

Computed Tomography and Cross Sectional Anatomy of the Metacarpus and Digits of the One-humped Camel and Egyptian Water Buffalo

Anatomía por Tomografía Computarizada y Sección Transversal del Metacarpo
y DÍgitos del Camello de Una Joroba y el Búfalo de Agua Egipcio

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SUMMARY: The use of advanced imaging in diagnostic patient evaluations is increasing as well as the availability of machines for veterinary practices. The purpose of this study was to provide an atlas of synchronized normal computed tomography and cross sectional anatomy of the metacarpus and digits in the one-humped camel and Egyptian water buffalo to provide a basis for diagnosis of their diseases by the aid of CT. One cm contiguous transverse CT images and cross sectional anatomy were obtained and photographed. Clinically applicable anatomic structures were identified and labeled at each level. In both animals, the medullary cavity of the fused third and fourth metacarpal bones was divided internally by a vertical bony septum which was a complete septum in the camel, complete at the proximal and distal extremities in the buffalo and small and incomplete in main part of fused shaft of metacarpal bones in buffalo. The CT of the present study in both camel and buffalo showed the adjacent extensor tendons as transverse narrow strap with undifferentiated outlines on the dorsal aspect of fused metacarpal bones, proximal phalanges and middle phalanges and the adjacent flexor tendons as roughly rounded mass with undifferentiated outlines on the palmar aspect of fused metacarpal bones, proximal phalanges and middle phalanges. The undifferentiated outlines of the adjacent extensor or flexor tendons in CT images is equivalent to cross sectional anatomy without dissection of the intervening fascia, where the outlines didn't appear in the latter also. Therefore, the cross sectional anatomy is superior to CT only when the intervening fascia is dissected. CT images of the current study have the potential to become part of our standard diagnostic investigation for anatomic regions previously difficult to be evaluated in the camel and buffalo.

KEY WORDS: Computed Tomography; Camel; Buffalo; Metacarpus; Digit.

INTRODUCTION

The camel and buffalo are very important meat producing animals, as well as the buffalo is the main milk producing animal in Egypt. The aggregate share of buffalo milk is about 81% of total milk production in Egypt (Soliman & Sadek, 2004). The diseases of limbs are not rare, which necessitates awareness with its normal structure. Classical anatomic atlases cannot provide the spectrum of views and the details required in modern diagnostic and surgical techniques (Gehrmann *et al.*, 2006; Dyson & Murray, 2007; Vanderperren *et al.*, 2008; Raji *et al.*, 2008).

Computed tomography (CT) is able to discriminate physical density differences as small as 0.5%, whereas in conventional radiography 10% physical density difference is needed for visual detection and the CT eliminates the problem of the organ shadow projection one upon another

in the conventional radiography (Assheuer & Sager, 1997). Also a major advantage of CT over plain radiography is the ability to visualize internal anatomy without superimposition of adjacent structures (Mackey *et al.*, 2008).

CT currently plays a prominent role in the diagnosis and evaluation of many human diseases. It was not initially used in veterinary medicine because of its limited accessibility and high costs. However recently the accessibility has improved, which has increased the need of expertise in the use of this technique in animals (Ottesen & Moe, 1998). Since CT has become more available to veterinarians, the knowledge of the normal conventional anatomy and radiographic anatomy could serve as a basis for recognizing structural abnormalities in diseased animals (Assheuer & Sager).

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No one can deny the importance of the limbs in body support and weight bearing of large animals. So the aim of the present study was the offering of an atlas of synchronized normal computed tomography and cross sectional anatomy of the metacarpus and digits in the camel and buffalo as well as to compare between metacarpus and digits in these species. And finally providing a diagnostic basis by the aid of CT in these economically important animals.

MATERIAL AND METHOD

The present work was carried out on the metacarpus and digits of twelve symptomatically healthy adult camel and buffalo (six camel of 10-15 years old and six buffalo of 5-7 years old) and 4 males and 2 females of each species. The specimens were obtained from Tok and Tala slaughter house immediately after slaughtering by disarticulating the carpometacarpal joint. The specimens were cooled and imaged within 12 hours to minimize post-mortem changes.

The specimens underwent consecutive CT scan, with slice thickening of 1 cm, using TOSHIBA 600 HQ (third-generation equip TCT). CT scan was carried out at Ahmed Farid radiology Center-Benha. After CT images were obtained, the buffalo and camel metacarpus and digits were frozen at -20° then sectioned transversely using an electric band saw, to correspond with the CT images. All sections were cleaned and photographed.

Important anatomic structures were detected and labeled in gross cross-sections photographs and its corresponding CT scans. These sections were exposed in a proximal to distal progression from the level of 1 cm below the carpus to 2 cm distal to the coffin joint. The nomenclature used in this work was adapted to (Schaller, 2007) and the (Nomina Anatomica Veterinaria, 2005).

RESULTS

The results of the present study were performed on 8 CT images and 8 gross-sections of the camel and buffalo metacarpus and digits. CT provided good discrimination between bone and soft tissue and slight to moderate discrimination between the adjacent soft tissues according to their physical density difference.

The skeleton of the metacarpus was formed in both animals by the fused third and fourth metacarpal bones. In buffalo they were fused along its length except its distal ar-

ticular surfaces while in the camel they were fused, except in its distal fifth where they still separated. The small metacarpal bone (Mc.V) (Figs. 1B and 1D/11) was present in the buffalo and absent in camel, where it lied against the proximal part of the lateral border of the large bone.

