Global Veterinaria 6 (4): 417-423, 2011
ISSN 1992-6197

Computed Tomographic Anatomy of the Fore Foot in One-Humped Camel *(Camelus dromedrus)*

Adel M. Badawy

Department of Surgery, Anaesthesiology and Radiology,
Faculty of Veterinary Medicine (Moshtohor), Benha University, Qalubia, Egypt

Abstract: The purposes of this study was to describe and identify , the complex anatomical structures of digits and foot pad of the fore limb in one-humped camel by using the computed tomography scan (CT scan) and gross anatomy, which would be used in diagnosis of foot and footpad disorders. The study was performed on three pairs of camel's fore feet. Transverse and sagital CT images were obtained by using Hitachi-CXR 4Multi-Slice CT Scanner. The different anatomical structures of the digits and footpad were identified in the frozen sections, the fixed slices and the dissected specimens. The CT images were compared with the corresponding sections at the same levels and selected for their identity and photographed. The analogous anatomical structures were identified on the transverse and sagital slices and labeled with the corresponding structures on the CT images. Results revealed that, the frontal tip of each digit was covered by a characteristic small nail. The distal and middle phalanges were horizontally situated, while the proximal phalanx obliquely positioned. Their planter surfaces were separated from the ground by foot pad. Three digital cushions enclosed in a common capsule were found underneath each digit. On CT images, the inner structures of the foot and foot pad were appeared with various gray scales. It was concluded that, camel has unique feet morphological peculiarities. CT was efficient imaging modality that provides a cross-sectional image with superior soft tissue differentiation and no superimposition of the overlying structures, which can be used for better diagnosis of foot and foot pad abnormalities.

Key words: Camel · CT scan · Cross-section · Digits · Footpad

INTRODUCTION

Camels are a fascinating and little studied animals. Camel is a unique among artiodactyls in their regular employment of pacing gait and having a unique foot morphology assumed to be an adaptation for this mode of locomotion [1-3]. The uniquely designed wide spread feet enable him to walk on shifting sand in the desert and rough rocky terrain whereas the footpad is used to grip onto rock and steep inclines. Their feet are secondarily digitigrade, with a splayed -toed foot, loss of hooves, addition of a broad foot pad and loss of the interdigital ligaments, allowing the divergence of the third and fourth digits [3-5]. Imaging techniques play a major role in the modern biomedical research [6,7]. Current diagnostic imaging techniques such as radiography and ultrasonography provide limited information for evaluation of the camel foot. Radiography has limited value to evaluation of soft tissue, although ultrasonography provides visualization of tendons and ligaments [8-10]. Alongside, ultrasonography provides a small view and each structure has to be separately imaged and a cross sectional examination through the entire digit is not possible. On the other hand, soft tissue is difficult to be evaluated by ultrasonography in the digit [11]. CT, through its high spatial resolution and moderate differentiation of tissue contrast is a fastened exceptionally useful technique for visualizing general anatomy [12].

The use of CT in large animal medicine is currently limited by logistical problems of acquiring CT images; meanwhile a few CT studies on horse's foot have been done [13]. Computed tomography (CT) is anatomic cross-sectional imaging that uses x-rays and x-ray attenuation to create the images [14, 15]. The CT gantry houses a row of x-rays detectors across from an x-ray generator.

Corresponding Author: Adel M. Badawy, Department of Surgery,Radiology and Anaesthesiology, Faculty of Veterinary Medicine Benha Univeisity, Qalubia, Egypt.
Tel: +202-42132555, Mob: +2011-8859378, E-mail: adelbadawybadawy@yahoo.com.

The gantry rotates around the region of interest on the patient creating a "cross-section x-ray image" in sequences of slices. The basic physics of CT are dependent on tissue density, similar to planar radiology, but CT's cross-sectional nature eliminates superimposition of structures and dramatically improves resolution. C.T imaging is particularly useful in the skull, thorax, abdomen and limbs. C.T image interpretation is based on the principles of radiology, as it made of black color, white and shades of gray (called gray scale), assigned to tiny squares (pixels) arranged in columns and rows(a matrix) and can record thousands of opacities ranging from air to high density metal images [16]. Accurate interpretation of ultrasonography or CT of the foot requires a thorough knowledge of the cross sectional anatomy of the region and accurate interpretation of the plan metric CT is necessary for the study and evaluation of the pathological condition or damaged tissues [9, 17].

