

Comparison between arthroscopy and 3 dimensional double echo steady state (3D-DESS) sequences in magnetic resonance imaging of internal derangements of the knee

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ABSTRACT

Objective: This study was performed with the aim of evaluating the usefulness of 3 dimensional double-echo steady state sequences in examining the internal derangements of the knee. Arthroscopy was used as a referral standard.

Methods: The study was performed in the Radiology and Arthroscopy Departments of King's College Hospital, London, United Kingdom, during a 6-month period from January 1997 to June 1997. All patients who had knee magnetic resonance imaging within 3 months of arthroscopy were retrospectively studied. Thirty-three patients fulfilled these criteria and were selected.

Results: Three dimensional double-echo steady state

sequences produced sensitivity for detecting meniscal tears of 87.5% for medial menisci (MM) and 75% for lateral menisci (LM). Specificity was 76% for MM and 96% for LM; positive predictive value (PPV) was 46.1% for MM and 85.7% for LM and negative predictive value (NPV) of 95% for MM and 96% for LM. The sensitivity for the anterior cruciate ligament was 83.3%, specificity was 77.7%, PPV was 45.4% and NPV was 95.4%.

Conclusion: Three dimensional double-echo steady state sequences are useful in evaluating internal derangement of the knee, especially in advanced cartilage lesions.

Saudi Med J 2004; Vol. 25 (6): 761-765

Magnetic resonance imaging (MRI) has revolutionized diagnostic imaging of the knee. It has evolved significantly since Kean et al described healthy and pathologic knee anatomy in 1983.¹ Magnetic resonance (MR) has established itself as the gold standard for non-invasive imaging of the knee. As in arthroscopy, assessment of injuries to the menisci, articular surfaces, synovium, and cruciate ligaments can be made. Additionally, MR has an advantage over arthroscopy in being able to assess the para-articular soft tissues and cortical and medullary bony compartments.² The main advantages of MRI are its noninvasive nature and its

high accuracy and negative predictive value in evaluating the menisci and anterior cruciate ligament. Magnetic resonance imaging has been shown to be useful in the detection and diagnosis of various traumatic and non-traumatic knee abnormalities. Magnetic resonance imaging can therefore help in the selection of those patients who need therapeutic arthroscopy.³ It has been found that when the MRI findings are available to the arthroscopist before the examination, it highlights areas with greatest disability and leads to best results.⁴ Magnetic resonance imaging was not found to increase the cost on health resources but, in

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Received 29th October 2003. Accepted for publication in final form 9th February 2004.

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fact, avoided unnecessary surgery in a considerable proportion of patients.⁴ Experience plays an important role in both MRI and performing arthroscopy. Different imaging sequences were evaluated in knee imaging with different results: A few studies have shown 3-D fast imaging technique to be a noninvasive alternative to diagnostic arthroscopy.⁵ Other studies compared 3-D gradient echo (GE) sequences with spin echo (SE) sequences and showed the relative strengths and weaknesses of the two imaging sequences. Spin echo and the 3-D gradient-echo sequences complement the diagnostic accuracy of knee injuries.⁶ The results of other studies suggest that, allowing for necessary discrepancies in imaging protocol, magnetic field strength is not a significant determinant of diagnostic reliability of MR assessments of internal derangement of the knee.⁷ Three dimensional double-echo steady state (3D-DESS) technique is a combination of fast imaging with steady precession (FISP) and reverse fast imaging with steady precession (PSIF). It is carried out by acquiring a 3D FISP with steady precession sequence with an additional late echo, which results in a sequence with a "mixed" contrast behavior (T1-weighted with bright fluid signal). This 3D double echo steady state (DESS) technique is a well suited for musculoskeletal imaging to detect joint lesions. In the 3D-DESS without fat suppression or water excitation, the cartilage has an intermediate signal intensity, but it is well delineated because joint fluid exhibits a very high signal intensity. It allows high quality multiplanar re-constructions and provides T1 contrast in the soft tissues. Therefore, it has the advantage of good visualization of menisci, muscles, ligaments and tendons in contrast 3D spoiled gradient recalled echo sequences using selective fat suppression or water excitation that can only be used to evaluate cartilage as all other tissues are dark and contrast is low.