The proximal extremity (base) of the fused third and fourth metacarpal bones showed an internal vertical bony septum in both camel and buffalo (Figs. 1A and 1D/2). The latter septum in the camel, is extended along the line of the fusion of the two bones thus completely dividing the medullary cavity of the proximal extremity and the shaft of fused third and fourth metacarpal bones (Figs. 1A, 1C, 2A, 2C/2, 3 and 4). While in the buffalo the septum was incomplete and extended only for about 4-5cm distal to the carpal articular surface. So it completely divided the medullary cavity of the proximal extremity and the first 4-5 cm of the shaft and partially dividing the medullary cavity of the main part of the shaft of the fused bones in buffalo (Figs. 1B, 1D, 2B, 2D/2, 3 and 4).

The vertical bony septum at the distal extremity (head) of the fused third and fourth metacarpal bones of buffalo was relatively thick and completely divided the medullary cavity of the distal extremity (Figs. 3B, 3D/3, 4 and 5). The latter septum of distal extremity extended proximally for only 3-4 cm where it became partial again similar to the main septum of the shaft. This septum was absent in the distal extremity of camel as the two metacarpal bones were separated (Figs 3A and 3C).

On the dorsal aspect of the fused third and fourth metacarpal bones of both camel and buffalo the tendons of *M. extensor digitorum lateralis* and *M. extensor digitorum communis* (Figs. 1C, 1D, 2C, 2D, 3A, 3C, 3D/6, 7 and 8) were only differentiated in the cross sectional anatomy when the intervening fascia dorsalis manus was dissected. These extensor tendons appeared in CT images as narrow undifferentiated transverse strap on the dorsal aspect of the fused bones in both animals (Fig. 3A/6).

On the palmar aspect of the fused third and fourth metacarpal bones in both animals, the interosseous muscle appeared more distinctly in the cross sectional anatomy than in CT (Figs. 1A-D/5, 2A-D/5 and 3A-D/8). The deep digital flexor tendon (Figs. 1A-1D/9, 2A-2D/8 and 3A-D/9) and the superficial digital flexor tendon (Figs. 1A-1D/10, 2A-2D/9 and 3A-3D/10) were only differentiated in the cross sectional anatomy when the intervening palmar fascia was dissected. These flexor tendons appeared in CT images on the palmar aspect of the interosseous muscle as well as the fused metacarpal bones where the outline of each tendon could be differentiated.

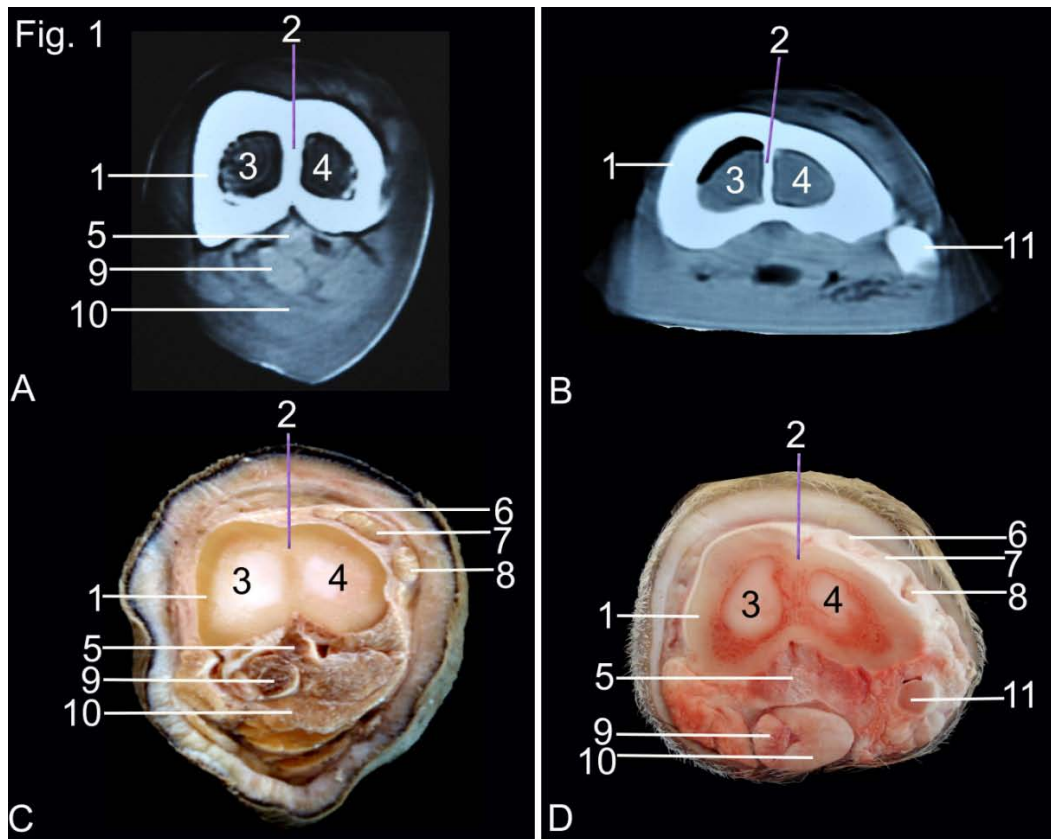


Fig. 1. CT scans and cross sections at the base of the left large metacarpal bone and 3cm distal to the carpal articular surface.
 1. Fused 3rd and 4th metacarpal bones.
 2. Bony septum.
 3. and 4. Medullary cavities.
 5. Interosseous muscle.
 6 and 7. Medial and lateral tendons of common digital extensor muscle, respectively.
 8. Tendon of lateral digital extensor muscle.
 9 and 10. Tendons of deep and superficial digital flexor muscles, respectively.
 11. 5th metacarpal bone in buffalo.