The objective of this study was to describe the cross-sectional anatomy compared with the corresponding CT images of the digits and foot pad in one-humped camel, which provides data, would be used for evaluation and diagnosis of foot and foot pad abnormalities.

MATERIALS AND METHODS

Three pairs of fore limbs of the camel (*Cameleus Dromadrius*) were used in this study; they had been obtained from the slaughter house of Toukh, Qalubia governorate, Egypt. Limbs were sectioned 10 cm above the level of the fetlock joint. Computed tomography was performed at 130 kiolvolt and 80 mA by using Hitachi-CXR 4Multi-Slice CT Scanar. Continuous transeverse and sagital series of CT scan were obtained every 1 cm thickness from one pair of the fore feet. The images were printed by using Hitachi-digital printer and photographed. Another pair of fore feet was frozen at-15°C and sectioned in transverse and sagital plans in slices of 1 cm thickness with high speed electric band saw and photographed. The frozen sections were fixed in formalin 10% for further anatomic investigations. The remaining pair of feet was dissected freshly for further identification of the anatomic structures, photographed and fixed in 10 % formalin. The different anatomical structures were identified in the frozen sections and the fixed slices with the aid of the available references [2-5]. The CT images were matched with the corresponding sections at the same levels and plans and selected for their identity. The relevant anatomical structures were identified on the transverse and sagital slices and labeled with the analogous structures on the corresponding CT images.

RESULTS

One hundered and thirty CT images were obtained for fore feet of one-humped camel *(Cameleus dromadrius)*. Twenty cross and Ten sagital sections photographed and matched with their identical corresponding CT images were selected and labeled. The transverse CT images provided excellent depiction and details of anatomical structures when compared to their identical photography. Dorsoplanter plans were not expressive for the relations of the anatomical structures of the digits or the foot pad (Fig. 1). Particularly, identifiable anatomical structures were labeled on the sections with their analogous corresponding CT images. Sections with bilateral symmetrical structures were labeled only on one side. Bones were the densest tissue on CT of the foot and appeared as the whitest hyperdense tissue, with a well-defined dark shaded medulla, similar to their appearance on radiographs. Superficial and deep digital tendons and their fibrocartilagenous enlargements, ligaments and foot pad were appeared on various gray scales on CT images. On CT images Synovial fluid, joint cavity and blood vessels were well-defined radiolucent (hypodense) smoothly margined.

The sole of the fore foot of the one-humped camel was characterized by its round shape with short interdigital cleft (notch) between the third and fourth digits (Fig. 3). Dorsally, the frontal tip of each digit had a characteristic small nail instead of skin appeared as hyperdense well-defined on CT images (Fig. 2). The nail measures about 5-6cm dorsoplanter and 4-5cm transversally. The inner structures of fore feet were included; the distal phalanx (3^{rd} Phalanx) and middle phalanx are nearly horizontally situated (position) and the proximal phalanx (1^{st} phalanx) was obliquely positioned (Fig. 2). The planter surfaces of the distal and middle phalanges as well as the distal half of the proximal phalanx of both digits were separated from the ground by the layers termed together foot pad (Fig. 2).

Proximodistally, they were, the sole, its epidermal layer, common capsule (layer of connective tissue fascia) covering three digital cushions for each digit and planterly the yellow fibroelastic bed, which separated from those of the other digit by a thick highly vascular interdigital septum (Fig. 4). The digital cushions were included, axial, middle and abaxial cushions. CT images were providing good contrast between these structures.

