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ROLE OF DIAGNOSTIC IMAGING IN DIAGNOSIS OF CAMEL LAMENESS: CURRENT STATUS AND FUTURE PROSPECTIVES

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ABSTRACT

Camel lameness constitutes a major welfare problem and has a negative economic impact. Lameness in dromedaries has a different pattern than in cattle and horses, therefore it's diagnosis is a big challenge for veterinarians. Radiography and ultrasonography (US) are well-established in dromedaries, whereas computed tomography (CT) and magnetic resonance imaging (MRI) are becoming increasingly common. CT and MRI accurately describe the bones and soft tissues, eliminate structural superimposition in the dromedary camel's limbs and allow for the assessment of minute ligamentous and tendentious structures that are inaccessible by US. However, US and MRI are useful for assessing the articular cartilage that is not evident on normal CT images. Ultrasonography is a useful tool for assessing soft tissues, articular cartilage and bone shapes. However, CT and MRI may be used when US data are unclear or to assess inaccessible regions of the camel's limbs. MRI and CT are becoming more widely recognised as very accurate imaging techniques in camel practice. Nevertheless, restricted accessibility, the necessity for animal general anaesthesia and expensive expenses reduce the usefulness of these techniques in camels. As a result, all previous research on the use of CT and MRI in dromedary camels was done on cadavers. Future clinical trials are strongly recommended to document the usefulness of these techniques in diagnosis of camel lameness. Furthermore, the availability of adequate or customised CT and MRI machines for use in camel practice is essential. An atlas of normal CT and MRI scans of all regions of the musculoskeletal system in camels is desperately needed to cover the diagnostic imaging gap in camel practice. This narrative review describes the current status and future prospective of using diagnostic imaging techniques in diagnosis of camel lameness.

Key words: Camel, computed tomography, lameness, magnetic resonance imaging, radiography, ultrasonography

Lameness in camels has a negative economic impact, is a big welfare concern and emerges in a different pattern than in cattle and horses due to the unique anatomy, physiology, biomechanics, geoclimatic adaptability and usage of camel limbs (Gahlot, 2000; Janis *et al,* 2002). The economic losses include; low milk production, decreased reproductive performance, growth retardation, culling of the camel from competition or farm, decreased physiological vitality of the camel and increased costs for caring and treating the diseased animal (Al-Juboori, 2013).

Camel lameness has a wide range of causes, including physical trauma, diet, illness and fractures (Singh and Gahlot, 1997; Sharma and Sharma, 2006; Levine *et al,* 2007; Mohamed, 2012). According to the camel's age, traumatic injuries, fractures, soreness and punctures to the foot were the most prevalent causes of lameness in juvenile racing camels, whereas abscesses and muscle spasms were the most common causes in adult racing camels. Moreover, lameness of the distal limb area in dromedary camels is rather common (Al-Juboori, 2013).

Lameness is the fourth most economically important condition in camel cows, followed by mastitis, reproductive disorders and metabolic illnesses (Cynthia, 2005). The total prevalence of acute and chronic lameness in camel is 9.39% and 2.50%, respectively. Lameness was more common in forelimbs (67.76%) than in hindlimbs (32.24%) (Al-Juboori, 2013). The prevalence of musculoskeletal disorders is 10.14% and 55.62% in camels brought into clinics and field cases, respectively (Singh and Gahlot, 1997). In a recent survey, the incidence of the distal limb lameness is 28.22% and the foot disorders are the most common diseases causing lameness (59.05%) followed by the fetlock and metacarpus

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(MC)/metatarsal (MT) disorders (40.94%) (Mostafa, 2020).

Imaging methods give critical pathologic and physiologic information required to treat certain diseases. There are two types of imaging methods: anatomical and physiological. Radiology, ultrasonography, CT scanning and MRI are all examples of anatomic imaging modalities. Scintigraphy and thermography are two physiological imaging modalities. To provide a definitive diagnosis of orthopedic disorders in camels, a full orthopedic examination must be combined with appropriate imaging modalities (Ibrahim *et al,* 2019). Radiography and US are well-established in dromedaries, whereas CT and MRI are gaining popularity. In camels, CT delivers far more bone information than any other imaging method (Bhabhor and Tanwar, 2023). However, US and MRI remain the best alternatives for soft tissue imaging (El Nahas *et al,* 2024). This narrative review describes the current status and future prospective of using anatomic diagnostic imaging techniques in diagnosis of camel lameness.

