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RESEARCH ARTICLE

HIGH RESOLUTION 3D MAGNETIC RESONANCE IMAGING (MRI) VERSUS STANDARD 2D MRI AT 1.5T IN DETECTION OF MENISCAL TEARS IN KNEE WITH ARTHROSCOPIC CORRELATION

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ABSTRACT

Background: Aims & Objectives of this study is to evaluate meniscal injuries using volumetric MRI(VISTA) and to compare volumetric protocol with 2D protocol considering arthroscopy as reference standard. The purpose of this study is also to determine whether volumetric MRI is superior to 2D MRI in diagnosis of injuries AND/OR can allow reduction in total imaging time without loss of diagnostic efficiency.

Methods: Total 51 subjects were studied.Adult patients referred for MR evaluation of knee trauma and subsequently underwent arthroscopy included.Patients with previous knee surgery and non-traumatic pathologies excluded. Imaging performed on 1.5T Philips Achieva MRI machine. Conventional MRI images were acquired, followed by 3D VISTA data-sets in sagittal plane which were then reconstructed.

Results: Regarding detection of medial meniscus tears, overall sensitivity was similar for two techniques (88.2%), specificity of 2D & 3D protocol was 88.2% and 94.1% respectively. Regarding detection of lateral meniscal tears, specificity was similar for two techniques (84.9%) while sensitivity of 2D & 3D protocol was 72.2% & 83.3% respectively.

Conclusions: 3D TSE is a reliable technique and has diagnostic performance similar to that of routine 2D TSE MR for detecting meniscal tears at 1.5T. 3D TSE MRI protocol has advantage of faster acquisition time which potentially reduces patient discomfort and improves efficiency by reducing patient non-compliance. Results of this study represent an important step toward implementing this technique in routine clinical practice.

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INTRODUCTION

Traumatic and non-traumatic (degenerative) knee disorders involving menisci and standard ligaments (lateral and medial collateral ligaments, anterior and posterior cruciate ligaments) are extremely common indications for MR imaging. With increasing case-loads, it is becoming even more essential for radiologists to optimize MR protocols in a way that the right balance between adequate image quality and low scan times are achieved while still maintaining diagnostic efficacy and efficiency. The standard knee MRI protocol mainly use sequences based on two dimensional (2D) acquisitions in three orthogonal planes (coronal, axial and sagittal) and its utility is well established in evaluation of knee injuries (Kijowski, 2009; Peterfy, 2006 and Peterfy, 2008). Although 2D sequences exhibit high spatial resolution, they are acquired with relative thick slices with inter-slice gaps, making it impossible to generate orthogonal or oblique reconstructions from dataset thus generated without significant loss of quality. Three dimensional (3D) MRI acquisitions with isotropic or near-isotropic resolution have the potential to generate complete datasets from which multi-planar thin reconstructions with overlapping sections can be generated in virtually any plane. Not only can this potentially improve the spatial resolution of acquired images and avoid possible loss of information due to slice gaps in 2D sequences, it can also potentially improve the efficiency and increases patient comfort by reducing total time of study by eliminating the need to repeat 2D sequences in different planes (Kijowski, 2009 and Kijowski, 2010; Ristow, 2009; Jung, 2009 and Ai, 2012). If established that multiplanar reconstructions acquired from 3D MRI protocols can provide at least a similar image quality (if not better) in lesser scan time compared to those provided by standard 2D MRI protocols, replacing 2D protocols by 3D protocols could have a significant impact on clinical practice and research

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methodology. Most studies assessing the diagnostic performance of 3D MRI knee protocols have been performed on 3T MRI scanners (Kijowski, 2009; Kijowski, 2012; Ristow, 2009; Jung, 2009; Ai, 2012; Subhas, 2011; Jung, 2012 and Van Dyck, 2012). The VISTA sequence (Volume Isotropic Turbo Spin Echo Acquisition) is one such 3D sequence that provides high resolution volumetric intermediate weighted images and it is clinically available for both 1.5T and 3T MRI systems.The main purpose of this study is to evaluate the diagnostic performance of volumetric (VISTA) acquisition for meniscal injuries (medial and lateral menisci) compared to standard knee protocol, taking arthroscopic findings as the reference standard.