Hardy et al⁸ in 1996 optimized the sequence for use in the detection of articular cartilage abnormalities. They determined that an optimized sequence with a bandwidth of 98 Hz per pixel, TR of 30 msec, a TE of 7.1 msec and an alpha of 60 degrees produced the highest contrast between cartilage and fluid within a defined acquisition time of 6 minutes. Additional contrast was obtained by filtering the second-echo image to eliminate noise before adding it to the first-echo image. Ruehm et al⁹ have studied the efficacy of 3D-DESS optimized for cartilage imaging in patellar cartilage abnormalities and compared it to a standard turbo-spin-echo sequence. They concluded that the 3D-DESS sequence was moderately accurate in detecting patellar cartilage abnormalities and found that when it compared with the sagittal turbo-spin-echo sequence, the axial 3D-DESS sequence is superior in diagnosing cartilage softening but not surface lesions. Using a

time-consuming examination protocol including DESS in its protocol, the diagnostic accuracy of the open low-field MR unit are well comparable to those obtained with mid- or high-field units.¹⁰ But it was found that with the use of 3D pulse sequences including DESS, the high-field system demonstrated a significantly better diagnostic performance than the low-field system in the detection of grades 2 and 3 articular cartilage lesions.¹¹

Methods. The study was performed in the Radiology and Arthroscopy Departments of King's College Hospital, London, United Kingdom. We studied retrospectively all the patients who underwent both MRI and arthroscopy in the previous 6-months from January 1997 to June 1997. Fifty-seven patients had knee MRI over this period while 135 patients had arthroscopy over the same period. Only 36 patients had both MRI and arthroscopy. Thirty-four patients had the MRI within 3 months before the arthroscopy. One patient had incomplete records and was excluded from the study. Thus, 33 patients who undertook arthroscopy within 3 months after the knee MRI were retrospectively studied. Areas examined were menisci, cruciate ligaments, patellar tendons, collateral ligaments and articular cartilage. Magnetic resonance imaging images were obtained using a Siemens, 1.0 Tesla Impact Expert system. Using a dedicated knee coil, the knee was positioned in 10-12 degrees external rotation to align the anterior cruciate ligament.

Routine sequences: (1) Double Echo Steady State 3D acquisition in the sagittal, coronal and axial planes with a TR of 26.8MS, TE of 9ms, flip angle of 40, slab thickness of 89mm with 32 partitions resulting in an effective slice thickness of 2.78mm. Matrix of 54% (242 x 512) and field of view of 300mm (rectangular by 7/8). Time of scan 3 minutes and 29 seconds in one acquisition. The phase encoding direction was poster-anterior.

(2) Spin Echo T1W sagittal sequence to demonstrate cruciate ligaments with a TR of 532 ms, TE of 15 ms, flip angle of 90, number of slices = 19, slice thickness = 5mm, distance factor = 0.02. matrix = 92% (236x512) and field of view = 300 mm (rectangular by 4/8) in 2 acquisitions. The phase encoding direction was postero-anterior. Time of scan was 4 minutes and 14 seconds. Additional sequences also included short tau inversion recovery coronals and T1W fat suppression sequences.

The following codes were used to designate MRI findings: 1 = normal, 2 = abnormal signal and 3 = complete tear. The following codes were used to designate arthroscopy findings: 1 = normal, 2 = partial tear and 3 = complete tear. A partial tear was diagnosed when there was increased signal intensity within the ligament but with some fibers intact. A meniscal tear was diagnosed when there was a high signal within the meniscus reaching to an articular

surface (**Figure 1**) or the meniscus showed an abnormal shape (apart from discoid meniscus and buckling) in the absence of previous surgery. A partial ligamentous tear was diagnosed when there was increased signal intensity within the ligament but with some fibers intact. A complete tear was diagnosed whenever there was total discontinuity of the ligament, with areas of strongly increased signal intensity that extended across the whole ligament site (**Figure 2**).