Data collection

This narrative review was based on a comprehensive literature search for all relevant English-language articles on the use of imaging methods in diagnosis of camel lameness in February, 2024. The literature relevant to this issue for the previous 35 years (1989-2024) was searched in PubMed, Scopus and Google Scholar databases. This review examined and critically assessed the relevant literature. The search phrases included "camel", "radiography", "ultrasonography", "computed tomography", "magnetic resonance imaging" and "lameness".

Radiography

Radiologic techniques are the most routinely utilised to assess lameness in camels. Plain radiography is traditionally used in camels for diagnosis of fractures (Squire and Boehm, 1991), congenital limb anomalies like supernumerary digits (Bani-Ismai *et al,* 1999), angular fetlock deformity (Fahmy *et al,* 2006), panosteitis (Levine *et al,* 2007) and assessment of the normal structures of joints (Alsafy *et al,* 2018; 2021).

Contrast radiography offers information regarding articular cartilage and surfaces and is especially useful for detecting if subchondral cysts interact with the joint and outlining subcutaneous pathways (Mostafa *et al,* 1993). Puncturing and contrast arthrography of the interphalangeal, fetlock, intercarpal and radiocarpal joints are very simple compared to those of the shoulder and elbow joints (Mostafa *et al,* 1993; Al-Sobayil *et al,* 2015). In dromedary camels, arthrographic-guided approaches provide significant benefits for identifying anatomical landmarks and selecting the best intra-articular (IA) injection location in the hindlimb. Furthermore, a reference technique for camels is developed, which differs from the approach for cattle and horses (Al-Sobayil *et al,* 2021).

Radiography, either plain or contrast, is the most available and commonly used diagnostic imaging tool in both normal and injured camel limbs. Nevertheless, more future studies are recommended to investigate its role in diagnosis of various orthopedic disorders in camels.

Ultrasonography

Ultrasonography is widely utilised as a safe and non-invasive diagnostic method in farm animal practice (Abu-Seida, 2012; Abu-Seida, 2016; Hassan and Abdelgalil, 2020; Hassan *et al,* 2024). Compared to other farm animals, ultrasonography is underutilised in camel management; yet, it can help veterinarians with more precise diagnosis and treatment of a variety of dromedary disorders (Abu-Seida, 2016). Ultrasonography is particularly effective in assessing tendons and ligaments, although it may also be used to assess muscle, cartilage and bone shapes (Abu-Seida *et al,* 2012).

Several investigations have been undertaken on the normal carpal joint (Kassab, 2008), tarsus (Hagag *et al,* 2013) and foot (Abu-Seida *et al,* 2012) of camels. However, no investigations on ultrasonography diagnosis of lameness in camels have been recorded. Ultrasound can clearly identify the *extensor carpi radialis, extensor digitorum communis* and *extensor digitorum lateralis* tendons on the dorsal surface of the carpus and the distal radius. Meanwhile, the *extensor carpi obliqus* tendon is difficult to identify, whereas the *ulnaris lateralis* tendon is visible laterally. Furthermore, the *flexor carpi radialis, flexor digitorum superficialis* and *flexor digitorum profundus* tendons may be seen on the palmar side (Kasseb, 2008). Ultrasonography of the foot can scan the common digital extensor tendon and its medial as well as lateral branches, superficial digital flexor tendon (SDFT), deep digital flexor tendon (DDFT), synovial fluid, tendon sheath, phalanges, digital cushions (DC) and interdigital septum (Abu-Seida *et al,* 2012).

Arthrocentesis plays a crucial role in diagnosis and treatment of most joint disorders in camels (Badawy and Eshra, 2016). To increase the success

rate, feasibility, accuracy and simplicity of execution of this technique, it should be conducted under US guidance. A high-frequency ultrasound-guided approach has recently been recommended to ensure accurate needle placement for arthrocentesis of the lateropalmar pouch of the radiocarpal joint via a lateral approach in an extended position. This approach has many advantages like low risk of damaging the articulating cartilage surface and the elimination of inadvertent communication with the extensor carpi radialis, common digital extensor and DDFT sheaths (King *et al,* 2022). Also, a lateral arthrocentesis approach through the proximal palmar/plantar pouches of the metacarpophalangeal/metatarsophalangeal and proximal interphalangeal joints is advised under ultrasonography guidance. This method prevents the possible needle harm to the articulating joint cartilage and other adjacent joint components such tendons, blood vessels and nerves (Al Aiyan *et al,* 2023).