MATERIALS AND METHODS

Participants

This is a hospital based time bound prospective study conducted over a period of 14 months. After approval by the local institutional ethical committee, total number of 51 subjects studied. Adult patients referred to our department for MR evaluation of knee trauma and those underwent subsequent arthroscopic evaluation were included in this study, while patients with previous knee surgery and non traumatic knee pathologies were excluded. Written informed consent was obtained from all patients after fully explaining to them the nature of the examination.

Image acquisition and data processing

Imaging was performed on a 1.5T Philips Achieva MRI machine using a dedicated 4 channel elements phased array knee coil. Conventional MRI images were acquired for each patient, followed by 3D VISTA data-sets in sagittal plane. Thin axial and coronal images were then reconstructed from sagittal data sets using 3D workstation to allow comparison of the results. The MRI parameters and acquisition times for both protocols are summarized in Table 1.

Table 1. MRI parameters for the 2D and 3D protocols

Parameter		Pd tse fsSag	Pd tse fs Cor	Pd tse fsAx	Pdw vista spair clear
FOV	RL	79	160	150	110
FOV	AP	160	99	150	160
FOV	FH	160	179	118	140
MATRIX		268X265	268X297	248X250	280x270
Voxel Size(mm)	AP	0.6	0.6	0.6	0.6
Voxel Size(mm)	RL	-	-	-	0.35
	FH	0.6	0.6	0.6	0.50
TR/TE (ms)		2153/12	2691/12	3219/12	1200/30
Acquisition Time (min)		3 min 50 sec*	5 min 22 sec *	5 min 25 sec *	10 min 3 sec#
Slice Thickness (mm)		3	3	3	0.35
Turbo factor TSE		12.0/60	12.0/60	12.0/60	-

* Total 2D TSE multiplanar acquisition time: 14 min 37 sec.
# Total 3D TSE single sagittal plane acquisition time: 10 min 3 sec (approx. 28.3 % less than the 2D TSE protocol).

The sagittal source images from the 3D protocol were used to create coronal and axial re-formatted images by Insta3D Viewer on Meddiff PACS-RIS viewing station with a slice thickness of 0.5 mm. These reformatted images were used for 3D protocol assessment of the knee.

Image analysis

The images were interpreted while being blinded to all clinical information. Images-sets from 2D TSE and 3D protocols were assessed separately and independently.First 2D protocol was assessed and then after a period of two weeks the 3D protocol was assessed. This delay in the second reading was intended to minimize the risk of interpretation and recognition bias.The medial and lateral menisci were evaluated throughout their length (anterior horn, body and posterior horn) and were classified according to the presence or absence of a meniscal tear.A meniscal tear was defined as either meniscal distortion or intermediate to high signal intensity extending to the meniscal articular surface on at least two consecutive sagittal or coronal images (Fischer, 1991). Isolated intrameniscal signal intensity changes were not considered indicative of meniscal tear.

Arthroscopic knee surgery

All knee arthroscopies were performed within one month after the MRI, 75% being performed in the same week. The arthroscopies were performed by one of two experienced knee surgeons at our institution. During arthroscopies, a complete inventory of the joint was performed, with special attention to and documentation of menisci, which were assessed according to the presence or absence of tears.

Statistical analysis

- The sensitivity and specificity for the detection of meniscal tears were calculated separately for each of the MRI protocols, using arthroscopy findings as the reference standard.
- The statistical analysis was performed with the Statistical Package for the Social Sciences, version 16.0.
- Since medial and lateral collateral ligaments, quadriceps & patellar tendons and posterolateral corner structures are not visualized on arthroscopy, MRI findings could not be correlated and statistical analysis was not possible for these structures.

RESULTS

The present study sample included 51 patients who suffered from knee trauma.The number of positive findings (tears) detected in each MRI protocol is presented by Table 2, as is the number of positive findings detected by arthroscopy.The overall sensitivity and specificity for the detection of medial meniscus and the lateral meniscus tears in our study are displayed in Table 3. Regarding the detection of medial meniscus tears, overall sensitivity was similar for two protocols while specificity of 2D and 3D protocols were 88.2%

Table 2. Number of positive findings detected in each MRI protocol

Technique	MM tears (n=17)	LM tears (n=18)
2D protocol	15	13
3D protocol	15	15

n= number of positive findings at arthroscopy.