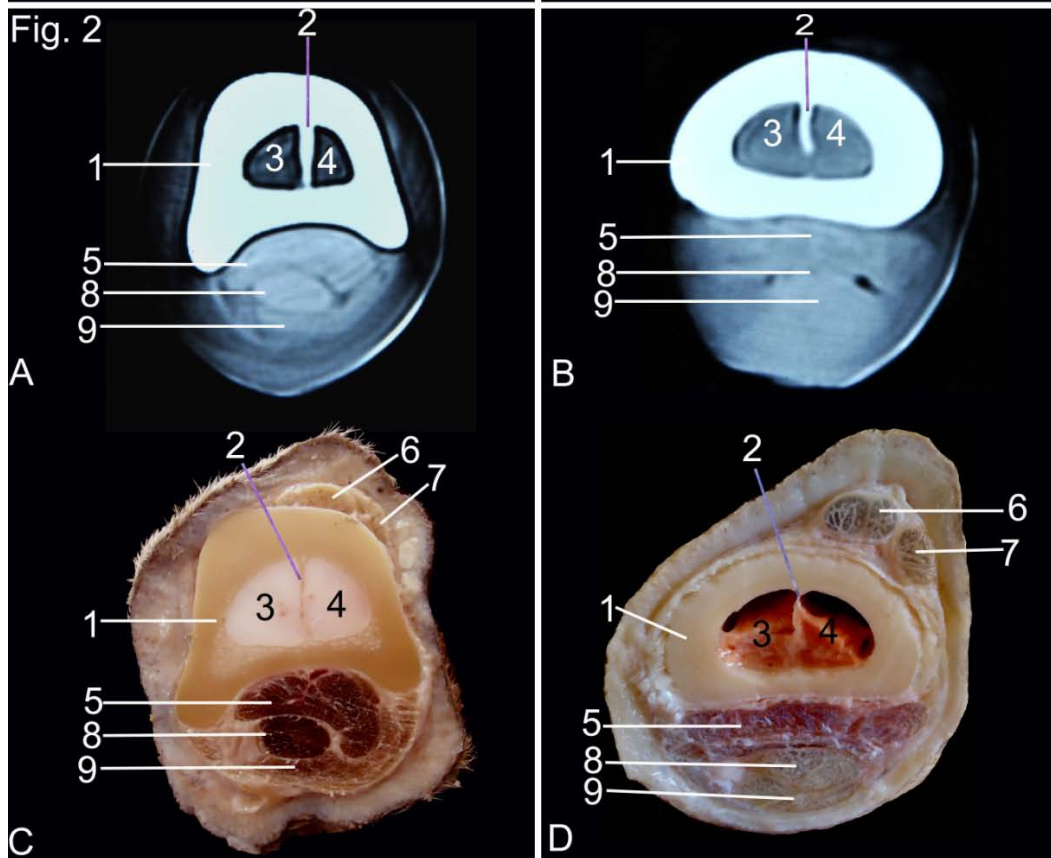


Fig. 2. CT scans and cross sections at the middle of the left large metacarpal bone.
 1. Fused third and fourth metacarpal bones.
 2. Bony Septum between fused third and fourth metacarpal bones.
 3 and 4. Medullary cavities.
 5. Interosseous muscle.
 6. Tendon of common digital extensor muscle.
 7. Tendon of lateral digital extensor muscle.
 8 and 9. Tendons of deep and superficial digital flexor muscles, respectively.

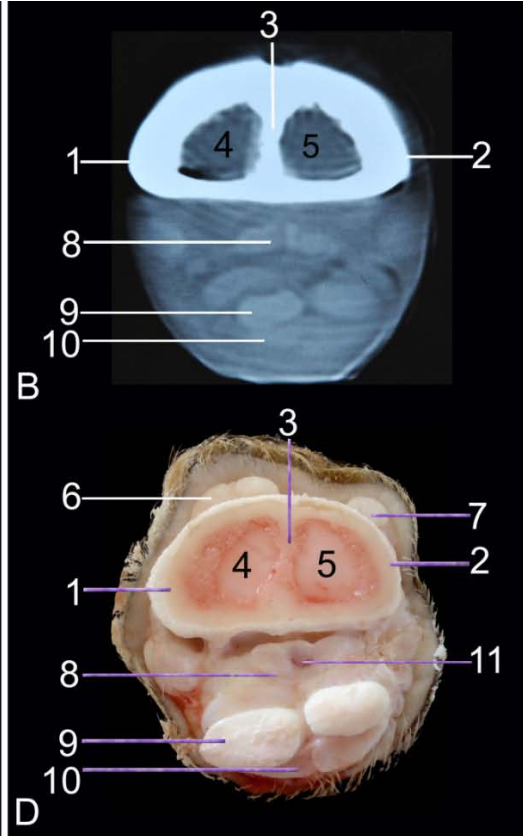
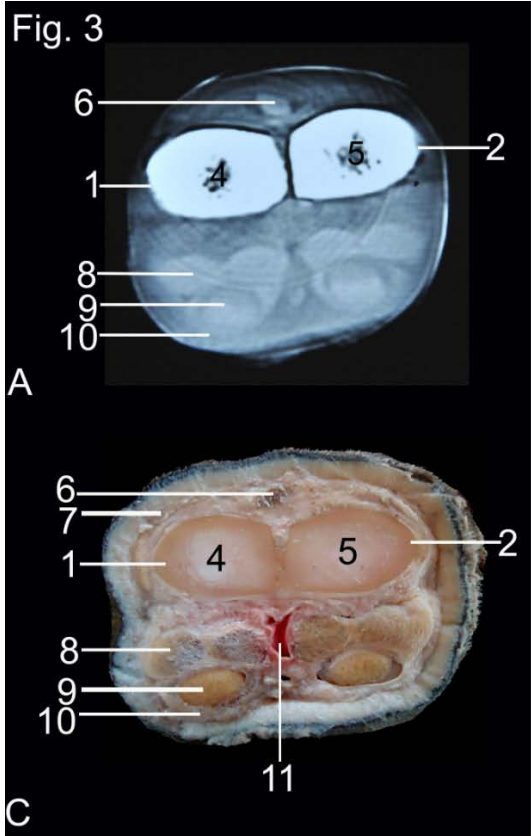


Fig. 3. CT scans and cross sections at the level of the head (distal extremity) of the left large metacarpal bone, 3cm above the distal articular surface.