Results. Ages range between 15-65 years with a mean of 35 years and a mode of 23 years. Fifteen patients were females and 18 were males. The results for medial meniscus are represented in **Table 1 & Table 4**. The results for the lateral meniscus are represented in **Table 2 & Table 4**. The results for the anterior cruciate ligament are represented in **Table 3 & Table 4**.

The MRI of all cases on posterior cruciate ligament were all normal. They were found all to be normal on arthroscopy except one of the 33 cases (3%) with partial fiber tear. Two cases of the 33 patients (6.1%) were reported with abnormal signal in the medial collateral ligaments (**Figure 3**) and had no matching report on arthroscopy. All patellar tendons were normal on both examinations. On other findings there were one case of meniscal cyst noted on MRI but no such report was found in arthroscopy. Twelve cases had cartilage abnormalities on arthroscopy but only 4 cases were matched in MRI, while another 2 cases were reported as osteochondritis dissecans (**Figure 4**).

Discussion. Meniscal injuries. Our study revealed sensitivities and specificities of 75-96% for meniscal injuries. This compares to previous studies.¹²⁻¹⁴ Other studies had achieved better results in their sensitivities and specificities. To better

Table 1 - Comparison of the magnetic resonance imaging (MRI) versus arthroscopy results in the sample studied for the medial meniscus.

MRI report on medial meniscus	Arthroscopy report on medial meniscus			
	Normal	Partial tear	Torn	Total
Normal	19	0	1	20
Abnormal signal	1	0	1	2
Tear	5	0	6	11
Total	25	0	8	33

Table 2 - Comparison of the magnetic resonance imaging (MRI) versus arthroscopy results in the sample studied for the lateral meniscus.

MRI report on lateral meniscus	Arthroscopy report on lateral meniscus			
	Normal	Partial tear	Torn	Total
Normal	24	0	2	26
Abnormal signal	1	1	0	2
Tear	0	0	5	5
Total	25	1	7	33

Table 3 - Comparison of the magnetic resonance imaging (MRI) findings versus arthroscopy results in the sample studied for anterior cruciate ligaments (ACL).

MRI report on anterior cruciate ligament	Arthroscopy report on ACL			
	Normal	Partial tear	Torn	Total
Normal	21	1	0	22
Abnormal signal	4	2	0	6
Tear	2	0	3	5
Total	27	3	3	33

Table 4 - Comparison of statistical results for different knee structures.

Structure	Sensitivity	Specificity	PPV	NPV
Medial meniscus	87.5	76	46.1	95
Lateral meniscus	75	96	85.7	96
ACL	83.3	77.7	45.4	95.4
ACL - anterior cruciate ligament, PPV - positive predictive value, NPV - negative predictive value				



Figure 1 - Sagittal magnetic resonance imaging of the knee using 3 dimensional double-echo steady state technique: showing complex tear of the posterior horn of the medial meniscus.



Figure 3 - Coronal magnetic resonance imaging of the knee using 3 dimensional double-echo steady state technique: showing abnormal signal of the medial collateral ligament, tear of the lateral meniscus and small joint effusion.



Figure 2 - Sagittal magnetic resonance imaging of the knee using 3 dimensional double-echo steady state technique: showing complete tear of the anterior cruciate ligament.