A recent study has been described the ultrasonography findings of the tendons and ligaments on the palmar (plantar) aspect of the cannon and phalangeal area of one-humped camels. SDFT, DDFT and suspensory ligament (SL) differ in form and echogenicity across the cannon bone's proximal, middle and distal thirds, as well as the phalangeal area. The authors reported that there is no discernible difference between live animals and cadaveric samples (Gadallah *et al,* 2023). Although, US is useful for assessing soft tissues, articular cartilage and bone shapes in camels, US cannot penetrate minute ligamentous and tendentious structures such as the axial collateral ligaments, ligaments supporting the proximal sesamoid bones and the palmar/plantar aspects of the interphalangeal joints (El Nahas *et al,* 2024).

The ultrasonography data obtained from previous studies on musculoskeletal system of camels will be used as a reference tool for practicing veterinarians as well as future investigations on camel orthopaedic injuries. Nevertheless, there is a significant lack of use of ultrasound to identify the rest of the musculoskeletal structures in camels. In addition, there is a lack of clinical research dealing with the use of US in diagnosing and treating orthopaedic problems in camels. Therefore, it is recommended to conduct future studies on the normal US characteristics of all parts of musculoskeletal system in camels and on the use of US in diagnosing and treating musculoskeletal injuries in dromedary camel.

Computed Tomography (CT)

It is a method that employs extremely tiny X-ray beams from many different angles around the body (known as slices) that are rebuilt by a computer to generate images. As a result, CT scanner produces the best possible pictures of the limbs, joints, skull, sinus cavities and neck. CT has several advantages, including the ability to portray precise cross-sectional anatomy, better contrast resolution and computer reformatting, making it a potentially useful diagnostic method (El-Shafey and Kassab, 2013).

Computed Tomographic Arthrography (CTA) is useful and highly sensitive for the evaluation of the clinically important osseous and soft tissues structures in camels (Badawy, 2016). The only difference between the plain CT and CTA is the intra-articular injection of contrast medium (non-ionic iodinated group) prior to CT scans for enhancement of the characters of CT images (Puchalski, 2012). Post contrast CT images provide better delineation of the intra-articular ligaments, capsular recesses, pre-articular soft tissues, articular margins and articular defects (Badawy *et al,* 2016). Camel CTA shows great promise. It has the potential to significantly improve both the evaluation of athletic animal performance and the identification of musculoskeletal issues in camels. In the subject of camel anatomy, it might disclose the varied anatomical aspects of joints (Badawy, 2016; Badawy *et al,* 2016). Although CT and CTA are now frequently utilised in the diagnosis of horse lameness (Crijns *et al,* 2010), their application in the examination of camel orthopedic disorders remains limited. This is because it relies on availability, the necessity for the animal to be anaesthetised for scanning and the paucity of literature concerning the normal and clinical CT data of particular camel joints (Badawy *et al,* 2016).

All hard and soft tissues in the pastern and coffin joints of the camel clearly appeared in CT images; however, the plantar ligaments of the pastern joint and ligaments of the navicular cartilage were identified on CT images. The CT soft tissue window visualised the joint cavity and their pouches and tendon sheath of the flexor tendons better than the bone window CT (Alsafy *et al,* 2021).

The traditional dorsal arthrocentesis approach of the metacarpophalangeal, metatarsophalangeal, proximal interphalangeal and distal interphalangeal joints, has limitations due to the risk of damaging the tendon structures and articular cartilage, which can lead to joint degeneration. A lateral arthrocentesis approach *via* the proximal palmar/plantar pouches

of the metacarpophalangeal/metatarsophalangeal and proximal interphalangeal joints is recommended after CT images (Al Aiyan *et al,* 2023). This approach eliminates the potential needle injury to the articulating joint cartilage and other surrounding joint structures, such as tendons, blood vessels and nerves.

The 3D CT creates detailed pictures of the digit bones; while the angiograph render volume 3D of the CT depicts the relationship between the digit's arteries, bones and tissues. As a result, these imaging techniques offer a comprehensive description of the origin, distribution and course of the digital bones and arteries, as well as their relationships with surrounding tissues in the dromedary camel (El-Gendy *et al,* 2022).

