Clinics in Diagnostic Imaging (63)

I Y Y Tsou, W C G Peh

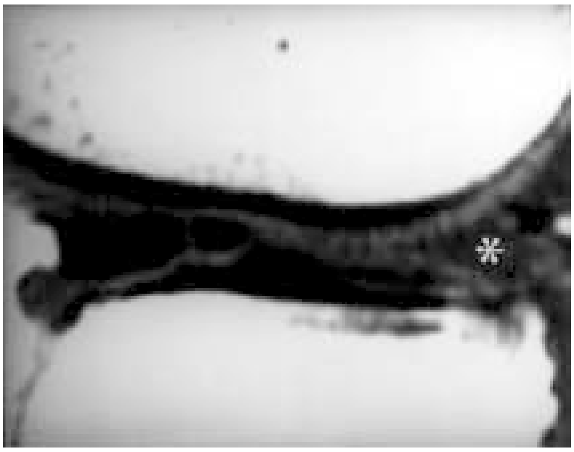

Fig. 1a Sagittal T1-weighted (TR/TE 640/14) MR image of the lateral aspect of the right knee.

Fig. 1b Sagittal T1-weighted MR image of the lateral aspect of the right knee, taken 4 mm medial to Fig. 1a.

A 21-year-old Chinese man presented with a twisting injury of the right knee. Clinical examination revealed swelling of the right knee, local tenderness over the right lateral joint line and lateral patello-femoral joint. The range of movement was from 10 - 120 degrees, and there was pain on varus stress as well. The McMurray's test was positive over the lateral joint space. Aspiration of the knee joint revealed blood-stained fluid. Magnetic resonance (MR) imaging of the right knee was performed. What do the MR scans (Figs. 1a - b) show? What is the diagnosis?

Department of Diagnostic Radiology
Tan Tock Seng Hospital
11 Jalan Tan Tock Seng
Singapore 308433

I Y Y Tsou, MBBS, FRCR
Registrar

W C G Peh, MD, FRCP, FRCR
Senior Consultant

Correspondence to:
Dr Ian Y Y Tsou
Tel: (65) 357 8110
Fax: (65) 357 8112
Email: radiology@singapore.com

IMAGE INTERPRETATION

The normal posterior horn of the lateral meniscus is absent (asterisk indicates expected position of the posterior horn). The anterior horn is abnormally large with a hyperintense vertical line (Fig. 1a), and a hyperintense oblique line (Fig. 1b) seen on two consecutive sagittal images. The complex appearance of the anterior horn is due to the true anterior horn, together with part of the displaced torn posterior horn that had flipped over onto the true anterior horn. Co-existing finding (not shown) of a complete tear of the right anterior cruciate ligament was also present.

DIAGNOSIS

Flipped bucket-handle tear of the lateral meniscus posterior horn.

CLINICAL COURSE

Arthroscopy of the right knee performed six weeks later confirmed both the bucket-handle tear of the posterior horn of the lateral meniscus and complete rupture of the anterior cruciate ligament.

DISCUSSION

Normal meniscus

The menisci in the knee have a multitude of functions, the dominant one being to act as a shock absorber. This reduction of transmission of force from the tibia to the femur is achieved by both the composition of the menisci, and by increasing the contact area across the joint. Other important functions include acting as joint lubricants, and with deficiency of the anterior cruciate ligament, the medial meniscus aids in maintaining joint stability.

The medial and lateral menisci are C-shaped structures, which are fixed firmly at their roots to the central portion of the tibial articular surface. The menisci are also anteriorly connected to each other. The posterior horn of the lateral meniscus is linked to the medial femoral condyle via the meniscofemoral ligaments of Humphrey or Wrisberg. Laterally, the menisci are attached to the capsule of the knee, except at the postero-lateral aspect, where the popliteus tendon is interposed. The medial meniscus is larger in size with a C-curve shape when viewed from supero-inferiorly, while the lateral meniscus is more circular in shape (Fig. 2). In cross-sections taken in the coronal and sagittal planes, they are triangular in shape, with the apex pointing towards the centre of the knee.

