Hong Kong J Radiol. 2020;23:191-7 | https://doi.org/10.12809/hkjr2017025

ORIGINAL ARTICLE

Magnetic Resonance Imaging of Ankle Syndesmotic Ligament Injuries: Comparison of Three-dimensional Isotropic Intermediate-weighted Fast Spin Echo with Conventional Two-dimensional Imaging

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ABSTRACT

Purpose: *We sought to compare the diagnostic performance of three-dimensional (3D) isotropic intermediate-weighted fast spin echo (FSE) magnetic resonance imaging (MRI) sequences with that of conventional two-dimensional (2D) FSE sequences for the assessment of syndesmotic ligament injuries associated with ankle fractures.*

Methods: *Between January 2014 and December 2015, 37 patients who underwent both conventional 2D MRI and 3D MRI of an ankle fracture were evaluated. All patients underwent subsequent ankle arthroscopy. Two radiologists retrospectively reviewed the imaging findings of syndesmotic ligament injury, with an interval of at least 2 weeks between sessions of interpretation. Sensitivity, specificity, and accuracy were calculated for each ligament, and McNemar's paired proportion test was performed to compare the diagnostic performance.*

Results: *Injuries of the anterior inferior tibiofibular ligament were the most common finding in the patients (31/37, 83.8%). The 3D sequences showed a sensitivity of 96.8% to 100% and a specificity of 50% to 66.7% in these injuries, whereas the 2D sequences showed a sensitivity of 96.8% to 100% and a specificity of 33.3% to 66.7% (p = 0.114-0.588). Injuries of the posterior inferior tibiofibular ligament and transverse tibiofibular ligament also showed no significant difference in diagnostic accuracy between 2D and 3D sequences.*

Conclusion: *There was no statistically significant difference in the diagnostic performance of 3D FSE sequences compared with that of 2D FSE sequences for syndesmotic ligament injuries associated with ankle fractures. The 3D MRI can be considered for syndesmotic ligament injury instead of 2D MRI, with shortened acquisition time.*

Key Words: *Ankle joint; Ligaments; Magnetic resonance imaging; Sensitivity and specificity; Wounds and injuries*

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Submitted: 21 Sep 2018; Accepted: 2 Jan 2019

Contributors: JWP, SJL, and MWK designed the study. All authors were responsible for acquisition of data and contributed to the analysis of data. JWP, SJL, and HJC wrote the manuscript. All authors made critical revisions of the intellectual content of this article. All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of Interest: The authors have no conflicts of interest to disclose.

Funding/Support: This research was supported by the Ministry of Trade, Industry & Energy (MOTIE, Korea) under industrial Technology Innovation Program. No.10062728. The funder had no role in study design, data collection / analysis / interpretation or manuscript preparation.

Ethics Approval: The research protocol was approved by the Institutional Review Board of Inje University Busan Paik Hospital (Ref 17-0181).

中文摘要

高位踝關節韌帶損傷的磁共振成像：三維各向同性中間加權快速自旋回波磁共振成像與常規二維磁共振成像的比較

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目的：本研究旨在比較三維（3D）各向同性中間加權快速自旋回波（FSE）磁共振成像（MRI）序列與常規二維（2D）FSE序列於評估與踝部骨折相關高位踝關節韌帶損傷時的診斷表現。

方法：2014年1月至2015年12月期間，對37例同時進行常規2D MRI和3D MRI的踝關節骨折患者進行評估。所有患者均接受踝關節鏡檢查。兩名放射科醫生回顧分析高位踝關節韌帶損傷的影像學表現，兩次闡釋的時間相隔至少2週。計算每條韌帶的敏感性、特異性和準確性，並進行McNemar配對比例測試以比較診斷表現。

結果：最常見為前下距腓韌帶（AITFL）損傷（31例，83.8%）。3D序列顯示對AITFL的敏感性為96.8%至100%，特異性為50%至66.7%；2D序列顯示的敏感性為96.8%至100%；特異性為33.3%至66.7%（p = 0.114-0.588）。後下距腓韌帶（PITFL）和脛骨橫韌帶（TrTFL）損傷在2D和3D序列的診斷中沒有顯著差異。

結論：3D FSE序列與2D FSE序列於與踝部骨折相關高位踝關節韌帶損傷的診斷表現無統計學差異。可考慮使用3D序列MRI代替2D圖像進行高位踝關節韌帶損傷檢查，縮短採集時間。

INTRODUCTION

Ankle disorders are a relatively common pathological condition, and ankle injuries account for approximately 14% of sports-related orthopaedic emergency visits.[1] Ligamentous injuries occurring with ankle fractures have a significant impact on ankle instability; therefore, identifying ligamentous injuries in the setting of ankle fractures is critical for appropriate treatment decisions.

