

The sensitivity and specificity of high field and low field standing MRI for detection of cartilaginous and osseous lesions of the equine fetlock joint

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Introduction:

The appearance of the structures of the equine fetlock joint on magnetic resonance (MR) images was first accurately described in 1996, prior to the clinical application of magnetic resonance imaging (MRI) in the equine veterinary profession [1,2]. Since that study, the further development of sequences optimised for equine limbs on both high field and low field MR systems in routine clinical use have enabled us to more consistently interpret the appearances of structures such as cartilage and subchondral bone with MRI [3,4]. However, the reliability of detection of lesions of cartilage, subchondral or trabecular bone using clinically available 1.5 Tesla (T) and 0.27T magnets has not been determined.

It was hypothesised that: 1. Clinical sequences used in a 1.5 T magnet would enable reliable detection of lesions of cartilage, subchondral and trabecular bone within the equine fetlock joint, 2. Clinical sequences used in a 0.27 T magnet would be less reliable than sequences from a 1.5T magnet in detection of cartilage lesions, but lesions of subchondral and trabecular bone would be detectable with similar accuracy.

Our objectives were: 1) To compare interpretation of MR images using a pre-determined grading system with

histopathology for cartilage, subchondral and trabecular bone, and 2) to calculate sensitivity and specificity for detection of lesions of cartilage, subchondral and trabecular bone for a range of clinical MR sequences for the two magnets.

Materials and Methods

Nineteen cadaver distal limbs from 10 horses of mixed age (2 – 18 years), gender and breed, with a history of fore or hind limb lameness that was localised to the fetlock region prior to euthanasia were used in this study. The horses were humanely destroyed for reasons other than this study. Following euthanasia, all limbs were sectioned at the level of the proximal aspect of the third metacarpal or metatarsal bone and stored frozen at -20° C within 8 hours of euthanasia. The shoes and all traces of clenches were removed and each limb was double wrapped and snugly taped in plastic bags and stored frozen at -20° C until imaging. The time that each limb was in the freezer prior to MR imaging varied. Freezing has been reported not to interfere with the diagnostic value of MRI provided the limbs are thoroughly defrosted prior to imaging [5,6,7].

At the time of MRI, each limb was thawed to room temperature over approximately

12 hours. All limbs were imaged in two magnets. The magnet in which each limb was scanned first was randomly selected. The magnets used were: 1) a 1.5 T Signa Echospeed short bore magnet (General Electric, Milwaukee, Wisconsin, USA). Standard clinical positioning with the limbs parallel to the static magnetic field and a standard sequence protocol was used for imaging the limbs in this system [8]. 2) a 0.27 T system designed for standing horses (Hallmarq Veterinary Imaging Ltd, Guildford, Surrey, UK). In this system, each limb was fixed vertically with the metacarpal or metatarsal region positioned proximally, in a custom designed support stand. The purpose of the stand was to mimic weight bearing.

Following MRI, each limb was dissected. Three sections in a parasagittal plane were taken through the articular surfaces of the distal aspect of the third metacarpal or metatarsal bone (MC3/MT3) and the proximal aspect of the proximal phalanx (P1). This gave a total of 6 sections (MC3/MT3: lateral condyle, sagittal ridge, medial condyle; P1: lateral epicondyle, sagittal groove and medial epicondyle), which underwent routine histological preparation.

Definitions for grading cartilage and subchondral bone [9] and trabecular bone on MR images and histology slides were developed during pilot studies. Interobserver repeatability was performed during development of the definitions. Once repeatability was established, all analysis for this study was carried out by one trained analyst. Three categories of grades for the histological appearance of cartilage lesions were used (mild, moderate and severe), and one grading system each for the histological

appearance of subchondral and trabecular bone. MR images were graded from 0 – 4, at six sites (MC3/MT3: lateral condyle, sagittal ridge, medial condyle; P1: lateral epicondyle, sagittal groove and medial epicondyle). MR images were interpreted using a General Electric workstation (1.5T system) or e-film software (0.27T system). Histology specimens were evaluated microscopically. Histology and MR grades for five sequences from two magnets (high field T1 gradient echo (GRE), high field T2* GRE, low field T1 and T2* GRE and T2 Fast Spin Echo (FSE) sequences (Table 1) were compared at each section. Sensitivity and specificity of each pulse sequence on each MRI system for detection of cartilage, subchondral and trabecular bone lesions were calculated using statistical analysis software (Analyse-it for Microsoft excel 2003, Analyse-it software Ltd.).

