Determination of Tendon Pathology Using Magic Angle Imaging and Magnetisation Transfer Contrast

K. E. Gannon[1], M. J. Graves[1], R. C. Murray[2], R. T. Black[1]

[1]Department of Medical Physics & Clinical Engineering, Addenbrookes NHS Trust, Cambridge, Cambridgeshire, United Kingdom, [2]Centre for Equine Studies, Animal Health Trust, Newmarket, Cambridgeshire, United Kingdom

Introduction:

Clinical investigations of soft tissue can be optimised by manipulation of contrast using MRI. However, for ordered structures such as tendon, where signal originates from protons tightly bound to macromolecules, visualisation is not straightforward. Spin-spin interactions are more abundant in densely packed fibres and as a result the T_2 component becomes so short that the tendon is MR invisible. There are techniques to enhance signal intensity in short T_2 tissue such as magic angle imaging, but it is not always possible to obtain quantitative results on tendon pathology as these methods will lead to general enhancement which may be mistaken for pathological effects. Magnetisation Transfer Contrast (MTC) is an indirect method of assessing the abundance of bound protons by considering their interactions with mobile protons following saturation of the bound pool. This method is characterised by a drop in signal intensity and therefore is effective only in tissue that already yields a strong signal. It is our intention to use MTC in conjunction with magic angle imaging to qualitatively assess both human and equine tendon damage in the lower limb.

Method:

In order to achieve our objective it was necessary to optimise a suitable interleaved MTC/ GRE sequence [1]. Using a 1.5T GE Signa Excite system, excised equine tendon samples supplied by the Animal Health Trust U.K. were imaged with MTC parameters suggested by Barker GJ *et al* [2]. A single tendon was placed at several angles with respect to the magnet bore to ensure that maximum signal intensity was achieved at the magic angle (55°). Once this was established, a series of optimisation experiments were conducted to determine the ideal values for MTC parameters. The saturation pulse widths and pulse angles were varied to identify the correct combination for a maximum B_1 field, consistent with clinically acceptable specific absorption rates. The number of saturation pulses was varied to determine the effect on contrast in a single slice acquisition, and the offset frequency was altered over a range of 500-20000Hz to maximise the signal difference between the MTC and GRE images. The following parameters were then used to image fourteen cadaverous equine limbs using a multi-slice sequence: Pulse Width = 12.8ms, Pulse Angle = 1432°, Offset Frequency = 1500Hz, TR/TE = 1500/ min full, Flip Angle = 20°, Slice Thickness = 5mm, No. Slices = 6 or 10, N_{EX} = 0.75, Matrix Size = 256 x 192.

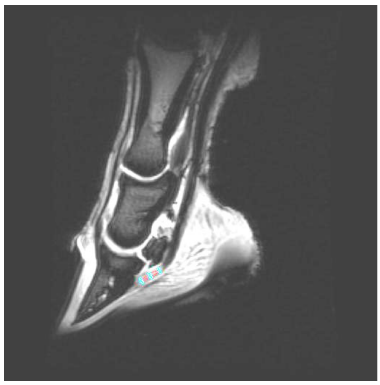

Figure 1. Gradient Echo image from interleaved sequence.

From these images a value for the magnetisation transfer ratio (MTR) was calculated from the following relationship using regions of interest (ROI's) drawn in the deep digital flexor tendon (see figure 1):

$$MTR = \frac{M_0 - M_s}{M_0}$$

M_0 is the net magnetisation in the gradient echo image and M_s is the net magnetisation in the saturated image.

Following this investigation, a normal human volunteer was imaged using identical parameters and the MTR results were compared to that of normal equine tendon.

Results:

From the fourteen limbs provided, seven were diagnosed with tendon problems and seven were classified normal limbs by the attending veterinarian. Figure 2 shows the distribution of damaged (red) and normal (blue) tendons in terms of their MTR values. The results revealed that in the damaged limbs the MTR was significantly lower than in normal limbs ($p \leq 0.0341$). However, the MTR values indicated that only three of the limbs had damaged tendons, rather than the seven diagnosed.

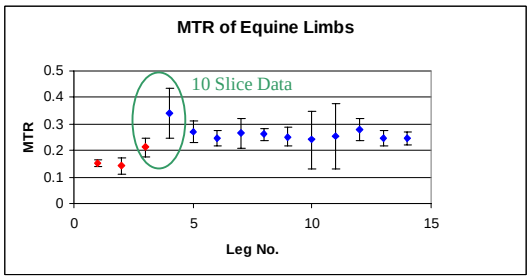

Figure 2. Results of cadaverous limb MTR study

After histopathology results were obtained, it was discovered that despite a history of lameness and adhesions between the tendon and ligament, the tendon itself remained undamaged in the four limbs previously thought to have tendon damage.

The tendon from the normal human volunteer had an MTR of 0.29. This is within the normal range for the equine tendons.

Conclusions:

A robust protocol has been developed to assess *in-vivo* tendon damage using MRI as a diagnostic imaging tool. This protocol has been used successfully to visualise MT effects *in-vivo* in normal human volunteers and in the future will be used for quantitative assessment of tendon damage.

References:

[1] MTC sequence provided by GJ Barker

[2] Barker GJ, Tofts PS, Gass A "An interleaved sequence for accurate and reproducible clinical measurement of magnetisation transfer ratio" MRI 1996: 14(4): 403-411