Magnetic Resonance Imaging (MRI)

It is a very detailed anatomic imaging technology. There are two types of MRI magnets: low-field and high-field. High-field scanners provide a stronger signal and higher resolution images in less time than low-field scanners. MRI for orthopaedic disorders is conducted in multiple acquisition sequences. Each sequence conveys distinct anatomical, physiological and pathologic information. The proton density and T1- as well as T2-weighted images, are the most commonly used sequences. Proton density offers the highest anatomical detail. T1-weighted pictures show the structural qualities of bone and soft tissues, but T2-weighted images show the fluid properties of tissues and are good at identifying synovial effusions, cysts and oedema. Special sequences can help explain or emphasise a lesion (Elemmawy *et al,* 2020). MRI is the most adaptable and useful imaging technique for the diagnosis of locomotor injuries in equine practice (Elemmawy *et al,* 2020; Abu-Seida and Elemmawy, 2023). However; veterinary literature on the MRI of the dromedary camel limbs is limited (Ibrahim *et al,* 2019; Al Mohamad *et al,* 2021).

El-Shafey and Al-Galil (2012) described the normal anatomical structures of the camel's digits and footpad using MRI. They used a magnet of 0.2 Tesla and T1 weighted sequence to produce sagittal, dorsopalmar and transverse MRI images of three camel cadaver digits. The distal limbs were investigated using a 1 Tesla MRI scanner and the acquired MR images clearly scanned the soft tissues of the dromedary camels' pastern and coffin joints (Ibrahim *et al,* 2019). However, the MR scans did not show the palmar/plantar ligaments of the pastern joint or the navicular cartilage ligaments (Ibrahim *et al,* 2019).

MR imaging was performed on the brain of a newborn camel (Arencibia *et al,* 2004) and adult camels (Arencibia *et al,* 2005; Cartiaux *et al,* 2023) using a superconducting magnet with field strength of 1.5-3 T and a human head coil. The authors obtained exceptional soft tissue contrast and anatomical features in the camel's brain and adjacent tissues.

Recently, the soft and osseous components of the dromedary camel tarsus were clearly delineated on MRI images and correlated closely to gross anatomic sections (Al Mohamad *et al,* 2021). In comparison to radiography and US, MRI can examine many structures such as the transverse inter-tarsal ligaments, the talocalcaneal ligament, the short dorsal ligament, branches of the short medial and lateral collateral ligaments and the tarsometatarsal ligaments. CT and MRI eliminate structural superimposition in the distal limbs of dromedary camels and allow for the assessment of minute ligamentous and tendentious structures that are inaccessible by US, such as the axial collateral ligaments, ligaments supporting the proximal sesamoid bones and the palmar/plantar aspects of the interphalangeal joints. US and MRI were useful for assessing the articular cartilage that was not evident on normal CT images (El Nahas *et al,* 2024). CT and MRI accurately detect and describe the bones and soft tissues that make up the dromedary camel's distal limbs. CT and MRI may be used when US findings are unclear or to assess inaccessible regions of the camel's distal limbs (El Nahas *et al,* 2024).

The use of MRI in camel practice is currently limited and no clinical studies have been undertaken on the use of MRI in camel orthopedic disorders due to practical issues with image capture. Limited accessibility, need for animal general anaesthesia and high costs diminish the valuable using of CT and MRI. Therefore, the availability of adequate or customised CT and MRI machines for use in camel practice is essential. Moreover, an atlas of normal CT and MRI scans of all musculoskeletal tissues in camels is desperately needed to cover the diagnostic imaging gap in camel practice.

Anatomic diagnostic imaging techniques play a crucial role in assessment of various musculoskeletal structures in camels. Although, radiography and US are the commonly used diagnostic imaging modalities in camel practice, there is a growing awareness in the use of CT and MRI as high definitive diagnostic imaging techniques. Nevertheless; limited accessibility, need for animal general anaesthesia and high costs diminish the valuable using of CT

and MRI in the camel practice. Radiography, either plain or contrast, is the most available diagnostic imaging tool for diagnosis of orthopaedic disorders in camels; however, US is useful for assessing soft tissues, articular cartilage and bone shapes. CT and MRI may be used when US data are unclear or to assess inaccessible regions of the camel's distal limbs. CT and MRI accurately describe the bones and soft tissues as well as eliminate structural superimposition in the distal limbs of dromedary camels and allow for the assessment of minute ligamentous and tendentious structures that are inaccessible by US. MRI and US are useful for assessing the articular cartilage that is not evident on normal CT images. Future clinical trials are strongly recommended to document the usefulness of these techniques in diagnosis of camel lameness. Furthermore, the availability of adequate or customised CT and MRI machines for use in camel practice is essential. An atlas of normal CT and MRI scans of all musculoskeletal tissues in camels is desperately needed to cover the diagnostic imaging gap in camel practice.

Conflicts of Interest

The authors declare no conflict of interest.

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