Table 3. Comparison of sensitivity and specificity of our study and other studies in the detection of tears in medial meniscus (MM) and lateral meniscus by both 2D and 3D protocols

MRI	OUR STUDY				Chagas – Neto *et al* study				Kijowski *et al* study			
	2D		3D		2D		3D		2D		3D	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
MM	88.2	88.2	88.2	94.1	83	71	85	68	97.1	65.6	98.1	70.8
LM	72.2	84.9	83.3	84.9	54	92	58	82	80	79.2	72.9	85.8

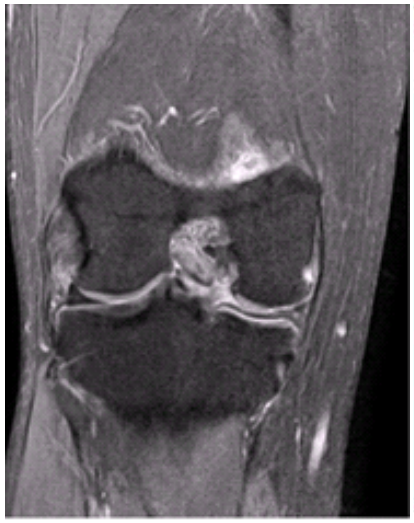

Fig. 1A.

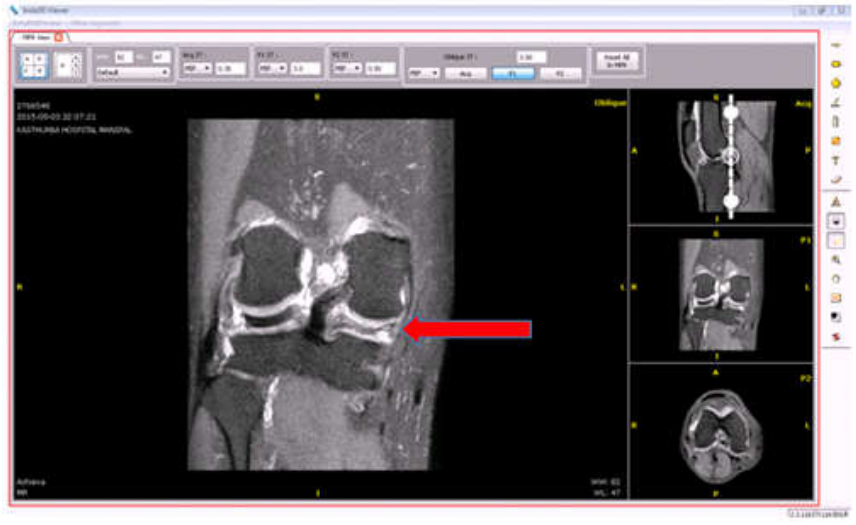

Fig. 1B.

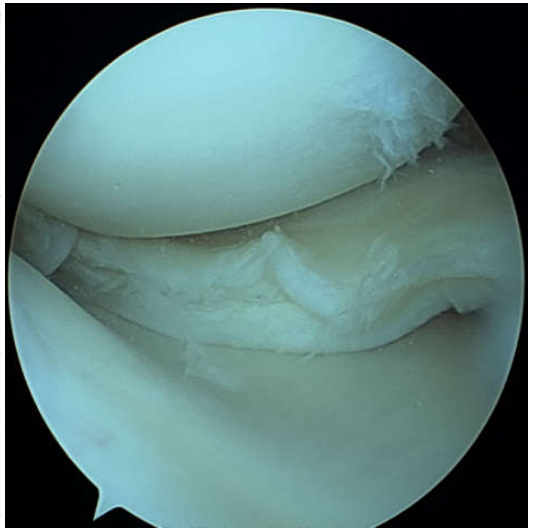

Fig. 1C.

Figure 1. A 51 year old male patient with trauma to right knee joint 10 days back came with complains of pain and instability. A. Coronal image acquired by 2D protocol. B. Coronal reconstruction of the acquired sagittal image by 3D protocol using Insta3D Viewer showing tear in the medial meniscus (arrow). C. Arthroscopy done after 8 days confirmed the finding

and 94.1% respectively. For lateral meniscal tears, overall specificity was similar for two protocols while sensitivity of 2D and 3D protocols were 72.2 % and 83.3% respectively.Out of 51 patients, 17 cases found to have tear in the medial meniscus in arthroscopy out of which 15 were picked up by both standard 2D and 3D MR protocols and 2 cases were missed by both protocols. In 18 cases, tear of lateral meniscus found in the arthroscopy out of which 13 were picked up by both standard 2D and 3D MR protocols and 3 cases were missed by both protocols.We applied McNemar's test to find association between two methods and we got same *p* valueof 0.5 for both medial and lateral menisci which is statistically not significant. There was no significant difference between the protocols for the detection of meniscal tears (Figure 1). This suggests that, results of MRI for the evaluation of medial and lateral menisci by both 2D and 3D protocols are comparable.