(A) (B)

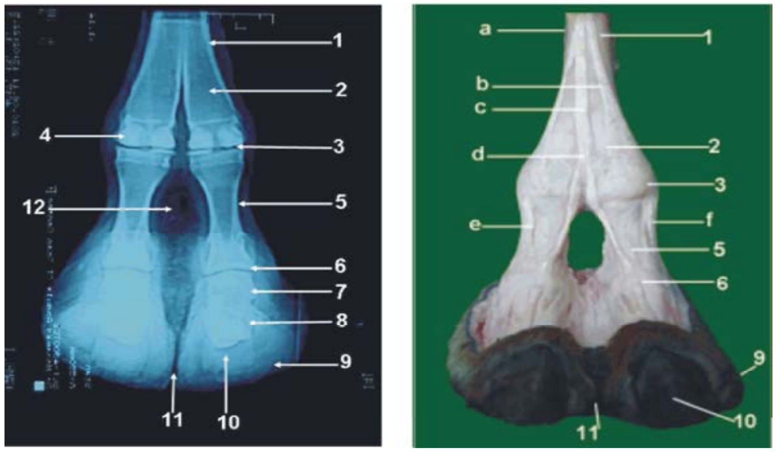


Fig. 1: (A) Dorsoplanter CT image and (B) Dorsal view of dissected foot. 1, metacarpal bone ;2, divided metacarpal bone; 3, fetlock joint; 4, proximal sesamoid bones; 5, proximal phalanx; 6, pastern joint; 7, middle phalanx; 8, distal phalanx; 9, sole; 10,nail or pes; 11, interdigital notch; 12, interdigital septum; a, tendon of muscle extensor digitorum lateralis; b and c , medial and lateral tendons of muscle extensor communis; d, true common extensor tendon ; e, proper extensor tendon of the third digit ; f, proper extensor tendon of the fourth digit.

(A) (B)

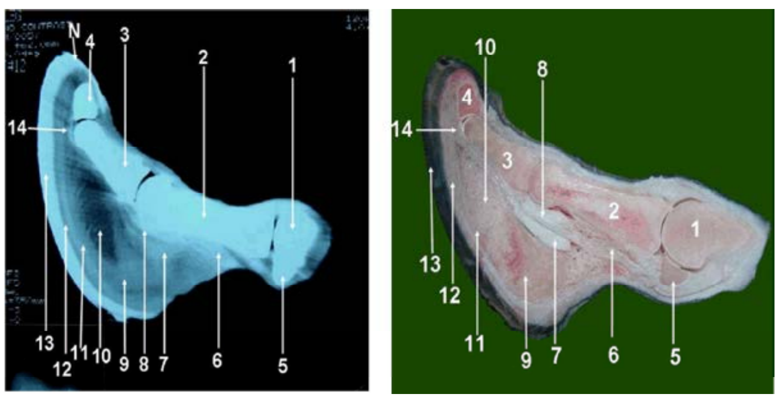


Fig. 2: (A) Sagital CT image and (B) cross section at the level of the middle of the nail. 1, distal exterimity of the metacarpal bone ;2, proximal phalanx; 3, middle phalanx ;4, distal phalanx; 5, proximal sesamoid bone; 6, deep digital flexure tendon; 7, fibrocartilagenous enlargement of the deep digital flexure tendon; 8, middle scutum; 9,yellow bed; 10, digital cushion; 11, common capsule of the digital cushions; 12 epidermal layer of the sole; 13 sole pad; 14, distal scutum;,N, nail.

(A) (B)

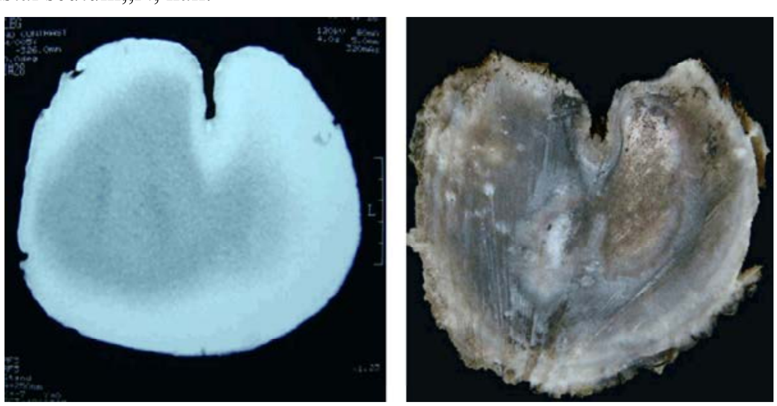


Fig. 3: (A) Transverse CT image and (B) cross section at the level of the sole pad, showing some what round sole and interdigital notch.