The ligaments of the ankle are composed of three ligamentous groups: the syndesmotic ligament complex, the lateral ligamentous complex, and the deltoid ligament. The syndesmotic ligament complex is composed of four separate ligaments: the anteroinferior tibiofibular ligament (AITFL), the posteroinferior tibiofibular ligament (PITFL), the transverse tibiofibular ligament (TrTFL), and the interosseous ligament. The syndesmotic ligaments stabilise the distal tibia and fibula and are injured in 1% to 18% of all ankle sprains. This rate increases to 12% to 32% of all ankle sprains among athletes.[2-4] If diagnosis and appropriate treatment are delayed, ligament injuries may lead to posttraumatic arthritic changes and chondral defects over time. In the absence of abnormal radiological findings, it may be difficult to detect syndesmotic ligament damage on arthroscopy due to its anatomical location.

To evaluate the ligamentous structure of the ankle joint, variable imaging planes and sequences are required. Increasing the number of imaging sequences inevitably increases the scan time, but three-dimensional (3D) isotropic images solve this problem. The use of 3D isotropic sequences enables multiplanar reformatted images and shortens the acquisition time by obtaining the same sequence in different planes.[5-7] However, most 3D magnetic resonance imaging (MRI) sequences provide insufficient soft tissue contrast and therefore have limited value in the evaluation of musculoskeletal images, especially for ligament structures.[8,9]

The aims of this study were to investigate whether the image quality of 3D isotropic-weighted fast spin echo (FSE) sequences is comparable to that of two-dimensional (2D) T2-weighted FSE sequences for the assessment of the syndesmotic ligaments and to compare the diagnostic performance of 3D isotropic-weighted FSE sequences with that of 2D T2-weighted FSE sequences.

METHODS

Subjects

Between January 2014 and December 2015, we evaluated the images of 45 consecutive patients with ankle fracture who had undergone preoperative ankle MRI. We excluded patients with a history of underlying systemic pathological findings such as gouty arthritis in the affected ankle (1 patient) or who did not undergo operation in this hospital (7 patients). A total of 37 patients were ultimately included in the analysis, comprising 21 women (aged 21-82 years; mean age, 47 years) and 16 men (aged 24-78 years; mean age, 48 years). The mean interval (± standard deviation) between trauma and MRI was 1.4 ± 2.3 days, and the mean interval between MRI and operation was 2.4 ± 2.3 days. The requirement for patient informed consent was waived because of the retrospective nature of the study, and the study was approved by the Institutional Review Board at Inje Medical University.

Imaging

All images were acquired using a 3.0-T MRI unit with either a 16-channel phased array coil (Achieva; Philips, Best, The Netherlands) [12 patients] or a 20-channel phased array coil (Skyra; Siemens Healthcare, Erlangen, Germany) [25 patients]. The patients were examined in the supine position with the ankle in neutral position using a phased-array foot and ankle coil. Then, 2D T2-weighted FSE images in the axial, coronal, and sagittal planes as well as 3D isotropic-weighted FSE images were acquired. The 3D intermediate-weighted FSE images were obtained in the sagittal plane and then reconstructed on the axial and coronal axes to increase time efficiency. The number of sections in the cranial to caudal direction was larger than that in the medial to lateral direction. The parameters used for these imaging sequences are listed in Tables 1 and 2.

Imaging Interpretation

Two radiologists (one expert musculoskeletal radiologist with 15 years of experience and one fourth-year radiology resident), who were blinded to the surgical findings, analysed the 2D and 3D imaging findings independently. To minimise recall bias, each set of magnetic resonance images was reviewed in a separate setting with an interval of at least 2 weeks between the two interpretation sessions.