DISCUSSION

Radiologic imaging is essential for the evaluation of knee injuries. Among the various imaging protocols, MRI is of considerable importance. Three-dimensional MRI protocol obtained with isotropic or nearly isotropic resolution techniques can be manipulated to provide high-resolution multiplanar reconstructions. The diagnostic performance of several 3D isotropic-type gradient-echo sequences have been previously tested in the evaluation of articular cartilage pathologies like spoiled gradient-recalled echo, double-echo steady-state, driven equilibrium Fourier transform, fast low-angle shot and balanced steady-state free precession (Chagas-Neto, 2016). However, 3D gradient-echo acquisition protocols are time consuming and cannot completely replace routine 2D TSE, as they do not allow accurate assessment of other important joint structures such as the menisci, ligaments and subchondral bone changes (Chagas-Neto, 2016). Recently, 3D TSE MRI techniques were introduced, these provide isotropic or nearly isotropic resolution. Previous studies have shown these techniques to have good diagnostic performance for the detection of cartilaginous, meniscal and ligament lesions with a 3.0T magnet (Kijowski, 2009 and Kijowski, 2012). It should also be noted that acquisition of the source images was significantly faster with the 3D TSE protocol than with the triplanar 2D TSE protocol. The volume isotropic turbo spin-echo acquisition MRI sequence (VISTA) provides high-resolution volumetric intermediate-weighted images acquired with 3D TSE and is clinically available for 1.5T and 3.0T systems.

TSE (Turbo spin echo), also known as FSE (Fast spin echo) imaging are commercial implementations of the RARE (Rapid Acquisition With Refocused Echoes) technique originally described by Henning *et al* in 1986. Since that time TSE/FSE has grown to become one of the workhorse pulse sequences used in virtually all aspects of modern MR imaging.The purpose of the present study was to compare the diagnostic performance of this sequence in detecting meniscal tears of the knee joint in a 1.5T scanner and comparing the results promptly with arthroscopic correlation. To the best of our knowledge, there have been no previous studies comparing the diagnostic performance of 3D protocol on 1.5T scanner. We found no significant differences between 2D and 3D protocols regarding the detection of meniscal tears. Similar results have been obtained in previous studies testing 3D protocols (Kijowski, 2009; Kijowski, 2012; Ristow, 2009; Jung, 2009 and Ai, 2012). However, results from two other similar studies testing the 3D protocols differed from ours and concluded that 2D protocol is more reliable than 3D protocol (Subhas, 2011; Jung, 2012 and Van Dyck, 2012). Based on this we found that, for detecting medial meniscus tears, the 3D and routine 2D MRI protocols showed similar values for sensitivity (88.2%), however 3D showed a slightly higher specificity (i.e. 94.1% which was for 2D 88.2%). For detecting lateral meniscal tears, 2D and 3D techniques had sensitivity (83.3% and 72.2%, respectively) and similar specificity (i.e. 84.9%).