1. Third metacarpal bone.
2. Fourth metacarpal bone.
3. Septum between fused third and fourth metacarpal bones.
- 4 and 5. Medullary cavities.
6. Tendon of common digital extensor muscle.
7. Tendon of lateral digital extensor muscle.
8. Interosseous muscle.
9. Tendons of superficial digital flexor muscles.
10. Tendon of deep digital flexor muscles (divided).
11. Common palmar digital artery II (A. digitalis Palmaris communis II).
12. Common palmar digital vein II (V. digitalis Palmaris communis II).

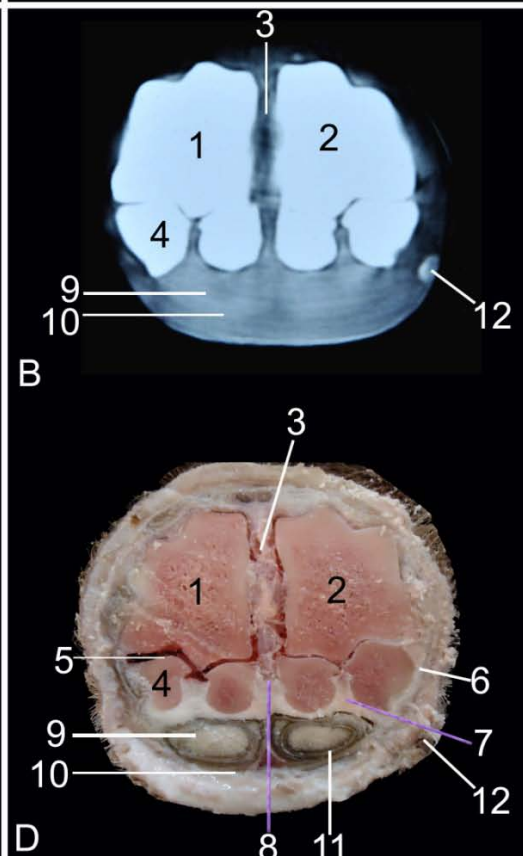
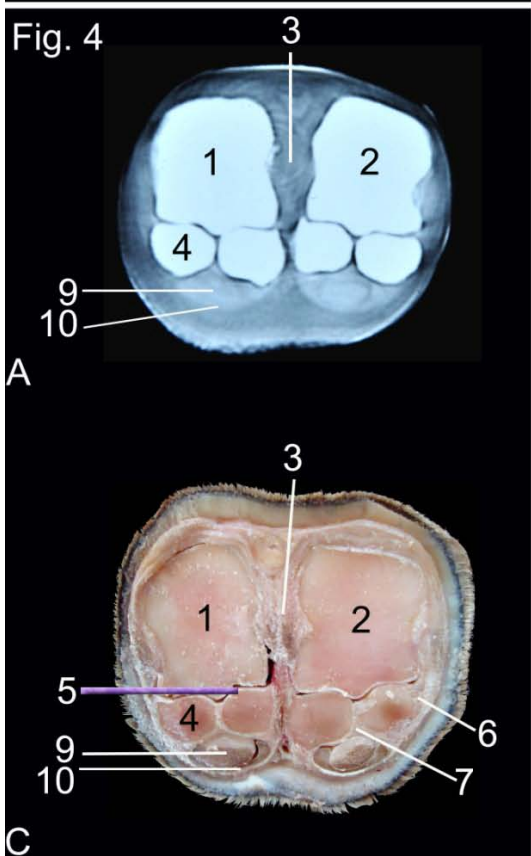


Fig. 4. CT scans and cross sections at the level of the left metacarpophalangeal (Fetlock) joint.

1. Distal end of third metacarpal bone.
2. Distal end of fourth metacarpal bone.
3. Intertrochlear notch.
4. Proximal sesamoid bone.
5. Metacarpophalangeal articulation.
6. Collateral sesamoid ligaments.
7. Palmar ligaments.
8. Inter-digital inter-sesamoid ligament.
9. Divided Tendon of deep digital flexor muscle.
10. Tendon of superficial digital flexor muscle.
11. Manica flexoria.
12. Fifth digit of buffalo.

