MAGIC ANGLE EFFECTS AND ULTRASHORT TE (UTE) IMAGING

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INTRODUCTION

Magic angle imaging effects are seen in tissues which contain abundant highly ordered collagen such as tendons and ligaments. These tissues have relatively short T_2s and when imaged with conventional pulse sequences with TEs of 2-20 msec display little or no signal when their fibers are parallel to B_0. However, if the angle of orientation of the fibers to B_0 is increased from 0° to 55°, an increase in signal intensity is frequently seen. If tendon and ligaments are examined with their collagen fibers parallel to B_0 using ultrashort TE (UTE) pulse sequences which have TEs 20-100 times shorter than those of conventional pulse sequences, they display a moderate or high signal rather than the very low or zero signal seen with conventional sequences It has been of interest to know whether tendons and ligaments display a magic angle effect when they are examined with UTE pulse sequences. It is possible that all the available signal from these tissues is detected with UTE sequences at an orientation of 0° to B_0 so that no increase in signal would be seen with a change in orientation to 55°. It is also possible that there are previously undetectable components with very short T2s which may produce signal when placed at the magic angle. In this case effects of UTE imaging and those of magic angle imaging (deliberately placing tendons, ligaments and other tissues with their fiber orientation at or near 55° to B_0) would be synergistic and might result in greater tissue signal than use of either technique alone. Another matter of interest is to observe the net effect of long T_2 reduction techniques in conjunction with UTE sequences on tissues or components of tissues which are at the magic angle. In addition, signal from some highly ordered tissues or components of tissues have only been detectable with UTE sequences and it has not been established whether these tissues display magic angle effects or not.

METHODS

Tendons, ligaments, hyaline, articular cartilage and fibrocartilage were examined in normal volunteers and tissue samples using UTE sequences with TRs of 500 msec, pulse duration of 400 microsec and TEs of 80 and 8 microsec as previously described (1,2). The traditional definition of TE was used i.e. from the end of the rf pulse to the beginning of acquisition. Tendons and ligaments were placed both parallel to B_0 and at the magic angle.

RESULTS

Increased signal was observed in tendons and ligaments placed at the magic angle at TEs of both 80 and 8 microsecs (Fig.1). Reduction of long T2 signal by subtraction of later echo images from the first produced both a relative increase and decrease on difference images of tendons, ligaments and articular cartilage. Magic angle effects were observed in the deep layer of articular cartilage and fibrocartilage as well as in sesamoid fibrocartilage.

DISCUSSION

The ordered dipolar coupling necessary for magic angle effects is a T_2 shortening process so that magic angle effects are typically associated with short T_2 components and tissues. The use of UTE sequences provides access to signal from these components and allows their magic angle effects to be detected. Even with the use of UTE sequences with a TE of 8 µsec increased signal was observed at the magic angle in tendons and ligaments. This implies that angles other than from 55°a significant proportion of the signal from protons has a T_2 which is too short to be detectable even with a TE of 8 µsec. There may therefore be scope for detecting more signal from tissues orientated at angles other than 55° to B_0 using UTE sequences with TEs even shorter than 8 µsec. Reduction in the duration of the rf pulse may also reduce the effective TE. The effects of the long T_2 signal reduction techniques used in conjunction with UTE sequences was variable. If T_2s are slightly prolonged a net increase in signal was seen on difference images found by subtraction of a later echo image from an earlier one but if T_2 was prolonged further this resulted in a net decrease of signal. In general articular cartilage showed the first effect, while tendons, ligaments and the deepest layer of cartilage showed the second effect. Strong magic angle effects were observed for the first time in sesamoid fibrocartilage and the calcified layer of hyaline articular cartilage. This is important in recognition of disease in these tissues and distinguishing disease from artifact.

REFERENCES

1. Brittain JH, Shankaranarayanan A, Ramanan V, et al. *Proc Int Soc Magn Resn Med* 2004; 11: 269.
2. Robson MD, Gatehouse PD, Bydder M, Bydder GM. *J Comp Assist Tomogr* 2003; 27: 825-846

Fig 1 Sagittal image of the thumb with proximal flexor tendons at the magic angle showing a higher signal (arrow) than the distal tendon (TR=500 msec, flip angle 60º, TE=8 microsec).