Figure 4 - Coronal magnetic resonance imaging of the knee using 3 dimensional double-echo steady state technique: showing osteochondritis dissecans of the medial femoral condyle, tear of the medial collateral ligament and abnormal signal of the lateral meniscus.

define the role of MRI in the evaluation of knee injuries, Baevé et al¹⁵ have analyzed 10 recently published articles comparing MRI and arthroscopy in the detection of meniscal and anterior cruciate ligament tears. Sensitivity (SN), specificity (SP), positive predictive value (PPV), and negative predictive value (NPV) for medial meniscus (MM) tears, lateral meniscus (LM) tears, and anterior cruciate ligament (ACL) tears were either obtained or calculated from data contained in each article. The medians of measurements for MM tears were 97% SN, 89% SP, 88% PPV, and 96% NPV. Measurement medians for LM tears were 85% SN, 94% SP, 86% PPV, and 95% NPV. Anterior cruciate ligament tear measurement medians were 100% SN, 96% SP, 80% PPV, and 98% NPV. Compared to this data, our study achieved poorer results, which in part could be explained by small sample size and the early experiences using the DESS sequence. Arthroscopy remains the standard against which the knee MRI accuracy is measured. Its accuracy is dependent on the experience of the arthroscopist (69-98%). Certain areas are more

difficult to visualize than others such as the inferior surfaces of the posterior third of the meniscus.^{16,17} These were the areas subsequently shown to have the highest rates of false positives.¹⁸ In most of similar studies, a higher false positive rate was noted than false negative rates in meniscal injuries.¹⁹ This is mostly explained by the fact that intra-substance tears, which can be seen in MRI, are usually not visible during arthroscopy. It has been well documented that MRI can detect intra-meniscal degenerative changes not visualized at arthroscopy.²⁰ If during MRI the increased linear signal is seen to reach to an articular surface on both coronal and sagittal images, the possibility of the tear becomes higher. But, if seen only in one set of images then the tear is probably small and not identifiable on arthroscopy. Sometimes it may be particularly difficult to ascertain whether the signal reaches to an articular surface. False negatives were predominantly reported at the periphery of the menisci and were attributed to volume averaging, where subtle tears are averaged within the thickness of the slice. On retrospective review, one cases with

a meniscal tear not detected on MRI in our study was a parrot-beak tear. Under-reading it also plays a part when small peripheral areas of signal change are considered insignificant. Another possible source of MR images and arthroscopy discordance was the time span between the MR images and arthroscopy examination. The meniscal injuries are known to heal spontaneously and appear normal on subsequent arthroscopies. But, even then the intra-substance high signal persists. In our study, the examinations were carried out within 3 months of the procedure.

Cruciate ligaments. Twelve cases were found to have abnormalities in the ACL. Out of 12, only 5 were correctly identified compared to arthroscopy. One case of a partial tear could not be identified. Explanations for false negative diagnosis may be due to displaced bucket handle tears of the medial meniscus and joint effusions.²¹ The use of GE T2W images in our study may have contributed to inaccuracy. Coronal images may also be useful for evaluation of the assessment of the proximal portion of the ACL, which tends to be obscured by volume averaging with the femoral condyle. In cases of chronic tears when the distal edge of the ACL becomes adherent with the PCL, identification of the tear becomes difficult. The presence of multiple injuries decreases diagnostic accuracy.²² Identification of posterior cruciate ligament injuries by MRI has been shown to approach 100% sensitivity and specificity.²³ In our study, only one case with partial fiber tear was missed.

Hyaline cartilage changes. Magnetic resonance imaging was shown to be relatively insensitive to minor degrees of cartilage changes and highly sensitive to grade 2 and 3 of cartilage loss.²²⁻²⁴ In our study, 6 cases out of the 12 were correctly identified. On further review, 5 cases of the 6 cases not noted on MRI were grade 1: agreeing with the literature. As seen from the results, this study highlighted the added advantage of MRI in imaging the collateral ligaments.

In conclusion, MRI examination using DESS technique has been shown to provide moderately accurate non-invasive evaluation of the injured knees. Its high negative predictive value in all areas assessed suggests that it is an accurate method of channeling the right candidates for arthroscopy. Double echo steady state technique has moderate accuracy in the delineation of early cartilage lesions and moderately high accuracy in detection of advanced cartilage lesions.

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