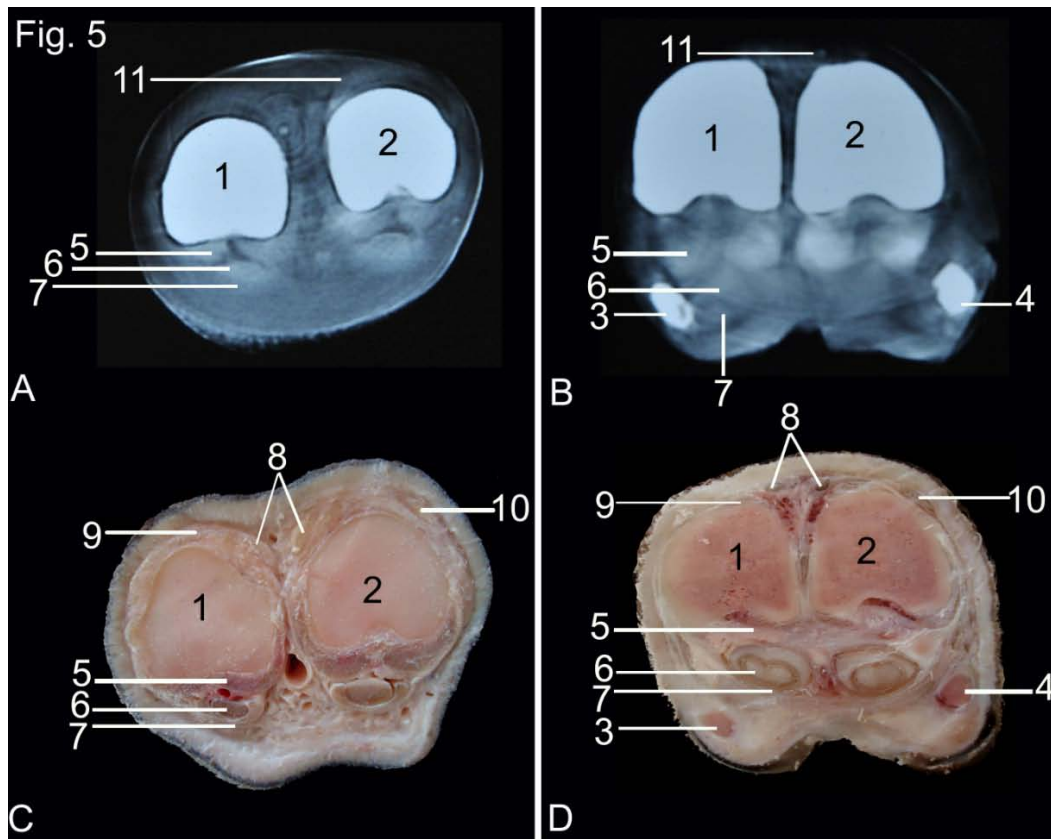


Fig. 5. CT scans and cross sections of the left fore digits at the level of the proximal end of the proximal phalanx.
 1. Proximal end of proximal phalanx of third digit.
 2. Proximal end of proximal phalanx of fourth digit.
 3. Second digit.
 4. Fourth digit.
 5. Interosseous muscle.
 6. Tendon of deep digital flexor muscle.
 7. Tendon of superficial digital flexor muscle.
 8. Lateral tendons of common digital extensor muscle.
 9. Medial tendon of common digital extensor muscle.
 10. Tendon of lateral digital extensor muscle.
 11. Extensor tendons (not outlined).

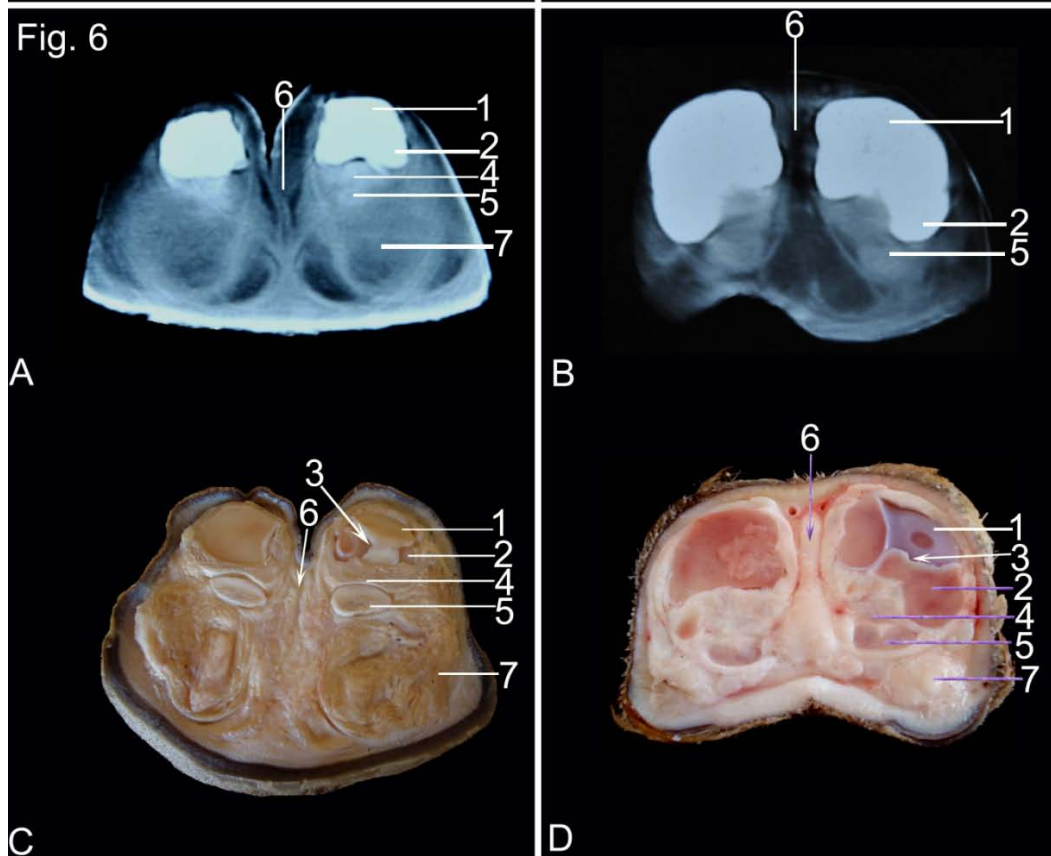


Fig. 6. CT scans and cross sections of the left fore digits at the level of the proximal interphalangeal (pastern) joint.
 1. Distal end of proximal phalanx of fourth digit.
 2. Proximal end of middle phalanx of fourth digit.
 3. Proximal interphalangeal articulation.
 4. Tendon of superficial digital flexor muscle.
 5. Tendon of deep digital flexor muscle.
 6. Proximal interdigital ligament.
 7. Tela subcutanea tori (digital cushion).