Table 1. Imaging parameters for MRI sequences (Skyra).

Parameter	3D intermediate-weighted FSE	2D T2-weighted FSE		
		Axial	Sagittal	Coronal
Repetition time (ms)	1100	3300	4100	300
Echo time (ms)	54	58	57	69
Field of view (mm)	150	140	150	150
Section thickness (mm)	0.5	3	3	3
Intersection gap (mm)	0	0.3	0.3	0.3
Acquisition matrix	320×320	448×314	448×310	448×310
Bandwidth (Hz/pixel)	391	266	260	260
No. of sections	144	30	24	24
Flip angle (degrees)	132	130	128	128

Abbreviations: 2D = two-dimensional; 3D = three-dimensional; FSE = fast spin echo; MRI = magnetic resonance imaging.

Table 2. Imaging parameters for MRI sequences (Achieva).

Parameter	3D intermediate-weighted FSE	2D T2-weighted FSE		
		Axial	Sagittal	Coronal
Repetition time (ms)	1300	3028	2497	3055
Echo time (ms)	33	60	70	70
Field of view (mm)	150	120	150	150
Section thickness (mm)	0.5	3	3	3
Intersection gap (mm)	0	0.3	0.3	0.3
Acquisition matrix	300×300	316×270	356×307	356×240
Bandwidth (Hz/pixel)	360	165	228	159
No. of sections	150	30	20	24
Flip angle (degrees)	90	90	90	90

Abbreviations: 2D = two-dimensional; 3D = three-dimensional; FSE = fast spin echo; MRI = magnetic resonance imaging.

To grade acute syndesmosis injury, the radiologists classified the injury as ruptured (including complete and partial tears) or unruptured (including normal and oedematous ligaments). Complete tear was used to describe the injury when there was definite discontinuity or when the ligament was not visible, whereas partial tear was used to describe the injury when ligaments presented with laxity, irregular contour or partial discontinuity without bony avulsion.[8]

Ankle Surgery

Arthroscopic findings were considered the reference standard. One orthopaedic surgeon specialising in foot and ankle surgery performed all surgical procedures after assessment of the preoperative MRI findings. Any abnormalities of the syndesmotic ligaments were recorded during arthroscopy. All 37 acute fractures were treated with internal fixation.

Statistical Analysis

Statistical analyses were performed using SPSS (Windows version 22.0; IBM Corp, Armonk [NY], United States) for a comparison of area under the receiver operating characteristic curve (AUC) values. We compared the diagnostic performance of 3D isotropic intermediate T2-weighted FSE and conventional 2D T2-weighted FSE sequences; the sensitivity, specificity, and accuracy were calculated in relation to a reference standard of arthroscopic diagnosis. McNemar's paired proportion test was used to measure the concordance of 2D and 3D sequences with the arthroscopic diagnosis.[10] The AUC value was used to compare the discriminatory power of the two imaging methods. AUC values range between 0 and 1, with a higher value indicating better overall performance of the diagnostic test.[11]

Interobserver agreement was calculated using Cohen's kappa test, where $\varkappa < 0$ indicates no agreement, $0 < \varkappa \leq 0.2$ indicates slight agreement, $0.2 < \varkappa \leq 0.4$ indicates fair agreement, $0.4 < \varkappa \leq 0.6$ indicates moderate agreement, $0.6 < \varkappa \leq 0.8$ indicates substantial agreement, and $0.8 < \varkappa \leq 1$ indicates almost perfect agreement.[12] For the aforementioned statistical analyses, $p < 0.05$ were considered statistically significant.