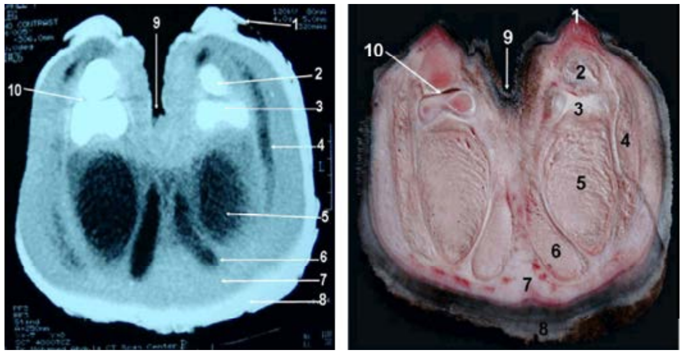
(A)  (B)

Fig. 4: (A) Transverse CT image and (B) cross section at the level of middle of the nail. 1, nail or pes; 2, distal phalanx; 3, middle phalanx; 4, abaxial digital cushion; 5, middle digital cushion; 6, axial digital cushion; 7, epidermal layer of the sole ; 8, sole pad; 9, interdigital notch; 10, coffin joint.

(A)  (B)

Fig. 5: (A) Transverse CT image and (B) cross section at the level of nail connection with the skin. 1, nail or pes; 2, middle phalanx; 3, fibrocartilagenous enlargement of the deep digital flexure tendon; 4, yellow fibroelastic bed highly vascular interdigital septum

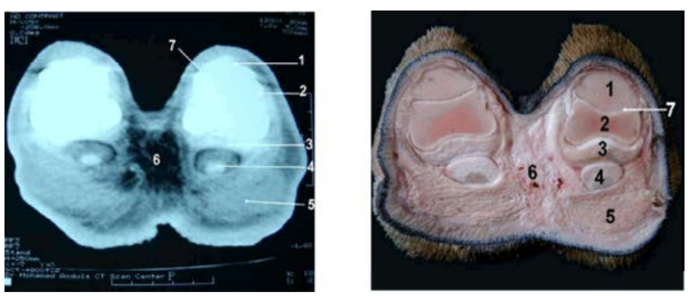
(A)  (B)

Fig. 6: (A) Transverse CT image and (B) cross section at the level of pastern joint. 1, proximal extremity of the middle phalanx; 2, distal extremity of the proximal phalanx; 3, middle scutum; 4, fibrocrtilagenous enlargement of the deep digital flexure tendon; 5, yellow fibro-elastic bed; 6, highly vascular interdigital space; 7, pastern joint.

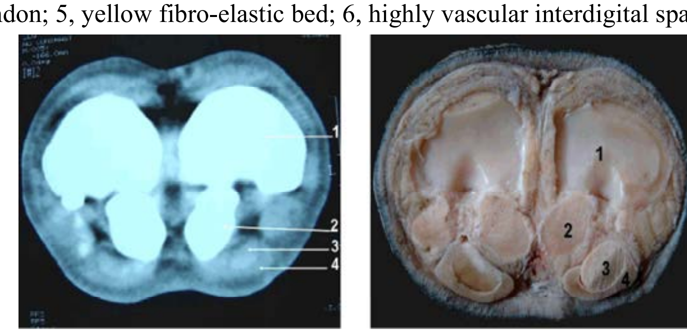
(A)  (B)

Fig. 7: (A) Transverse CT image and (B) cross section at the level of fetlock joint.1, the articular surface of the proximal extremity of the proximal phalanx; 2, proximal sesamoid bones; 3, deep digital flexure tendon enclosed in; 4, superficial flexure tendon.