The menisci are composed of fibrocartilage, predominantly of type 1 collagen. This highly organised collagen structure causes restriction of movement of protons and water, increasing dipole-dipole interactions which promote T2 relaxation, leading to a low signal intensity appearance on MR imaging sequences. The menisci are relatively avascular, except for the peripheral one-third. This accounts for the reddish appearance of the peripheral zone at arthroscopy, as compared to the avascular white central zone[1]. This vascularity is important in meniscal healing and repair.

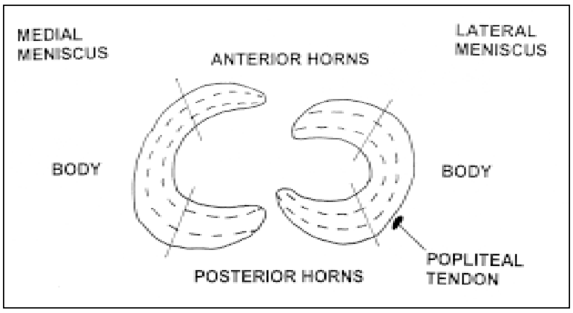

Fig. 2 Diagram showing anatomy of the medial and lateral menisci when viewed from above.The menisci can be divided into thirds, from the anterior to posterior horns, and from centrally to peripherally.

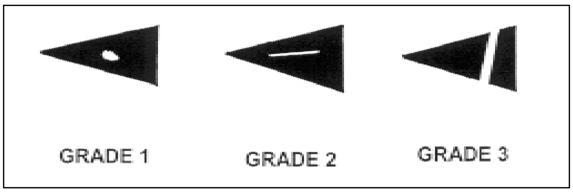

Fig. 3 Diagram showing grading of intrameniscal signal on MR imaging.

MR imaging technique

The majority of MR imaging studies of menisci have been done using high-field magnets of 1 to 2 Tesla. Midfield magnets (0.3 to 0.5 Tesla) generally have inherently lower signal-to-noise (SNR) ratios. The usage of thin (3 to 4 mm) sections reduce partial volume effects, and allow better visualisation of the menisci. The field of view is between 16 to 20 cm, while higher matrices (320 x 224) reduce the truncation artifact. The standard validated traditional MR pulse sequence is the proton density weighted spin-echo sequence, with long TR/ short TE. Most centres currently use a fast spin-echo (FSE) sequence which allows reduction in the scan time. When FSE sequences were first adopted, it was suggested that the image quality was suboptimal for meniscal imaging[2], but subsequent studies have shown that these fears were unfounded[3].

Meniscal tear criteria and classification

The two criteria for diagnosis of a meniscal tear are (i) intrameniscal signal that comes into contact with the articular surface of the meniscus, and (ii) abnormal meniscal configuration.

The intrameniscal signal is due to macromolecules being exposed on the edge of the tear, leading to absorption of protons that increase the local spin density. This causes an abnormal increase in signal

Fig. 4a Complete oblique meniscal tear. Sagittal proton-density weighted (TR/TE 3420/42) MR image shows an oblique hyperintense line (arrow) through the anterior horn of the lateral meniscus, with slight displacement.

Fig. 4b Same patient as figure 4A. Sagittal proton-density weighted (TR/TE 3420/42) MR image taken 4 mm medially shows continuation of the oblique tear (arrow), linking the superior and inferior surfaces of the anterior horn of the lateral meniscus.

intensity. If the tear is of a large enough size, the cleft may actually contain free fluid from the knee joint. A widely accepted grading of intrameniscal signal has been adopted[4], with grade 1 signal described as focal or globular intrasubstance signal that does not abut or communicate with an articular surface. The articular surface refers to the superior or inferior surface of the meniscus, with the peripheral meniscocapsular junction not being considered. Grade 2 signal is a horizontal linear signal, also confined to the meniscal substance, without extension to an articular surface. A true meniscal tear is represented by grade 3 signal, which abuts or communicates with an articular surface[5] (Fig. 3). This may be linear (grade 3A) or globular (grade 3B). It must be remembered that this grading system is based on signal, and only grade 3 signal indicates a tear.