Chagas-Neto *et al* determined the diagnostic performance and agreement between standard multiplanar 2D and 3D TSE techniques in the same 1.5 T MRI scanner. They found that for detecting medial meniscal tears, the two techniques had similar sensitivity (85% and 83%, respectively) and specificity (68% and 71%, respectively). In addition, for detecting lateral meniscal tears, the two techniques had similar sensitivity (58% and 54%, respectively) and specificity (82% and 92%, respectively) (Tyrrell, 1988). Van Dyck *et al*. suggested that, 3D TSE cannot entirely replace routine 2D MRI in the assessment of the knee (Van Dyck, 2012). They found a total number of 5 false-positive MR interpretations of medial meniscal tear using 3D (specificity 69 %). In the detection of eight lateral meniscal tears, the 3D and 2D protocols had similar performance (accuracy 95 %). Subash N *et al* found 10 false-positive cases and 6 false-negative casesby the 3D technique. The cause of misdiagnosis was assigned to one of the following: poor image contrast, reader interpretation error, artifact or noise (Subhas, 2011). However, other authors who tested 3D TSE MRI of the knee have concluded that its diagnostic performance is comparable to that of conventional 2D protocol in the detection of meniscal tears (Jung, 2009 and Ai, 2012). Ai *et al*. stated that the 3D protocol is comparable if not superior to conventional 2D protocol for comprehensive joint assessment of knee injuries and predicted that it is likely to replace the currently used 2D protocol for the evaluation of knee injuries (Ai, 2012). Kijowski *et al*. (Kijowski, 2006), found that there was no significant differences (P = 0.18–0.99) in sensitivity and specificity between FSE-CUBE and the routine MR imaging protocol in the detection of medial or lateral meniscal tears. Table 3 shows comparison of sensitivity and specificity of our study and other studies in the detection of tears in medial and lateral meniscus by both 2D and 3D protocols.However, in our study, both 2D and 3D MRI protocols showed false results in significant proportion. For example as far as medial meniscus concerns, there were 4 false positive and 2 false negative diagnoses whereas for lateral meniscus, there were 5 false positive and 5 false negative diagnoses by 2D MR protocol. And by 3D MR protocol, for medial meniscus, there were 2 false positive and 2 false negative diagnoses whereas for lateral meniscus, there were 5 false positive and 3 false negative diagnoses.

There are several explanations for the misleading results of MRI regarding the menisci. Firstly, meniscal tears and meniscus degenerative changes have the same appearance in MRI, by giving high signal within the meniscus. Diagnosis then depends on the expansion of the high signal line towards meniscus articular surface (Spiers, 1993). Moreover, one of the most frequent causes for false positive MRI regarding the lateral meniscus is the misinterpretation of the signal coming from the inferior knee artery (Herman, 1988). Herman *et al*accredited in this structure about 38% of false positive MRI results. Often, the popliteal bursa or Humphry's' ligament may

mimic posterior lateral meniscus tears as well (Mackenzie, 1996). McKenzie *et al* summarized the four most common reasons for false positive diagnosis; wrong diagnosis due to variable anatomic structures, overestimation of pathology countered as meniscus tear (for example chondral injuries that mimic meniscus tears), false negative arthroscopic findings and tears within the meniscus without expansion to the articular surface. On the other hand the false negative results seem to occur exclusively from misinterpretation of MRI (Duc, 2007). Also, in one case where there was no tear in arthroscopy, we found thatboth sagittal and coronal images of routine MRI by 2D protocol and acquired sagittal MRI image by 3D protocol showing false positive tear and it was not seen only on coronal reconstructed MRI image by 3D protocol. This indicates the importance of reconstruction of acquired images.

In previous studies, the mean time between imaging and arthroscopy has ranged from four weeks to four months, which could compromise the reliability of the imaging findings in relation to the surgical data(Kijowski, 2009; Kijowski, 2012; Ristow, 2009; Jung, 2009; Ai, 2012; Subhas, 2011; Jung, 2012 and Van Dyck, 2012). The major limitation of the study was, PACS workstations were used to evaluate sagittal 3D datasets. Axial & coronal planes were both reconstructed and evaluated on PACS workstations using proprietary 3D image manipulation software, which may not be available to all radiologists.

Conclusion

Using 3D VISTA MRI protocol, we demonstrated that 3D TSE is a reliable technique and has a diagnostic performance similar to that of the routine 2D TSE MR protocol for detecting meniscal tears at 1.5T. The 3D TSE MRI protocol has the advantage of faster acquisition time – scanning time can be effectively shortened by approximately 28.3% by using a 3D protocol compared to conventional 2D protocol. This is of significant importance in clinical practice, especially in acute injuries where the patient may not be able to remain motionless for long duration. Therefore to 3D protocol can potentially reduce patient discomfort and improve efficiency by reducing possibility of patient non-compliance.Over-estimation of tears by 3D protocol can be reduced by comparing all three planes before coming to a final diagnosis, as is done when using the 2D protocol. In fact, the 3D protocol may prove to be a valuable problem solving tool in difficult cases, since non-orthogonal plane reconstructions (double oblique planes) and curved planar reconstructions can be generated from the 3D dataset to better evaluate complex or non-planar structures/tears.Since we could not compare the efficacy of 3D and 2D protocols for extra capsular structures which need surgical correlation, we cannot immediately recommend completely replacing routine 2D MRI protocol with 3D protocol for knee. However, the results of this study do represent an important step toward implementing this technique in routine clinical practice.

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