(A) (B)

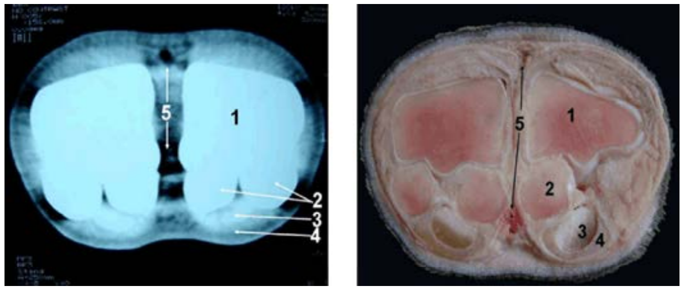


Fig. 8: (A) Transverse CT image and (B) cross section at the level of proximal sesamoid bone .1, distal extremity of the metacarpal bone ; 2, proximal sesamoid bones; 3, deep digital flexure tendon enclosed in; 4, superficial flexure tendon.

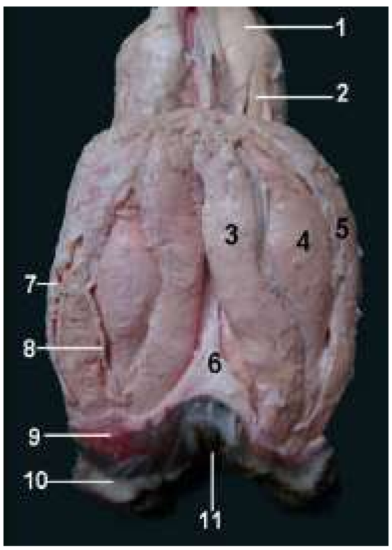


Fig. 9: Dissected planter aspect of the camel fore foot and foot pad (sole removed). 1, superficial flexure tendon split to pass ; 2, deep digital flexure tendon; 3, axial digital cushion; 4, middle digital cushion; 5, abaxial digital cuhion; 6, middle fibrous septum of the common capsule; 7, outer part of the common capsule; 8, fibrous connective tissue septa between digital cushions; 9, epidermal layer of the sole pad; 10 sole pad; 11, interdigital notch.

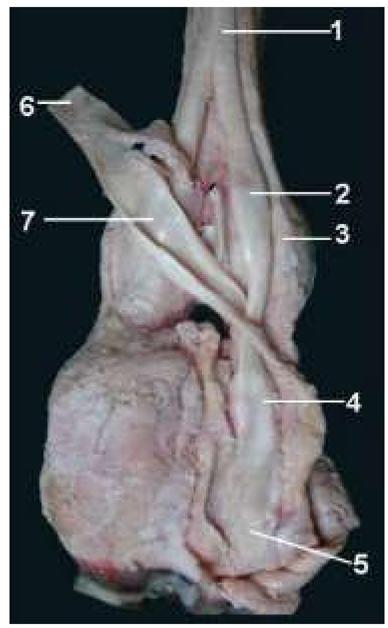


Fig. 10: Dissected planter aspect of the camel fore foot. 1, DDFT; 2, upper fibrocartilagenous enlargement of the (DDFT); 3, proximal scutum; 4, middle fibrocartlagenous enlargement and underneath it middle scutum; 5, insertion of the DDFT in the distal phalanx; 6 and 7, SDFT

The superficial digital flexure tendon (SDFT) were bifurcated distal to the middle of the metacarpal and split below the fetlock joint to allow for passage of the deep digital flexure tendon (DDFT) and inserted in the proximal aspect of the 2nd phalanx by means of the fibrocartilagenous middle scutum. Deep digital flexure tendon was passed between the interosseus medius and superficial digital flexure tendon (Figs. 5-10). At the level of the distal third of the metacarpus it splits, each branch run over the palmar ligament of the proximal sesamoid, pierce the bifurcation of the superficial digital flexure tendon and run over the middle scutum whereas it is enlarged and thickened by fibrocartilage. The tendon fattened and inserted on the flexure surface of the distal phalanx. There were no evident for the presence of distal sesamoid bones in dissected sections or on the CT images.

