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Clinical value of routine use of thin-section 3D MRI using 3D FSE sequences with a variable flip angle technique for internal derangements of the knee joint at 3T

Hideyasu Kudo [a], Tsutomu Inaoka [a,*], Noriko Kitamura [a], Tomoya Nakatsuka [a], Shusuke Kasuya [a], Rumiko Kasai [a], Mitsuyuki Tozawa [b], Koichi Nakagawa [c], Hitoshi Terada [a]

[a] Department of Radiology, Toho University Sakura Medical Center, Sakura, Japan
[b] Division of Radiologic Technology, Toho University Sakura Medical Center, Sakura, Japan
[c] Department of Orthopaedic Surgery, Toho University Sakura Medical Center, Sakura, Japan

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ABSTRACT

Purpose: To determine the clinical value of routine use of thin-section 3D MRI using 3D FSE sequences with a variable flip angle technique for internal derangements of the knee joint at 3 T.
Method and Materials: Thirty-four knees in 34 patients suspected of having internal derangements of the knee joint were included. Following standard 2D MRI protocol including sagittal PDWI, T1WI and T2*WI, coronal fat-suppressed PDWI, and axial fat-suppressed PDWI with 3-4 mm thicknesses, fat-suppressed and water-excitation PDWI using 3D FSE sequences with a variable flip angle technique with 0.6 mm thickness were obtained in coronal plane and the three major planes with 1 mm thickness (3D MRI) was reformatted. The standard 2D MRI protocol and reformatted 3D MRI protocol (three sagittal 2D sequence images plus 3D MRI) were independently analyzed by two radiologists concerning presence or absence of lesions in the menisci, cartilage, and ligament. Interobserver agreements in both the MRI protocols were assessed by weighted-kappa coefficients. Regarding diagnostic accuracy, areas under the receiver operating characteristic curves (Az values) of both the MRI protocols were compared.
Results: Thirty-eight meniscal lesions, 39 cartilage lesions, and 20 ligamentous lesions were surgically detected. Excellent interobserver agreements (kappa = 0.91–0.98) were seen in both the MRI protocols, with a slightly better tendency in the reformatted 3D MRI protocol. Average Az values in detection of the meniscal, cartilage, and ligamentous lesions were significantly higher in the reformatted 3D MRI protocol than in the standard 2D MRI protocol ($p < 0.01$ or $p < 0.001$).
Conclusion: Routine use of reformatted thin-section 3D MRI using 3D FSE sequences with a variable flip angle technique may improve diagnostic accuracy and confidence in detection of internal derangements of the knee joint.

1. Introduction

Different three-dimensional (3D) sequences have recently been proposed in routine musculoskeletal magnetic resonance imaging (MRI). In knee MRI, currently, gradient-echo (GRE) sequences have predominantly been used in the 3D sequences [1–5]. The 3D GRE sequences have been very useful for assessing cartilage abnormalities, but they are less accurate than two-dimensional (2D) fast spin-echo (FSE) sequences for assessing meniscus or ligaments [1–5]. Therefore, 3D FSE sequences have been attempted for comprehensive joint imaging, but a quite long imaging time has been a major disadvantage in conventional 3D FSE sequences. With the use of 3 T MRI systems, multichannel coils, and parallel imaging technique, images have been acquired with isotropic voxels in a shorter imaging time. By using 3 T MRI systems, however, high specific absorption rate (SAR) is a critical issue. With using a new variable flip angle technique, SAR can be reduced even at 3 T [6,7]. So far, 3D FSE sequences with a variable flip angle technique have now been attracted attention in comprehensive assessment of joint imaging at 3 T [1,8,9].

The primary advantages of imaging using 3D FSE sequences with a variable flip angle technique for knee MRI are the ability to obtain submillimeter contiguous slices with higher signal-to-noise ratio (SNR) and to generate isotropic images reformatted into various planes of better image contrast [1,8,9]. Therefore, 3D FSE sequences with a variable flip angle technique have been expected to be useful for the detection of smaller intraarticular lesions or for the preoperative planning by using postprocessing, highly resolved

* Corresponding author. Toho University Sakura Medical Center, Department of Radiology, 564-1 Shimoshizu, Sakura City, Japan. Tel.: +81 434628811.
E-mail address: tsutomu.inaoka@med.toho-u.ac.jp (T. Inaoka).

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Table 1
Parameters of MRI of the knee.

