاوعية في قدم الجمل. الصور السهمية سمحت بتقييم مُفصل لتضاريس المفاصل بينما الصور الظهرية سمحت بالتقييم الشامل للاربطة الجانبية للمفاصل. في هذه الدراسة كانت الاشعة المقطعية وسيلة تصويرية مفيدة للتعريف والتعرف على التراكيب العظمية والانسجة الرخوة لقدم الجمل ذو السنام الواحد. هذه التقنية يمكن ان تكون ذات فائدة عندما تكون النتائج من التقنيات التصويرية الاخرى غير حاسمة. الصور المقدمة ستكون كصور اشعة مقطعية مرجعية لقدم الجمل ذو السنام الواحد.

Introduction

The camel foot has a special anatomic structure (Smuts and Bezuidenhout, 1987; Arnoutov and Abdalla, 1969) and considered as an important source of lameness in camels (Singh and Gahlot, 1997). Camels are unique among other artiodactyls in their regular employment of pacing gait and having a unique foot morphology assumed to be an adaptation for their mode of locomotion (Web, 1972 and Janis *et al.*, 2002). A satisfactory diagnosis of most orthopedic 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) through its high spatial resolution and moderate differentiation of tissue contrast.

Hence, it is a fastened exceptionally useful technique for visualizing general anatomy (Prokop, 2002). In addition, it allows cross-sectional imaging without bone and soft tissue overlap and 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 and 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 diseases of the talus, and preoperative planning for fracture repair (Gielen *et al.*, 2001). The CT technology can reach its full potential as an effective diagnostic modality when a normal species specific anatomic reference is provided.

In a previous study (Badawy, 2011), the complex anatomical structures of digits and foot pad of the fore limb in one humped camel was described and identified using CT. It was reported that CT proved to be an efficient imaging modality that provide a cross sectional image with superior soft tissue differentiation and no superimposition of overlying structure making it suitable for better diagnosis of foot and foot pad abnormalities. Therefore, this study provided an anatomic description of the dromedary hind limb via CT to have a complete reference of the dromedary camel foot.

Material and Methods

Six cadaver pelvic limbs were obtained from three adult dromedary camels euthanized for reasons unrelated to musculoskeletal disorders in the veterinary hospital of King Faisal University, Kingdom Saudi Arabia. Camels were one male and two females. Their age was four, eight and fourteen years, respectively. Limbs were disarticulated at the tarsometatarsal joint and wrapped at its stump with plastic sheath to prevent contamination of the working area. Tarsi of each camel were radiographically prior to examination in order to ensure that no radiographic abnormalities were present.

The CT images were obtained with multi-slice CT scanner, which 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-millimeter collimator), high speed, decrease in noise and huge number of images generated at the same scanning time (Berland and Smith, 1998). The CT examination of the foot was performed within 4 hours 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 of 5 cm proximal to the fetlock joint and continuing distally to the tip of toe). 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 foot.

Results

In the current study with window settings adjusted for bone, the entire images had excellent delineation between the cortex and medulla of bones and the trabecular pattern of the cancellous bone was clearly depicted. The soft tissue window allowed identification of the most clinically important soft tissue structures including proper extensor tendons, superficial and deep digital flexor tendon, the digital scutum, the collateral ligaments,

sesamoidean ligaments and the joint capsules in the foot region.

All bone structures, including the diaphysis of the metatarsus, the collateral fossae, the first, the second and the third phalanges, the proximal and the distal sesamoid bones were seen on the transverse-, sagittal-, and dorsal-plane images (Figures. 1, 2 and 3). The soft tissue window allowed identification of the most clinically important soft tissue structures including proper extensor tendons, superficial and deep digital flexor tendon, the digital scutum, the collateral ligaments, sesamoidean ligaments and the joint capsules in the foot region.

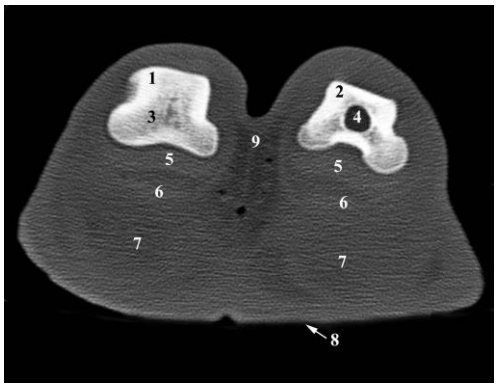

Figure 1: Transverse computed tomography slice at the level of the distal third of the first phalanx