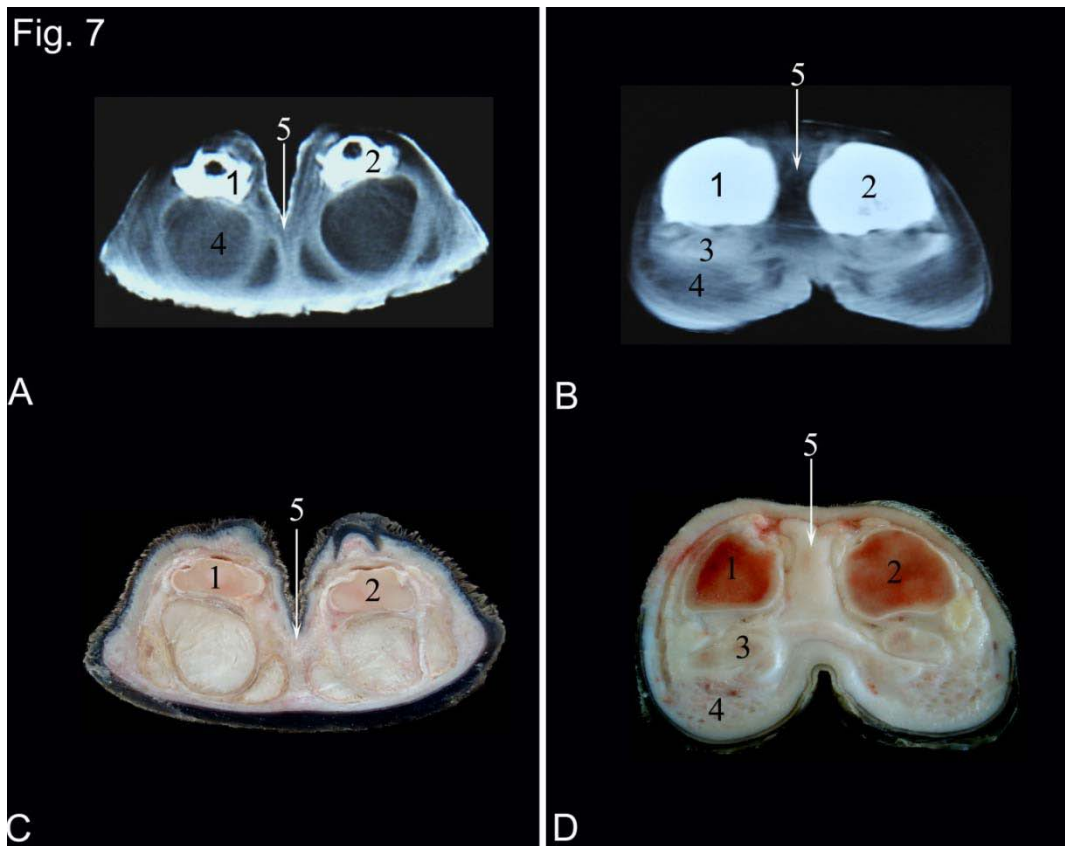


Fig. 7. CT scans and cross sections of the left fore digits at middle of the middle phalanx. . Body of middle phalanx of third digit. 2. Body of middle phalanx of fourth digit. 3. Tendon of deep digital flexor muscle. 4. Digital cushion. 5. Interdigital ligament.

The Manica flexoria that was a tubular sheath formed by the superficial digital flexor tendon and the interosseous muscle around the bifurcated deep digital flexor tendon in the vicinity of the metacarpophalangeal (fetlock) joint. It was easily demarcated only in the cross sectional anatomy in buffalo (Fig. 4D/11).

Two metacarpophalangeal (fetlock) joints were present in each forelimb, in both animals, one for each digit. The articular cavity was a potential cavity so it did not appear in the CT images, while in the cross sectional anatomy, it appeared linear, except if it was widened artificially (Figs 4C&4D/5). The axial and abaxial proximal sesamoid bones of each metacarpophalangeal joint were connected by a palmar ligament (Figs. 4C and 4D/7). The two axial proximal sesamoid bones in the buffalo were connected together by the inter-digital intersesamoidean ligament (Fig 4D/8). The later ligament was absent in the camel. Each abaxial proximal sesamoid bone was attached to the corresponding (medial or lateral) aspect of the head (distal extremity) of the fused third and fourth metacarpal

bones by a collateral sesamoidean ligament (Fig. 4A-D/6).

The 2nd and 5th digits of the buffalo appeared in both CT and cross sectional anatomy at the level of the base of the proximal phalanx (Figs 5B, 5D/3 and 4). These digits were absent in the camel.

In the camel the interdigital ligament connect the third and fourth digits from the level of the middle interphalangeal joint and continuous distally to the level of the coffin joint (Figs. 6A, 6C/6, 7A, 7C/5, 8A and C/9). While in the buffalo there were two interdigital ligaments. The first was the proximal interdigital ligament that connected the proximal phalanges of the third and fourth digits along its interdigital surfaces (Figs. 6B and 6D/6). The second was the distal interdigital ligament that connected the third and fourth digits at the level of the distal interphalangeal joints (Figs. 8B and 8D/9).

