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A comparison of 3-T magnetic resonance imaging and computed tomography arthrography to identify structural cartilage defects of the fetlock joint in the horse

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ABSTRACT

Articular cartilage defects are prevalent in metacarpo/metatarsophalangeal (MCP/MTP) joints of horses. The aim of this study was to determine and compare the sensitivity and specificity of 3-Tesla magnetic resonance imaging (3-T MRI) and computed tomography arthrography (CTA) to identify structural cartilage defects in the equine MCP/MTP joint. Forty distal cadaver limbs were imaged by CTA (after injection of contrast medium) and by 3-T MRI using specific sequences, namely, dual-echo in the steady-state (DESS), and sampling perfection with application-optimised contrast using different flip-angle evolutions (SPACE). Gross anatomy was used as the gold standard to evaluate sensitivity and specificity of both imaging techniques.

CTA sensitivity and specificity were 0.82 and 0.96, respectively, and were significantly higher than those of MRI (0.41 and 0.93, respectively) in detecting overall cartilage defects (no defect vs. defect). The intra and inter-rater agreements were 0.96 and 0.92, respectively, and 0.82 and 0.88, respectively, for CT and MRI. The positive predictive value for MRI was low (0.57). CTA was considered a valuable tool for assessing cartilage defects in the MCP/MTP joint due to its short acquisition time, its specificity and sensitivity, and it was also more accurate than MRI. However, MRI permits assessment of soft tissues and subchondral bone and is a useful technique for joint evaluation, although clinicians should be aware of the limitations of this diagnostic technique, including reduced accuracy.

Introduction

Osteoarthritis (OA) is a common cause of lameness and remains an expensive problem for horse owners (Caron and Genovese, 2003). It is a degenerative and inflammatory condition in which there is a loss of articular cartilage matrix (Hamerman, 1989). The metacarpo/metatarsophalangeal (MCP/MTP) joint is frequently involved and various pathologies of articular cartilage have been reported in Thoroughbred racehorses (Barr et al., 2009; Neundorf et al., 2010).

Conventional magnetic resonance imaging (MRI) sequences used to assess the equine MCP/MTP joint include T2 weighted (T2W)-turbo spin echo (TSE), proton density (PD) weighted-TSE and three-dimensional (3D) gradient echo (GE) sequences (Tucker and Sampson, 2007). In the Thoroughbred racehorse, it has been reported that articular cartilage defects of the distal aspect of the third metacarpal bone could not be detected accurately using a 1.0-Tesla (1.0-T) MRI system, fat-saturated PD-weighted and T1-weighted sequences. Furthermore, any defects present would not have been detected directly but inferred from signal alterations in the subchondral bone (SB) (O'Brien et al., 2011).

In a study of MCP/MTP joints obtained from the cadavers of lame horses, none of the pulse sequences evaluated had both high sensitivity (percentage of lesions detected as such by the pulse sequence) and high specificity (percentage of negatives detected as such by the pulse sequence) in identifying articular cartilage defects. Sensitivity and specificity were 0.34 and 0.66, respectively, with a 1.5-T 3D T1-weighted spoiled gradient echo (3D T1-W SPGR) sequence, and 1.00 and 0.12, respectively, with a T2*-weighted gradient echo (T2*-W GE) sequence (Smith et al., 2012). A further study used a 1.5-T SPGR with fat saturation (FS)

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Table 1
Parameters of the magnetic resonance imaging (MRI) sequences used in this study. The 'sampling perfection with application-optimised contrast using different flip-angle evolutions' (SPACE) sequence was acquired in 2D (sagittal and coronal planes). The double-echo in the steady-state (DESS) sequence was acquired in 3D. The images were acquired using a 256 × 256 matrix. After interpolation using a Fourier transformation, the images were reconstructed in a 512 × 512 matrix.

Acquisition parameters	DESS (isotropic)	SPACE 2D	SPACE 2D
TE (echo time) (ms)	5.04	48	48
TR (repetition time) (ms)	14.84	2800	2800
Acquisition time (min)	7′08	5′52	5′52
Acquisition plane	Sagittal	Sagittal	Coronal
FOV read (field of view) (mm)	140	100	100
Pixel size (mm)	0.558 × 0.558	0.4 × 0.4	0.4 × 0.4
Slice thickness (mm)	0.6	0.8	0.8
Matrix	256 × 256	256 × 256	256 × 256
Flip angle	25	120	120
Reconstruction parameters	DESS (isotropic)	SPACE 2D	SPACE 2D
Reconstruction matrix	512 × 512	512 × 512	512 × 512
Pixel size after reconstruction (interpolation in a Fourier transformation plan)	0.279 × 0.279	0.195 × 0.195	0.195 × 0.195

sequence on abattoir-derived thoracic limbs with low grade macroscopic cartilage lesions. The sensitivity and the specificity were 0.75 and 0.59, respectively, in detecting all cartilage defects (Olive et al., 2010a).

The accuracy of MRI in identifying cartilage defects has been documented in human patients (Karvonen et al., 1990; Disler et al., 2000; McCauley and Disler, 2001; McGibbon and Trahan, 2003). The MRI sequences used in routine evaluation of the musculoskeletal system (for example T2W-TSE, PD) did not provide adequate assessment of articular cartilage. High-field magnets and specific sequences, providing either better resolution or better cartilage-to-fluid contrast than conventional ones, have been recommended for the detection of cartilage defects (Gold et al., 2009; Kijowski et al., 2009, 2011; Ai et al., 2012; Crema et al., 2013). The 3-T systems can produce images of articular cartilage with higher spatial resolution and decreased slice thickness than 1.5-T systems (Friedrich et al., 2011). The signal to noise ratio (SNR) at 3-T is roughly twice that at 1.5-T, allowing improved image quality and spatial resolution within a similar acquisition time.