Abnormal meniscal shape is just as important in the evaluation of meniscal tears, with any contour defect or fragmentation being abnormal if there has not been any previous surgery or intervention. A common tear pattern is that of amputation of the apex of the meniscus, which represents involvement of the free inner edge. With more detailed imaging and treatment options available for the management of meniscal tears, it becomes more important to be able to describe and classify tears accurately[6]. The location, plane, shape and completeness of each individual tear should be reported. With regard to the location, the menisci are usually divided into thirds along their circumference, giving an anterior horn, a body and a posterior horn. The width of the menisci is also divided into thirds, with central, middle and peripheral portions (Fig. 2).

In cross-sectional sagittal or coronal images, meniscal tears can be vertically or horizontally oriented. Vertical tears may be longitudinal, running parallel to the circumferential axis of the meniscus, or radial, where it is perpendicular to this axis. An oblique or "parrot-beak" vertical tear has both longitudinal and radial components, and extends to the inner free edge of the meniscus. Another variant of a vertical tear is the "bucket-handle" tear, where the longitudinal tear leads to displacement of the medial fragment into the intercondylar notch. These patients commonly present with symptoms of joint locking. Two useful MR imaging signs of a bucket-handle tear are the "double PCL" sign, and the "flipped meniscus" sign[7]. The former refers to the direct visualisation of the torn displaced fragment in the intercondylar notch, and may be seen as a structure inferior to and paralleling the posterior cruciate ligament. This simulates a double PCL ligament. The flipped meniscus sign is seen as an abnormally large anterior horn, due to a posterior horn fragment which has flipped anteriorly, and is inseparable from the anterior horn (Figs. 1a - b).

Most radial tears involve the free inner edge of the meniscus, giving a blunted or truncated inner margin. A complete longitudinal tear is one where it extends to both the superior and inferior surfaces, while a partial tear only contacts either the superior or inferior surface. The length of the tear can be estimated, depending on its orientation and complexity (Figs. 4a - b).

MR imaging accuracy

The accuracy of MR imaging in the diagnosis of meniscal tears has been reported in comparison with arthroscopy as the "gold" standard. The results from large studies show that sensitivities range from 70% to 97%, and specificities from 82% to 98%. However, just as important is the negative predictive value of MR imaging in meniscal tears, which is

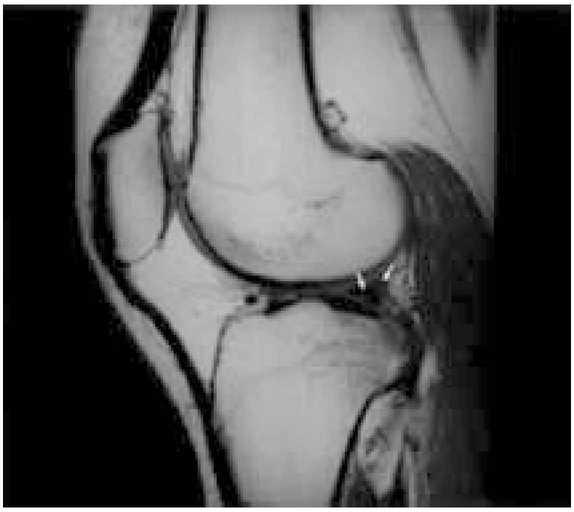

Fig. 5a Common pattern of associated injury involving the lateral meniscus, anterior cruciate ligament and bone contusion. Sagittal T1-weighted (TR/TE 540/12) MR image shows a complex tear (arrows) involving the posterior horn of the lateral meniscus.