1, Middle Phalanx of digit III, compact bone; 2, Middle Phalanx of digit IV, compact bone; 3, Cancellous bone; 4, Bone marrow; 5, Middle scutum; 6, Deep digital flexor tendon; 7, Adipo-elastic cushion; 8, Sole; 9, Interdigital ligament

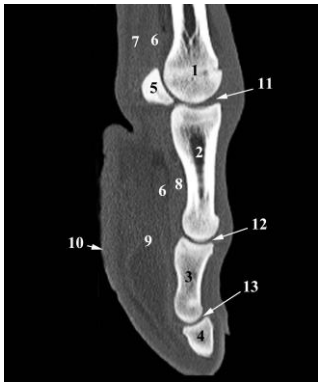

Figure 2: Sagittal computed tomography slice through the digit III

1, Distal extremity of metatarsus articulating with the digit III; 2, Proximal phalanx; 3, Middle phalanx; 4, Distal phalanx; 5, Proximal sesamoid bone, compact bone; 6, Deep digital flexor tendon; 7, superficial digital flexor tendon; 8, Middle scutum; 9, Adipoelastic cushion; 10, Sole; 11, Fetlock joint; 12, Pastern joint; 13, coffin joint

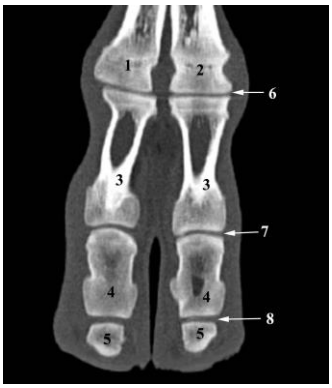

Figure 3: Dorsal computed tomography slice through the camel foot

1, Distal extremity of metatarsus articulating with the digit III; 2, Distal extremity of metatarsus articulating with the digit IV; 3, Proximal phalanx, compact bone; 4, Middle phalanx, cancellous bone; 5, Distal phalanx; 6, Fetlock joint; 7, Pastern joint; 8, Coffin joint

The digital extensor tendons were seen as an oval shaped hyper-attenuated structure on the transverse images (Fig. 1). The joint capsule could be seen as a hypo-attenuated zone and was best identified on the transverse and sagittal reconstructions (Fig. 1 and 2). The lateral and medial collateral ligaments as well as the collateral sesamoidean ligaments were identified as hyper-attenuated structures and were best seen on the transverse and dorsal reconstructed images (Fig.1 and 3). The superficial digital flexor tendon was smoothly marginated, and its margins were clearly demarcated on the transverse, dorsal, and sagittal images (Figures. 1, 2 and 3). The deep digital flexor tendon was seen on all images as hyper-attenuated structure running on the plantar aspect of the third and fourth digits.

Discussion

The data represented in this study will help understanding the anatomy and imaging feature of the hind limps of dromedary camels. Using radiographic examination is often the first imaging test to be used when a pathological condition is suspected (O´Brien *et al.*, 1996), however it has sometimes the disadvantage of super im-positioning of many anatomic structures, leading to obscure or confuse of important radiographic findings.

Since its introduction, computed tomography (CT) has revolutionized veterinary medicine and currently plays a prominent role in the diagnosis and evaluation of many orthopedic 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 are appearing in the literature (Smallwood *et al.*, 2002 and Puchalski, 2007). Nevertheless, 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 aims at providing a solid knowledge on the anatomic description of the dromedary camel foot via computed tomography in which the bony structures were clearly identified, as were the most clinically important soft tissue structures.

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 which are the Paramount factors for prognosis (Gielen *et al.*, 2001 and Raes *et al.*, 2011). The 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 camel foot is an anatomically complex region with numerous bony and soft tissue structures (Smuts and Bezuidenhout, 1987) so that it is highly susceptible to orthopedic problems. Correct identification of the lesion is necessary to initiate an appropriate management. Multiple imaging modalities are often required to accurately identify these lesions. 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, is hampered by the possibility of bone superimposition, and the acute skeletal abnormalities may not be radiographically visible (Stover *et al.*, 1986). Ultrasonography of

A previous study on the usage of computed tomography of the fore foot of camel was carried by Badawy (2011). It was shown that CT has considerable advantages over the other diagnostic imaging techniques to describe and investigate the detail of the anatomical structures of the fore foot in camel. The results represented in this study will make it clear how CT is useful identifying and describing the anatomy and possible abnormalities in the hind limb as well. However the major disadvantages of CT are the need for general anesthesia, the need for a dedicated table and the high purchase and maintenance costs (Kraft and Gavin, 2001).

Conclusion

In the current study, computed tomography allowed a full assessment of the dromedary camel foot 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 foot.

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