Improved SNR and spatial resolution in cartilage imaging have been achieved by using 3D fast spin echo sequences such as the Siemens 'sampling perfection with application-optimised contrast using different flip-angle evolutions' (SPACE) sequence (Mosher, 2006). These 3D cartilage imaging sequences can be broadly divided into dark-fluid sequences and bright-fluid sequences on the basis of the signal intensity of synovial fluid. The main disadvantage of using dark-fluid sequences, such as SPGR, for clinical cartilage imaging is the low signal (dark grey to black) intensity of synovial fluid (SF) and the low contrast between articular cartilage (dark grey) and SF that may decrease the visualisation of superficial cartilage lesions (Kijowski, 2010). The best contrast-to-noise ratio (CNR) between fluid and cartilage is achieved by the bright fluid sequences, such as the dual-echo in the steady-state sequence (DESS) (Mosher, 2006; Kijowski, 2010; Friedrich et al., 2011). It creates an arthrogram-like effect within the knee joint that may increase the detection of superficial cartilage lesions (Kijowski, 2010).

In horses, computed tomography (CT) and CT arthrography (CTA) have been used to detect cartilaginous (O'Brien et al., 2011) and non-cartilaginous changes of the MCP/MTP joint (Olive et al., 2010b). CTA involves the intra-articular injection of a radiopaque contrast medium. However, CTA does not appear to improve the detection of AC defects (O'Brien et al., 2011), unlike reports from human patients (Daenen et al., 1998; Vande Berg et al., 2002; El-Khoury et al., 2004; Lecouvet et al., 2007; Shahabpour et al., 2008).

In the present study, our aim was to assess the limits of MRI and CTA to identify structural articular cartilage defects of the equine MCP/MTP joint. This ex vivo investigation compared the sensitivity and specificity of high resolution CTA and 3-T MRI cartilage specific sequences (DESS, SPACE).

Materials and methods

Specimens

Distal limbs (n = 40, 20 forelimbs and 20 hindlimbs) of adult horses of various ages and sizes, were collected within 12 h of euthanasia in a slaughterhouse. These were mixed breed horses but no Thoroughbreds or ponies were included in this population. Limbs were stored at −20 °C and each limb was identified by a number. As required, specimens were thawed to room temperature, clipped and cleaned. No clinical data relating to those animals were known.

Imaging

Images were acquired with a 3-T MRI system (Magnetom Verio, Siemens). A 15 channel-knee coil (Siemens) was used. Sequences, acquisition planes and acquisition parameters are summarized in Table 1. After MRI, 20 mL of ionic contrast material at 37 °C (14 mL saline with 6 mL meglumine ioxalate and sodium ioxalate; Hexabrix 320, Guerbet) were injected through a 21 G 38 mm (1.5 inch) needle placed in the dorsal recess of the MCP/MTP joint. As there is no established consensus on the need for dilution that mainly depends on the radiologist's preferences (Omouri et al., 2011), our technique was mostly based on the authors' experience.

Before CT was performed, the injected joints were flexed and extended 30 times to provide a homogeneous spread of the contrast material through the synovial cavity. The limbs were subsequently examined by CTA with a 6-slice Emotion 6 (Siemens). The acquisition protocol was: 130 kV, 80 mA s (pitch 0.4 with tube rotation time of 0.6 s) and collimation 0.63 mm. The time to acquire the scans was recorded. The images were acquired from 2 cm above the proximal limit of the dorsal recess of the MCP/MTP joint to 2 cm distal to the proximal articular surface of the proximal phalanx. The transverse resolution was 0.20 × 0.20 mm. Slices of 0.63 mm were reconstructed with an increment of 0.3 mm resulting in an overlap between the different slices and a resultant longitudinal resolution of 0.3 mm without gap. Voxel dimensions were 0.20 × 0.20 × 0.30 mm.

Macroscopic observation

The joint was carefully opened by a circumferential incision of the periarticular tissues and the joint capsule. The cartilage was kept moist by covering the joint surface with gauze sponges soaked in lactated Ringer's solution. The articular surfaces of the metacarpus or metatarsus III (MC/MT3), proximal phalanx and proximal sesamoid bones were examined by gross observation by two investigators (FH, JMV). Both investigators identified and scored the abnormalities of the articular cartilage following OARSI[1] recommendations for macroscopic scoring of cartilage defects (McIlwraith et al., 2010) (Table 2). Scoring of articular surfaces was performed by macroscopic examination in 16 anatomic regions of each MCP/MTP joint (Fig. 1).

The most severe defect was used to score the articular surface of one region. Joint surfaces were digitally photographed for records, with standardised lighting conditions (two Illustar SM-300 lighting and a Sony Alpha DSLR-A230 digital camera, Sony SAL 1855 zoom lens, aperture 4.5, shutter speed 1/60, object distance 30 cm, resultant resolution 3872 × 2592 pixels).

[1] Osteoarthritis Research Society International. See: http://www.oarsi.org/.