On the cross sectional anatomy of both animals, the tendon of M. extensor digitorum lateralis appeared on the

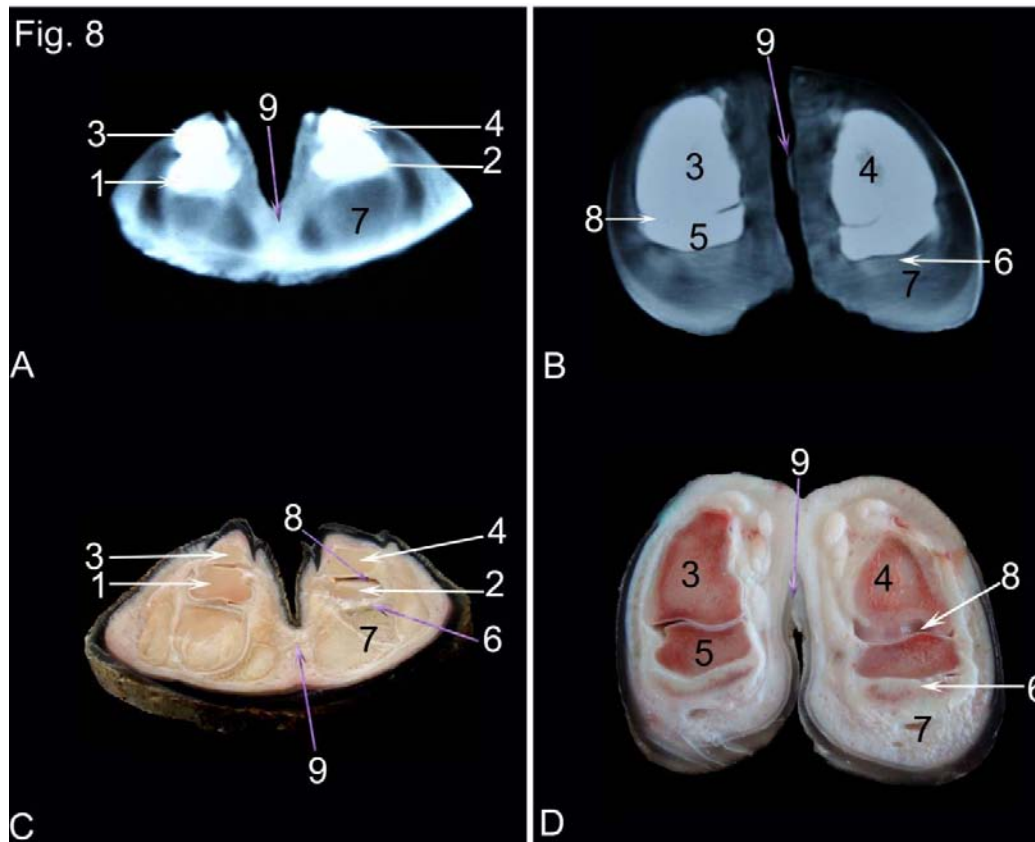


Fig. 8. CT scans and cross sections of the left fore digits at the level of the distal interphalangeal (Coffin) joint. 1. Distal end of middle phalanx of third digit. 2. Distal end of middle phalanx of fourth digit. 3. Distal phalanx of third digit. 4. Distal phalanx of fourth digit. 5. Distal sesamoid bone. 6. Tendon of deep digital flexor muscle. 7. Tela subcutanea tori (digital cushion). 8. Distal interphalangeal articulation. 9. Distal Interdigital ligaments.

dorsal abaxial surface of the proximal and middle phalanges of the 4th digit (Figs. 5C and 5D/9). And the tendon of the medial belly of *M. extensor digitorum communis* appeared on the dorsal abaxial surface of the proximal and middle phalanges of the third digit (Figs. 5C and 5D/9). On other hand the bifurcated tendon of the lateral belly of *M. extensor digitorum communis* were only differentiated after partial dissection of the dorsal fascia of the manus. The branches of this bifurcated tendon appeared on the dorsal axial surface of its corresponding digit (Figs. 5C and 5D/8). These extensor structures appeared in the CT images only as a narrow undifferentiated transverse strap on the dorsal surface of the proximal and middle phalanges in both animals (Figs. 3A/6, 5A and 5B/11).

On the palmar aspect of the digits in both animals, the cross sectional anatomy could only differentiated the deep digital flexor tendon (Figs. 5C, 5D/6, 6C, 6D/5, 7C, 7D/3, 8C and 8D/6) and superficial digital flexor tendon (Figs. 5C, 5D/7, 6C and 6D/4), when the palmar fascia was partially dissected. These structures of flexor tendons were

appeared in the CT images as a rounded gray mass, while their outlines were undifferentiated (Figs. 5A, 5B/6, 7, 6A and 6B/5). In both animals, the superficial digital flexor tendon (Fig. 6/4) gained a deeper position to that of the deep digital flexor tendon (Fig. 6/5), just distal to the fetlock joint, and prior to its insertion in the base of the middle phalanx.

In both animals, the proximal interdigital (pastern joint) (Fig. 6/3) was formed by articulation between the head of the proximal phalanx and the base of the middle phalanx. The distal interphalangeal (coffin) joint (Fig. 8/8) was formed by articulation between the head of the middle phalanx, the distal phalanx and the distal sesamoid (navicular) bone in the buffalo (Figs. 8B and 8D/5) while in camel the distal sesamoid bone was presented as distal sesamoid (navicular) cartilage. The latter joint is bounded palmarly by the digital cushion in both animals (Fig. 8/7) and the articular cavity (Fig. 8/8) was a potential cavity so it appeared linear in the cross sectional anatomy, but didn't appear in the CT images.

DISCUSSION

The present study stated the first information about the CT scans of the metacarpus and digits of one humped camel and Egyptian water buffalo. The present knowledge of normal cross sectional anatomy of the camel and buffalo metacarpus and digits is essential for evaluation of CT scans.

