Contrast Enhanced Magnetic Resonance of the Menisci of the Knee Using Ultrashort TE (UTE) Pulse Sequences: Imaging of the Red and White Zones

P. D. Gatehouse[1], B. K. Puri[2], T. He[1], R. D. Thomas[3], D. Resnick[4], G. M. Bydder[4]

[1]The Cardiac Magnetic Resonance Unit, Royal Brompton Hospital, London, United Kingdom, [2]Robert Steiner MR Unit, Clinical Sciences Center, London, United Kingdom, [3]Surgery, Imperial College, London, United Kingdom, [4]Radiology, UCSD, San Diego, CA, United States

Introduction

There is considerable interest in identifying the vascular (red) and avascular (white) zones of the meniscus with magnetic resonance (MR) imaging. This reflects the fact that tears in the vascular portion are more likely to heal than those in the avascular region. As a result meniscus-preserving surgical techniques may be appropriate treatment for tears in the red zone while debridement is generally more suited for those in the white zone. The red and white zones have not been distinguished with MR imaging, signal enhancement following contrast administration has not been observed previously in the normal meniscus in either cadavers or patients (1).

When the normal meniscus is examined with pulse sequences having echo times of 9-20 ms as used in previous studies, it typically shows very low or absent signal intensity due to its short T_2. When the meniscus is imaged with ultrashort TE (UTE) sequences with TEs of 0.08 – 0.20 ms (i.e., about 100 times shorter than those used in the previously reported studies), moderate or high signal is seen within it (2-4).

We were interested in the possibility that the presence of detectable signal might allow contrast enhancement to be observed in the red and white zones when UTE sequences were used. In addition, the perimeniscal tissue, associated blood vessels, and joint fluid all have longer T_2s than menisci. It might also be possible to subtract an image obtained with a later echo using a longer TE from the first UTE echo image and so obtain a difference image in which contrast enhancement was obvious in the short T_2 meniscus, but that in tissues or fluids with a longer T_2 (such as perimeniscal tissue) was much reduced and therefore not a source of confusion. We also planned to use a higher intravenous dose of Gadolinium chelate than in previous clinical studies and employ a non-ionic agent rather than an ionic one since the former might show greater uptake into the fibrocartilage and fibrous connective tissue of the meniscus. In order to assess the value of these approaches we have performed a pilot study.

Subjects and Methods

Institutional review board approval was obtained for this study. Two normal male subjects (aged 21 and 58 years) were studied after informed consent had been obtained. Neither had a history of knee injury or disease and both were presumed to have normal menisci. All studies were performed on a 1.5T Sonata MR system (Siemens, Erlangen, Germany) using an 18.5 cm flexiloop surface receiver coil. The UTE sequence employed a half radiofrequency excitation pulse with radial imaging of k-space from the center followed by another half-excitation with the polarity of the slice selection gradient reversed and repeated radial imaging as previously described (4).

Using this technique, four echoes of the same type were obtained at 0.08, 5.95, 11.08 and 17.70 ms. Three difference images were formed by subtracting each of the later TE images from the first image. Ten to 20 4mm multislice images were obtained in the sagittal plane with a 280-340mm field of view, TR of 500 ms, nominal flip angle (for long T_2 components) of 80^o, slice gap of 20-100% and scan time of 8.5-17 minutes. Gadodiamide (Amersham Healthcare, Amersham, UK) 0.3 mmol/kg was administered intravenously after the baseline images were obtained. Contrast enhanced images were obtained approximately 5-10 minutes later. The scans were observed for differences in signal intensity before and after contrast enhancement. Regions of interest were used to obtain signal intensity values and calculate T_2*.

Results

In both subjects an obvious increase in signal intensity was seen in the meniscus on the difference images. The enhancement had a well defined inner margin and extended to the outer margin of the meniscus as well as to its superior and inferior margins in a distribution consistent with anatomical descriptions of the location of the red zone. In addition, the fraction of the whole meniscus that showed enhancement ($26.8 \pm 7.3\%$) corresponded with published data (10-33%) for the fraction of the meniscus occupied by the red zone.

The greatest change in signal intensity was seen with the shortest TE which showed increases of 46, 76 and 86% in white zone, red zone and perimeniscal regions respectively. However, on the difference images the red zone showed the greatest change (109%) followed by the perimeniscal region (67%) and then the white zone (46%).

Discussion

The signal intensity in the red and white zones as well as the perimeniscal region showed an increase after intravenous contrast administration. This increase was most marked at short values of TE and less at longer values. The TEs employed in conventional sequences (e.g. 9-20 ms) are in the longer range and would be expected to show much lower signal increase with contrast administration than UTE images.

The use of a higher dose of contrast agent was also likely to have increased the level of tissue enhancement in comparison to previous studies. It is also possible that the use of a non-ionic agent rather than an ionic one may have increased transport of the contrast agent into the fibrocartilage of the meniscus and so increased the level of enhancement.

Enhancement in the white zone was manifest as an increase in signal intensity rather than an obvious change on the difference images. Because the white zone is avascular, the contrast agent must have diffused into this region from the red zone with a possible or probable contribution from the joint fluid.

The influence of disease is of interest since diseases which increase the T_2 of the meniscus may make enhancement more obvious on the longer TE images but less obvious on difference images.

References

1. Hauger O, Frank LR, Boutin RD, Chung CB, Haghighi P, Resnick D, Lektrakul N. Radiology 2000; 217: 193-200.
2. Gold GE, Pauly JM, Macovski A, Herfkens RJ. Magn Reson Med 1995;34:674-54.
3. Schroder C, Bornert P, von Eggermund J. ESMRMB Proceedings September 2003 p. 438
4. Robson MD, Gatehouse PD, Bydder M, Bydder GM. J Comput Assist Tomogr 2003; 27: 825-846