Results:

For the detection of mild cartilage lesions, 1.5T T2* gradient echo (GRE) and 0.27T T2 fast spin echo (FSE) sequences were most sensitive (100%) but less specific (12.6%) while 1.5T T1 GRE, 0.27T T1 GRE and 0.27T T2* GRE sequences had lower sensitivity (36% - 45%) but higher specificity (66% - 80%). Similar results were obtained for moderate and severe cartilage lesions. For all sequences analysed, high sensitivity (95% - 100%) but low specificity (2% - 38%) for detection of lesions within the subchondral bone of the MCP/MTP joint were determined. Specificities were higher for 0.27T sequences compared with 1.5T sequences. All pulse sequences had higher sensitivity (43% - 70%) and specificity (64% - 100%) for detection of lesions within

trabecular bone (Table 1).

Conclusions:

Using specific sequences (1.5T T2* GRE and 0.27T T2 FSE), detection of cartilage lesions was comparable between MRI systems, refuting hypothesis 2 and indicating that a combination of sequences is essential for diagnosis of cartilage lesions. However, both high field T2* GRE and low field T2 FSE sequences have a high likelihood of false positives, which may represent overinterpretation of the presence of cartilage lesions. High field T1 GRE and low field T1 and T2* GRE sequences are much less sensitive, but more specific for detection of cartilage lesions. For all sequences used, detection of subchondral bone lesions was comparable between MRI systems, supporting hypothesis 1. Of all tissues analysed, only the results for detection of lesions within trabecular bone showed a relatively high sensitivity and specificity for any given sequence. Use of FSE sequences during low field standing MRI is important for maximising the likelihood of detection of cartilage lesions, however GRE sequences showed higher sensitivity for detection of trabecular bone lesions in the low field system compared with FSE sequences. Given that no one sequence has both high sensitivity and high specificity for interpretation of cartilage or subchondral bone lesions in either system, interpretation of a combination of sequences is essential to reach an accurate diagnosis.

References

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Table 1 Sensitivity and specificity and 95% confidence intervals (CI) for the results of interpretation of 5 MRI sequences from two magnets (HF = high field 1.5T, LF = low field 0.27T) compared with the results of histopathology
SPGR = spoiled gradient echo, GRE = gradient echo, FSE = fast spin echo; cartilage 1, 2 and 3 correspond to three pre-determined histopathological grades of severity (mild, moderate and severe) for cartilage lesions.

Tissue	Sequence	Sensitivity (%)	95% CI	Specificity (%)	95% CI
Cartilage 1	HF SPGR	36.4	10.9 - 69.2	66	56 - 75.1
	LF T1W GRE	36.4	10.9 - 69.2	81.6	72.7 - 88.5
	HF T2*W GRE	100	71.5 - 100	12.6	6.9 - 20.6
	LF T2*W GRE	45.5	16.7 - 76.6	79.6	70.5 - 86.9
Cartilage 2	LF T2W FSE	100	71.5 - 100	12.6	6.9 - 20.6
	HF SPGR	32.9	22.5 - 44.6	63.2	46 - 78.2
	LF T1W GRE	19.7	11.5 - 30.5	78.9	62.7 - 90.4
	HF T2*W GRE	89.5	80.3 - 95.3	13.2	4.4 - 28.1
Cartilage 3	LF T2*W GRE	23.7	14.7 - 34.8	78.9	62.7 - 90.4
	LF T2W FSE	86.8	77.1 - 93.5	7.9	1.7 - 21.4
	HF SPGR	44.4	21.5 - 69.2	67.7	57.4 - 76.9
	LF T1W GRE	27.8	9.7 - 53.5	81.3	72 - 88.5
Subchondral bone	HF T2*W GRE	100	81.5 - 100	13.5	7.4 - 22
	LF T2*W GRE	27.8	9.7 - 53.5	78.1	68.5 - 85.9
	LF T2W FSE	94.4	72.7 - 99.9	12.5	6.6 - 20.8
	HF SPGR	100	83.9 - 100	7.5	3.1 - 14.9
Trabecular bone	LF T1W GRE	95.2	76.2 - 99.9	37.6	27.8 - 48.3
	HF T2*W GRE	95.2	76.2 - 99.9	2.2	0.3 - 7.6
	LF T2*W GRE	100	83.9 - 100	22.6	14.6 - 32.4
	LF T2W FSE	95.2	76.2 - 99.9	33.3	23.9 - 43.9
Trabecular bone	HF SPGR	67	56.9 - 76.1	71.4	41.9 - 91.6
	LF T1W GRE	48	37.9 - 58.2	85.7	57.2 - 98.2
	HF T2*W GRE	70	60 - 78.8	78.6	49.2 - 95.3
	LF T2*W GRE	63	52.8 - 72.4	64.3	35.1 - 87.2
	LF T2W FSE	43	33.1 - 53.3	100	76.8 - 100