Parameter	2D MRI					3D MRI
	Sagittal 2D FSE PDWI	Sagittal 2D FSE T1WI	Sagittal 2D GRE T2*WI	Coronal 2D FSE FS PDWI	Axial 2D FSE FS PDWI	Coronal SPACE FS PDWI
TR (msec)	3500	520	700	2500	2500	1200
TE (msec)	30	11	16	11	11	15
FOV (cm)	16	16	16	16	16	16
Slice thickness (mm)	3-4	3-4	3-4	3-4	3-4	0.6
Matrix size	384 × 384	448 × 448	384 × 256	448 × 448	448 × 448	256 × 256 (512 × 512*)
Voxel size (mm)	0.4 × 0.4 × 3-4	0.4 × 0.4 × 3-4	0.4 × 0.4 × 3-4	0.4 × 0.4 × 3-4	0.4 × 0.4 × 3-4	0.6 × 0.6 × 0.6 (0.3 × 0.3 × 0.6*)
Turbo factor	12	2		6	6	70
Number of signal acquisition	2	1	1	1	1	1
Imaging time	1 min 36 sec	1 min 25 sec	1 min 50 sec	1 min 14 sec	1 min 19 sec	5 min 21 sec–6 min 20 sec

Note. 2D: two dimensional, 3D: three-dimensional, FS: fat-suppressed, FSE: fast spine echo, GRE: gradient-echo, SPACE: sampling perfection with application-optimized contrasts using different flip-angle evolutions (3D FSE with a variable flip angle technique), PDWI: proton density-weighted image, TR: repetition time, TE: echo time, FOV: field of view.
* Interpolation.

isotropic 3D MRI. Many preliminary studies comparing diagnostic efficacies of isotropic 3D MRI using 3D FSE sequences with a variable flip angle technique versus standard 2D MRI of the knee at 3 T have been done, and the diagnostic efficacies for internal derangements of the knee joint between them are reportedly the same [8,10–13]. In clinical practice, however, it is reasonable that a 3D FSE sequence with a variable flip angle technique is combined with several standard 2D sequences for the knee joint since a single of the 3D FSE sequence may not be thought to replace all the 2D sequences. To our knowledge, there is no study simply assessing clinical value of reformatted thin-section 3D MRI using 3D FSE sequence with a variable flip angle technique in routine MRI examinations for internal derangements of the knee joint at 3 T. The purpose of this study was to determine the clinical value of routine use of thin-section 3D MRI using 3D FSE sequences with a variable flip angle technique for internal derangements of the knee joint at 3 T.

2. Materials and methods

2.1. Patient sample

The institutional review board in our hospital approved this study. Informed consent was obtained for the limited use of MRI data without the disclosure of any patients' information. The addition of 3D FSE sequence with a variable flip angle technique was approved since it has already been commercially available and total examination time is within the MRI examination time prescribed in our hospital. There were 352 consecutive patients suspected of knee abnormalities who underwent MRI in our hospital from October 2011 to July 2012. Patients with rheumatoid arthritis, septic arthritis, and tumors were excluded since such patients needed contrast-enhanced MRI sequences. Patients with severe osteoarthritis (Kellegan-Lawrence grade 4 on the knee radiographs) were excluded since their cartilages or meniscus might be severely destructed. Patients who had undergone surgery involving the implantation of metal hardware around the knee joint were also excluded since metallic artifacts might reduce the diagnostic performance. Finally, 34 knees in 34 patients who underwent optimal standard 2D sequences and a 3D FSE sequence with variable flip angle technique at 3 T and whom diagnoses were surgically confirmed in our hospital were included in this study. All the patients were Asian population. There were 21 male and 13 female patients (mean age ± standard deviation, 46.5 ± 23.4 years; age range, 11–85 years). Twenty patients involved the right knee and 14 involved the left knee. The mechanisms of injury were sport-related injury in 15 patients, degenerative change (knee pain) in 12 patients, fall in three patients, motor vehicle accident in one patient, and other trauma in three patients.

2.2. MRI

All imaging was performed by a 3 T MR scanner (Magnetom Skyra, Siemens Medical Solution, Enlargen, Germany) with a 15-channel knee coil (TxRx, Quality Electrodynamics, Ohio, USA). The imaging protocol consisted of five 2D sequences and a single 3D FSE sequence with a variable flip angle technique with the parameters shown in Table 1. As 3D FSE sequence with a variable flip angle technique, 3D sampling perfection with application-optimized contrasts using different flip-angle evolutions (SPACE) sequence was used. The 2D sequence protocol consisted of sagittal 2D FSE proton density-weighted, 2D FSE T1-weighted, and 2D GRE T2*-weighted sequences, coronal fat-suppressed 2D FSE proton density-weighted sequence, and axial fat-suppressed 2D FSE proton density-weighted sequence. The imaging time of the five 2D sequence protocol was 7 min 24 sec. The 3D sequence protocol consisted of a single fat-suppressed 3D FSE proton density-weighted sequence in the coronal plane using SPACE 3D FSE sequences with a variable flip angle technique. Water-excitation technique was also added to increase the signal intensity in intraarticular fluid. The imaging times were 5 min 21 sec through 6 min 20 sec, which varied depending on the size of

Table 2
Type and location of the 38 meniscal lesions.

	Medial meniscus	Lateral meniscus	Total
Vertical tear	7	6	13
Longitudinal tear	3	3	6
Radial tear	4	1	5
Oblique tear	0	2	2
Horizontal tear	2	5	7
Complex tear	15	3	18
Total	24	14	38

Table 3
Grade and location of the 39 cartilage lesions.

	Medial femorotibial joint	Lateral femorotibial joint	Patellofemoral joint	Total
Grade 2	3	5	6	14
Grade 3	6	3	6	15
Grade 4	6	1	3	10
Total	15	9	15	39