Advances in diagnostic techniques are continuously sought to assist clinical practitioners of veterinary medicine with making a definitive diagnosis, providing an accurate prognosis and determining the most appropriate treatment strategy. In the present study the CT images of the camel and buffalo metacarpus and digits provides acceptable details of the anatomical structures and were correlated well with its corresponding gross anatomical specimens. In accordance with some authors (Barbee & Alien, 1987; Peterson & Bowman, 1988; Dick, 1995; Whitton *et al.*, 1998; Arencibia *et al.*, 2000; Probst *et al.*, 2005; Vanderperren *et al.*) in horse, in bovine (Raji *et al.*), in small ruminant (Bahgat, 2007), in dog (Fike *et al.*, 1981, 1984; Feeny *et al.*, 1991; Ottesen & Moe) and in human (Gehrmann *et al.*) the CT provides good discrimination between bone and soft tissue architectures. Thus the computed tomography (CT) has become an important diagnostic imaging modality in the diagnosis of the musculoskeletal disorders (Bienert & Stadler, 2006).

The CT images and cross sectional anatomy of the present work revealed that both of proximal and distal extremities of the fused third and fourth metacarpal bones of buffalo had an internal vertical bony septum, which extended only for 4-5 cm while within the main part of the fused shaft the septum was small and incomplete and partially dividing the medullary cavity in this species. Similarly, in ruminant (Sisson, 1975) and in small ruminant (Bahgat) stated that the medullary cavity of the fused metacarpal bones is divided into two parts by a vertical septum, which is usually incomplete in the adult. While the present study in the camel revealed that the vertical bony septum was inclusive and completely dividing the medullary cavity of the fused 3rd and 4th metacarpal bones. The latter observation in camel is in agreement with the report of Smuts & Bezuidenhout (1987) in same species. The small incomplete bony septum within the main part of the fused metacarpal bones in buffalo and its inclusive nature in camel might be associated with the higher occurrence of metacarpus fractures in buffalo than that of camel.

The CT of the present study in both camel and buffalo showed the adjacent extensor tendons as transverse narrow strap on the dorsal aspect of fused metacarpal bones, proximal phalanges and middle phalanges. And the adjacent

flexor tendons appeared as roughly rounded mass on the palmar aspect of fused metacarpal bones, proximal phalanges and middle phalanges. While the distinct outline of each tendon was undifferentiated. This might be due to a physical density difference less than 0.5%. In this respect (Assheuer & Sager) mentioned that CT is able to discriminate physical density differences as small as 0.5%. On other hand the undifferentiated outlines of the adjacent extensor or flexor tendons in CT images is equivalent to cross sectional anatomy without dissection of the intervening fascia, where the outlines didn't appear in the latter also. Therefore, the cross sectional anatomy is superior to CT only when the intervening fascia is dissected. So CT may provide earlier detection of abnormalities and more accurate evaluation of clinical disease and can be considered a good tool for diagnosing diseases of the metacarpus and digits of the camel and buffalo. CT is an excellent imaging modality has some potential advantages over routine radiography; it provides a cross-sectional image which can be used for better diagnosis of abnormalities and for evaluating the extent and severity of the lesion (Walker *et al.*, 1993). It has also considerable advantages over ultrasonography because ultrasound images represent only a portion of the complete cross-sectional anatomy and is unable to penetrate structures that contain minerals (Samii *et al.*, 1998).

The present study serve as an initial reference aid in CT imaging diagnosis of the one-humped camel and Egyptian water buffalo metacarpus and digits disorders. More benefits could be harvested from CT imaging when a future study is focused on certain part or joint, especially when the inter-slicing space is few millimeters.

EL-SHAFFEY, A. & SAYED-AHMED, A. Anatomía por tomografía computarizada y sección transversal del metacarpo y dígitos del camello de una joroba y el búfalo de agua Egipcio. *Int. J. Morphol.*, 30(2):473-482, 2012.

RESUMEN: El uso de imágenes avanzadas en las evaluaciones diagnósticas del paciente es cada vez mayor, así como la disponibilidad de máquinas para la práctica veterinaria. El propósito de este estudio fue proporcionar un atlas de anatomía por tomografía computarizada sincronizada normal y sección transversal del metacarpo y los dedos en el camello de una joroba y búfalos de agua Egipcios para proporcionar una base para el diagnóstico de sus enfermedades con la ayuda de TC. Fueron obtenidas y fotografiadas imágenes anatómicas de TC transversales de 1 cm contiguas y de sección transversal. Las estructuras anatómicas de aplicación clínica fueron identificadas y etiquetadas en cada nivel. En ambos animales, la cavidad medular de los

huesos metacarpianos tercero y cuarto fusionados se dividió internamente por un septo vertical de hueso, el cual era un septo completo en el camello y completo en los extremos proximal y distal en los búfalos, y pequeños e incompletos en la parte principal de eje de fusión de los huesos metacarpianos en los búfalos. La TC mostró tanto en camellos como en búfalos a los tendones extensores adyacentes como una correa transversal estrecha con los contornos indiferenciados en la cara dorsal de los metacarpianos fusionados, falanges proximales y falanges media y, los tendones flexores adyacentes como una masa más o menos redondeada con contornos no diferenciados en la cara palmar de la fusión de los huesos metacarpianos, falanges proximales y falanges medias. Las líneas diferenciadas de los tendones extensores o flexores adyacentes en las imágenes de TC fue equivalente a la anatomía de sección transversal sin disección de la fascia de intervención, donde las líneas no aparece en el último. Por lo tanto, la anatomía de sección transversal es superior a la TC sólo cuando la intervención disecciona la fascia. Las imágenes de TC del presente estudio tienen el potencial para convertirse en parte de nuestra investigación de diagnóstico estándar para las regiones anatómicas previamente difíciles de evaluar en el camello y el búfalo.

PALABRAS CLAVE: Tomografía computarizada; Camel; Bufalo; Metacarpos; Dígitos.

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