DISCUSSION

The data presented in this study would serve as an initial reference for the evaluation of CT imaging diagnosis of the one-humped camel foot and foot pad disorders and understanding the complex anatomy of the foot and foot pad in camel. Radiology is a very useful tool and is often the first ancillary imaging test used when a pathological condition of the foot is suspected [18]. It is a planar imaging modality whereas a three-dimensional structure is projected onto two dimensional image results in superimposition of many anatomic structures, which can obscure or confuse important radiographic findings. In general, radiology has significant limitations in evaluation of soft tissues this in a line with that mentioned by Dixon and Dacre [15] and Weller and Taylor [19]. Computed tomography scan is excellent imaging modality. Its usage in veterinary medicine is, however, limited as it is expensive and the animal should be anaesthetized [9, 20]. Nevertheless, it has some potential advantages over the routine radiography; it provides a cross-sectional image with superior soft tissue differentiation and no superimposition of the overlying structures, which can be used for better diagnosis of abnormalities and for evaluating the extent and severity of the lesion , this similar to that reported by Walker *et al* [21]. Between four diagnostic imaging techniques such as radiography, ultrasonography, CT scan, magnetic resonance image (MRI), ultrasonography is most powerful and readily available tool providing cross-sectional imaging with high quality, high frequency system particularly for imaging of digits, but there are many major limitations associated with ultrasonography that make it an unsatisfactory method for the study of the cross-sectional anatomy [9]. The diagnostic ability of the ultrasound is highly operator dependent and that in-depth knowledge of the topographical anatomy is of paramount importance in making accurate diagnosis, in addition to, individual ultrasound images represent only apportion of the complete cross-sectional anatomy [22]. Furthermore, the ultrasound is unable to penetrate bone and structures containing minerals [19,23]. Normal CT image is necessary for identifying anatomical structure of the animal. The present study demonstrates that CT scanning have considerable advantages over the other diagnostic imaging techniques to describe and investigate the detail of the anatomical structures of the camel foot and foot pad. The transverse and sagital sections with their identical CT images were provided more excellent depictions of the anatomical structures of the digits and footpad in camel, while the dorsoplanter plane was not descriptive; this is attributed to the relatively horizontal position of the distal and middle phalanx. In our study, frozen anatomical sections with their analogous CT images revealed that, the nail and proximal, middle and distal phalanges and sesamoid bones were hyperdense on CT images, this is in agreement with Raji *et al.* [9], Baptsite *et al.* [24] whose mentioned that bone and hard tissues appear radio-opaque(hyperdense) on CT images. The deep digital flexure tendon was enclosed by the superficial digital flexure tendon, which appeared with mixed contrast. In the present investigation, it was observed that, in the dissected frozen sections the digital cushions were three fibroelastic soft structures, this confirmed on their analogous CT images where they observed as three slight radiolucent (hypodense) structures rested on more denser sole pad, similar anatomical findings were reported by Smuts and Bezuidenhout [2] Karkoura [4] and Shawki *et al.* [25]. The foot cushion might be serve to absorb mechanical shock, store and return elastic strain energy, protect against local stress and keep pressure low and exhibit similarities to the feet of humans , rhinoceroses and elephants [26]. On CT images the joints and the digital blood vessels were represented the exact radiolucent (hypodense) structures having the least density, these might be attributed to their contents are fluids [9, 27].

CONCLUSION

In conclusion, camel has unique foot morphology among artiodactyls. CT is excellent imaging modality that provides a cross-sectional image with superior soft tissue differentiation and no superimposition of the overlying structures, which can be used for better diagnosis of foot abnormalities.

ACKNOWLEDGMENT

I would like to thank Prof. Dr. Said M.S. Ammar, Professor of Anatomy and Embryology, Fac. Vet. Med., Zagazig University, Egypt, for his valuable advices during preparation of this work.

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