Diagnostic performance of 3D-TSE MRI versus standard multiplanar 2D-TSE MRI at 1.5T in the detection of meniscal and ligamentous tears in the knee with arthroscopic correlation

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Purpose

- Knee MRI protocols often use sequences based on two-dimensional (2D) acquisitions with different fluid sensitive weights, acquired in three orthogonal planes (coronal, axial and sagittal). These sequences are widely used in clinical practice in different scenarios as well as in clinical trials.\textsuperscript{1,2,3}

- Although the 2D sequences exhibit high spatial resolution, they are acquired with relatively thick slices, and may present gaps between slices, which might generate partial volume artifacts. It is also impossible to generate reconstructions in multiple planes without significant loss of quality using 2D sequences as the source for reformation.

- Three-dimensional (3D) MR imaging with isotropic or nearly isotropic resolution techniques has the potential to improve both quality and efficiency of MRI use in the musculoskeletal system, as well as increase patient comfort by reducing the time required for its acquisition\textsuperscript{1}. These volumetric acquisitions may be used to create multiplanar reconstructions, thereby eliminating the need to repeat sequences with the same tissue contrast in different planes.

- The VISTA (Volume Isotropic Turbo Spin-Echo Acquisition - Philips Medical Systems) MRI technique provides high-resolution volumetric intermediate-weighted images acquired with a 3D-Turbo Spin-Echo (TSE) acquisition and it is clinically available for both 1.5 and 3.0T systems.

- To the best of our knowledge, the diagnostic performance of 3D-TSE VISTA MRI sequence for detection of internal derangements of the knee has not yet been tested on a 1.5 T unit.

- The main purpose of this study is to evaluate the diagnostic performance of 3D-TSE (VISTA) MRI acquisition technique at 1.5T in the diagnosis of meniscal and ligamentous lesions compared to 2D-TSE standard protocol, taking prompt surgical findings (arthroscopy) as the reference standard.
Methods and Materials

Participants

- After approval by the institutional review board, a total of 38 patients who were already referred for knee arthroscopy in our institution, were invited to participate in this prospective study and were evaluated with a preoperative MRI of the knee to be operated.

MRI Acquisition

- All knees were imaged with the same 1.5T MRI unit (Philips Achieva 1.5T MRI System, Philips Medical Systems, Best, The Netherlands) using an 8-channel SENSE knee coil. Both standard 2D and 3D TSE techniques were acquired in the same day. Routine 2D TSE MRI consisted in 3 sequences, all acquired with SPAIR (spectral attenuated inversion recovery, a high uniform fat saturation method which uses adiabatic spectral saturation pulses): 1) sagittal lw TSE (repetition time (TR) 2342 ms, echo time (TE) 50 ms, 224 x 176 matrix, 16 x 16 cm field of view (FOV), 4 mm slice thickness, 4 number of excitations (NEX), echo train length (ETL) 14, bandwidth 395 Hz/pixel, acquisition time 2 minutes 43 seconds); 2) coronal lw TSE (TR 2342 ms, TE 50 ms, 224 x 176 matrix, 16 x 16 cm FOV, 4 mm slice thickness, 4 NEX, ETL 14, bandwidth 386 Hz/pixel, acquisition time 2 minutes 30 seconds); and 3) axial lw TSE (TR 3045 ms, TE 50 ms, 224 x 176 matrix, 16 x 16 cm FOV, 4 mm slice thickness, 4 NEX, ETL 14, bandwidth 429 Hz/pixel, acquisition time 3 minutes). The total acquisition time for routine 2D TSE MRI was 8 minutes 13 seconds.

- The 3D TSE sequence was also acquired with the SPAIR technique in the sagittal plane (source images), with lw contrast and nearly isotropic voxels (0.6 x 0.6 x 0.7 mm), with the following parameters: TR 2500 ms, TE 35 ms, 300 x 258 matrix, 18 x 18 cm FOV, 1 NEX, ETL 65, and bandwidth 255 Hz/pixel. The total time acquisition for the 3D sagittal sequence (source images) was 5 minutes.

- The source images were used to create sagittal, coronal, and axial reformatted images of the knee joint with 1.5 mm slice thickness, which were used for the 3D TSE MRI assessment of the knee. The post-processing of the 3D TSE sequence (VISTA) was performed by a fellowship in musculoskeletal radiology on the imaging workstation immediately after the MRI examination.

MRI Assessment
The interpretation of both techniques (2D and 3D MRI) was separately and independently made by two musculoskeletal radiologists, being the first reader a senior radiologist with more than ten years of experience and the second reader a fellow in musculoskeletal radiology with one-year experience. They were blinded to the medical and surgical history of the patient or any other information regarding the indication for the MRI. The time frame between the 2D and 3D readings was one month.

- The medial and lateral menisci were evaluated according to the presence or absence of a meniscal tear. A meniscal tear was defined as an abnormal signal extending into the articular surface of the meniscus on at least two sagittal or coronal consecutive slices. Intrameniscal degenerative changes were not considered as meniscal tears.

- Both anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) were analyzed according to the presence or absence of tears, regardless of being partial or complete tears.

**Arthroscopic knee surgery**

- All knee arthroscopies were performed within a maximum period of three days after the MRI, and in 80% of the cases the arthroscopy was performed on the same day of the MRI. The knee arthroscopies were performed by one of two experienced knee surgeons at our institution with 5 and 20 years of practice, respectively.

**Analytic Approach**

- The sensitivity, specificity, and accuracy for the detection of meniscal and cruciate ligaments tears were calculated separately for each MRI technique, taking prompt surgical findings (arthroscopy) as the reference standard.