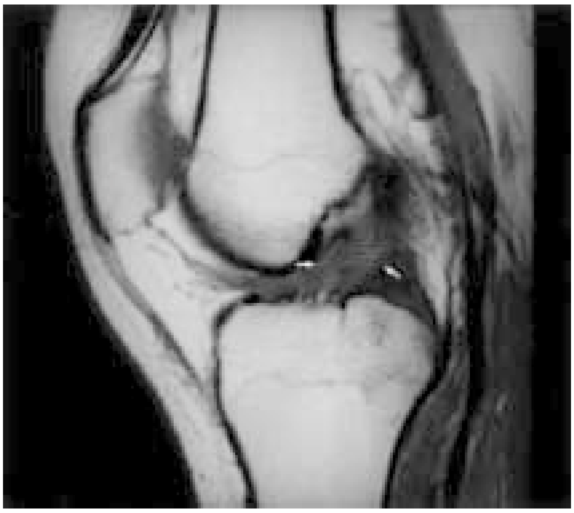

Fig. 5b Same patient as figure 5A. Sagittal T1-weighted (TR/TE 540/12) MR image shows complete rupture of the anterior cruciate ligament with a haemorrhagic mass (arrows).

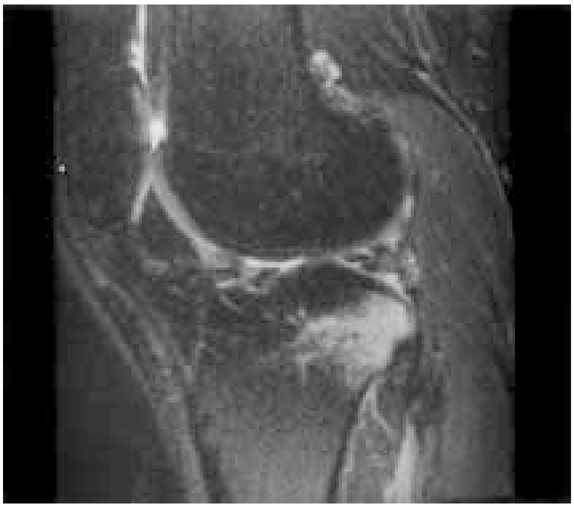

Fig. 5c Same patient as Figs. 5a and 5b. Sagittal fat-suppressed T2-weighted (TR/TE 5400/82) MR image shows a patchy area of hyperintensity in the posterior aspect of the lateral tibial condyle, consistent with marrow oedema from bone contusion.

consistently above 90%. This high value implies that few meniscal tears are missed[4,8]. MR imaging may also detect intrasubstance tears that may not be visible arthroscopically. Associated injuries such as anterior cruciate ligament tears, bone contusion or bruising, and occult fractures can also be detected on MR imaging (Fig. 5a-c).

Pitfalls in MR interpretation

It is just as important to be able to recognise normal variants that may mimic tears, in order that overdiagnosis can be avoided. Several normal anatomical structures may be misinterpreted as tears, due to their close proximity to the menisci. Anteriorly, the fat plane between the transverse meniscal ligament and the anterior horn of the lateral meniscus may simulate a tear on sagittal images[9]. Similarly, there may be a fat plane between the posterior meniscofemoral ligaments of Humphrey or Wrisberg and the posterior horn of the lateral meniscus. The plane between the popliteus tendon and the posterolateral aspect of the lateral meniscus may be misinterpreted as a tear, but careful examination will show that this tendon is a separate structure from the posterior horn of the lateral meniscus[10]. Meniscal folds or buckling of the inner free edge of the menisci have also been described, particularly in the presence of joint effusion or joint laxity. This results in contour deformity of the apex of the meniscal triangle without the presence of a tear. In general, these anatomical errors can be usually avoided by careful identification of a given structure on sequential images.