- The data from the independent assessment of both readers were analyzed separately and then combined when calculating sensitivity and specificity to increase statistical power for a comparison between 3D-TSE and the standard 2D-TSE MR protocol.

- Kappa statistics (k) were used to measure interobserver agreement between readers for determining the presence or absence of meniscal and cruciate ligament tears. K was also calculated to measure intraobserver agreement between both methods (2D-TSE versus 3D-TSE) for each reader.
The differences between 3D-TSE and the routine 2D-TSE MR techniques were calculated for dichotomized values (presence or absence of pathology) with 95% confidence intervals using the Fisher's test, and were considered to be statistically significant when the p-value was less than 0.05.
Results

- There were 38 participants, 28 men and 10 women, aged between 21 and 57 years (mean age of 33.5 +/- 10.4 years).

- Regarding the detection of ACL tears (Table 1), the overall combined sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were 93%, 85%, 95%, 81% and 91% using 2D-TSE MRI, and 93%, 80%, 93%, 80% and 89% using 3D-TSE MRI, respectively. No significant differences between both techniques were found (Figure 1). The agreement between both techniques was 0.83 [0.70-0.97].

- Regarding the detection of medial meniscal tears (Table 1), the overall combined sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were 83%, 71%, 83%, 71% and 79% using 2D-TSE MRI, and 85%, 68%, 82%, 73% and 79% using 3D-TSE MRI, respectively. No significant differences between both techniques were found (Figures 2 and 3). The agreement between both techniques was 0.89 [0.77-0.99].

- Regarding the detection of lateral meniscal tears (Table 1), the overall combined sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were 54%, 92%, 78%, 79% and 79% using 2D-TSE MRI, and 58%, 82%, 63%, 79% and 74% using 3D-TSE MRI, respectively. No significant differences between both techniques were found. The agreement between both techniques was 0.74 [0.58-0.92].

- Table 2 shows the sensitivity, specificity, and accuracy for both readers readings separately, as well as the intraobserver agreement comparing both MRI techniques (2D vs. 3D). No significant differences between both techniques were found. Table 3 shows the interobserver agreement regarding each feature assessed and each MRI technique used.
Images for this section:

Fig. 1: Figure 1 - Knee MRI sagittal images (A - 2D-TSE and B - 3D-TSE) show an anterior cruciate ligament complete tear (Arrows). C. Corresponding arthroscopic image confirmed the ACL tear (the black arrow points the ligament stump and the white arrow shows an empty intercondilar notch).

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Fig. 2: Figure 2 - Knee MRI sagittal images (A - 2D-TSE and B - 3D-TSE) depicts a medial meniscus posterior horn tear (Arrows). C. Corresponding arthroscopic confirmation of the medial meniscus tear (Arrow).

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**Fig. 3:** Figure 3 - Knee MRI coronal (A - 2D-TSE and B- 3D-TSE) and sagittal (D - 2D-TSE and E- 3D-TSE) images that show surgically confirmed bucket handle medial meniscus tear (Arrows). C. Corresponding arthroscopic image of the medial meniscus fragment (Arrow) deslocated to the intercondilar notch.

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| MRI Features | Both Readers Combined - 2D | | | Both Readers Combined - 3D | | | | Overall 2D x 3D Agreement (Kappa) | | [95%CI] |
|-------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | Sensitivity (%) [95%CI] | Specificity (%) [95%CI] | Accuracy (%) [95%CI] | Sensitivity (%) [95%CI] | Specificity (%) [95%CI] | Accuracy (%) [95%CI] | [95%CI] |
| ACL | 93[83-98] | 85[62-97] | 91[82-99] | 93[83-98] | 80[56-94] | 89[80-98] | 0.83[0.70-0.97] |
| MM | 83[70-93] | 71[51-87] | 79[67-91] | 85[72-94] | 68[48-84] | 79[67-91] | 0.89[0.77-0.99] |

**ACL** - Anterior Cruciate Ligament.  
**MM** - Medial Meniscus.  
**LM** - Lateral Meniscus.  
**CI** - Confidence Interval.
Table 1: Table 1 - Overall Combined Sensitivity, Specificity, Accuracy and agreement (Kappa) for standard 2D-TSE protocol and 3D-TSE MRI in detecting ACL, MM and LM tears.

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<table>
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<th>Reader 2 – 3D</th>
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<th>Intraobserver Agreement [95%CI]</th>
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ACL – Anterior Cruciate Ligament.  
MM- Medial Meniscus.  
LM- Lateral Meniscus.  
CI - Confidence Interval.

Table 2: Table 2 - Sensitivity, Specificity, Accuracy and intraobserver agreement (Kappa) for standard 2D-TSE protocol and 3D-TSE MRI in detecting ACL, MM and LM tears for both readers apart.

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<th>MRI Features</th>
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<td>LM</td>
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ACL – Anterior Cruciate Ligament.
MM- Medial Meniscus.
LM- Lateral Meniscus.
CI - Confidence Interval.

**Table 3:** Table 3 - Interobserver agreement (Kappa) for standard 2D-TSE protocol and 3D-TSE MRI in detecting ACL, MM and LM tears.

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Conclusion

- In conclusion, we demonstrated that 3D-TSE MRI had similar diagnostic performance to a standard 2D-TSE MRI protocol for detecting meniscal and cruciate ligament tears at 1.5T, both for junior and senior musculoskeletal radiologists.

- 3D-TSE MRI has the advantage of faster time acquisition, which would be important in clinical practice to increase the patient comfort and the performance of the MR unit.
References