Technical factors can also influence imaging, and as such, the diagnosis of a tear. The magic angle phenomenon is seen as diffusely increased signal in the posteromedial aspect of the lateral meniscus[11]. This is due to the slight upward slope of the meniscus at this point, producing an orientation of the collagen fibres such that it may form an angle of 55 degrees with respect to the direction of the static magnetic field. This effect can be minimised by sequences with a longer TE or slight knee abduction[12]. However, even if this effect is recognised to be due to the magic angle phenomenon, the presence of increased signal may mask subtle underlying tears. Truncation artifacts may also be seen, due to misregistration of signal that occurs at the high signal interface of hyaline and fibrocartilage. Many MR artifacts affecting the musculoskeletal system can be identified and avoided[13].

Even with foreknowledge of such pitfalls, occasional misinterpretation may occur. Most of such errors are found during examination of the posterior horn of the lateral meniscus, as well as at the inner free edge. However, approximately half of the tears missed at

MR imaging are small, and of the menisci would not require surgical treatment anyway. In particular, errors in detection of lateral meniscal tears are more frequent in knees with a torn anterior cruciate ligament.

REFERENCES

1. Hauger O, Frack LR, Boutin RD, Lektrakul N, Chung CB, Haghighi P et al. Characterization of the "red zone" of knee meniscus: MR imaging and histologic correlation. Radiology 2000; 217:193-200.
2. Rubin DA, Kneeland JB, Listerud J, Underberg-Davis SJ, Dalinka MK. MR diagnosis of meniscal tears of the knee: value of fast spin-echo vs conventional spin-echo pulse sequences. Am J Roentgenol 1994; 162:1131-5.
3. Cheung LP, Li KC, Hollett MD, Bergman AG, Herfkens RJ. Meniscal tears of the knee: accuracy of detection with fast spin-echo MR imaging and arthroscopic correlation in 293 patients. Radiology 1997; 203:508-12.
4. Crues JV, Mink JH, Levy TL, Lotysch M, Stoller DW. Meniscal tears of the knee: Accuracy of MR imaging. Radiology 1987; 164:445-8.
5. De Smet AA, Norris MA, Yandow DR, Quintana FA, Graf BK, Keene JS. MR diagnosis of meniscal tears: Importance of high signal that extends to the surface. Am J Roentgenol 1993; 161:101-7.
6. Newman AP, Daniels AU, Burks RT. Principles and decision making in meniscal surgery. Arthroscopy 1993; 9:33-51.
7. Singson RD, Feldman F, Staron R, Kiernan H. MR imaging of displaced bucket-handle tear of the medial meniscus. Am J Roentgenol 1991; 156:121-4.
8. De Smet AA, Tuite MJ, Norris MA, Swan JS. MR diagnosis of meniscal tears: Analysis of causes of errors. Am J Roentgenol 1994; 163:1419-23.
9. Herman LJ, Beltran J. Pitfalls in MR imaging of the knee. Radiology 1988; 167:775-81.
10. Watanabe AT, Carter BC, Teitelbaum GP, Seeger LL, Bradley WG. Normal variations in MR imaging of the knee: Appearance and frequency. Am J Roentgenol 1989; 153:341-4.
11. Peterfy CG, Janzen DL, Tirman PFJ, van Dijke CF, Pollack M, Genant HK. "Magic-angle" phenomenon: A cause of increased signal in the normal lateral meniscus on short-TE images of the knee. Am J Roentgenol 1994; 163:149-54.
12. Peh WCG, Chan JHM. The magic angle phenomenon in tendons: effect of varying the MR echo time. Br J Radiol 1998;71:31-6.
13. Peh WCG, Chan JHM. Artifacts in musculoskeletal magnetic resonance imaging: identification and correction. Skeletal Radiol 2001;30:179-191.

ABSTRACT

Tears of the menisci in the knee are common after trauma, especially following sports injuries. A 21-year-old Chinese man with a flipped bucket-handle tear of the posterior horn of the lateral meniscus is reported. The MR imaging findings were confirmed at surgery. The classification and different types of meniscal tears, and the role of MR imaging in the diagnosis of meniscal lesions, are discussed.

Keywords: bucket-handle tears, knee, knee injury, meniscus, meniscal tears, magnetic resonance imaging

Singapore Med J 2001 Vol 42(7):332-336