RESULTS

Arthroscopically confirmed diagnoses were used as reference standards. In arthroscopic records, the AITFL was most frequently ruptured (31/37, 83.8%), followed by the PITFL (25/37, 67.6%) and TrTFL (5/37, 13.5%) [Table 3]. Normal ligaments and those with oedema were included in the 'unruptured' group, and ligaments with complete or partial tears were included in the 'ruptured' group. The sensitivity and specificity were calculated for these categories. When diagnoses were classified as 'unruptured' or 'ruptured' for each syndesmotic ligament injury associated with ankle fracture, the 3D sequences showed a sensitivity of 96.8% to 100% and a specificity of 50% to 66.7% for injuries of the AITFL, whereas the 2D sequences showed a sensitivity of 96.8% to 100% and a specificity of 33.3% to 66.7% (p = 0.114-0.588) [Figures 1 and 2]. The 3D sequences showed a sensitivity of 60% and a specificity of 71.9% for injuries of the PITFL, while the 2D sequences showed a sensitivity of 60% and a specificity of 68.8% to 71.9% (p = 0.317-1.0) [Figure 3]. The 3D sequences showed a sensitivity of 52% to 60% and a specificity of 83.3% for injuries of the TrTFL, whereas the 2D sequences showed a sensitivity of 52% to 68% and a specificity of 83.3% (p = 0.417-1.0) [Figure 4 and Table 4].

Table 3. Arthroscopic findings of syndesmotic ligament injury.

Injured ligament	No. (complete rupture / incomplete rupture)	%
AITFL	31 (18 / 13)	83.8%
PITFL	25 (7 / 18)	67.6%
TrTFL	5 (1 / 4)	13.5%

Abbreviations: AITFL = anteroinferior tibiofibular ligament; PITFL = posteroinferior tibiofibular ligament; TrTFL = transverse tibiofibular ligament.

Table 5 summarises the estimated AUC values for diagnostic performance for syndesmotic ligament injury. For both readers, the accuracy of interpretation of PITFL injuries was higher for the 3D isotropic intermediate-weighted T2 FSE images than for the 2D T2-weighted FSE images. The accuracy of diagnosing AITFL and TrTFL was slightly higher with conventional 2D FSE for one of the readers, but the difference was not statistically significant.

There was good interobserver agreement in assessments of the syndesmotic ligaments, with substantial agreement for the AITFL ($\varkappa = 0.631$) and TrTFL ($\varkappa = 0.728$) and almost perfect agreement for the PITFL ($\varkappa = 0.847$).

DISCUSSION

According to arthroscopic findings, the most commonly injured ligament of the distal tibiofibular syndesmosis in ankle fractures was the AITFL (83.8%). AITFL is the weakest of the four syndesmotic ligaments and is the first to yield to forces that create an external rotation of the fibula around its longitudinal axis.

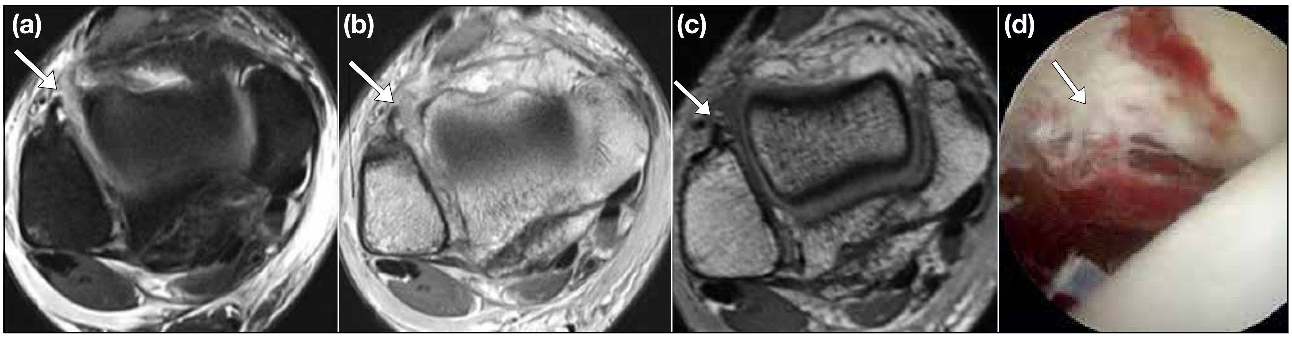

Figure 1. A 54-year-old man with a right distal tibiofibular fracture; concordance was observed between two-dimensional (2D) and three-dimensional (3D) sequence images. (a) 2D fat-suppressed T2-weighted fast spin echo sequence, (b) 2D intermediate-weighted sequence, and (c) 3D isotropic intermediate-weighted axial images showing discontinuity of the anterior inferior tibiofibular ligament (AITFL) [arrows], which is considered a tear. (d) Subsequent ankle arthroscopy showing a tear of the right AITFL in the right upper portion of the image (arrow).

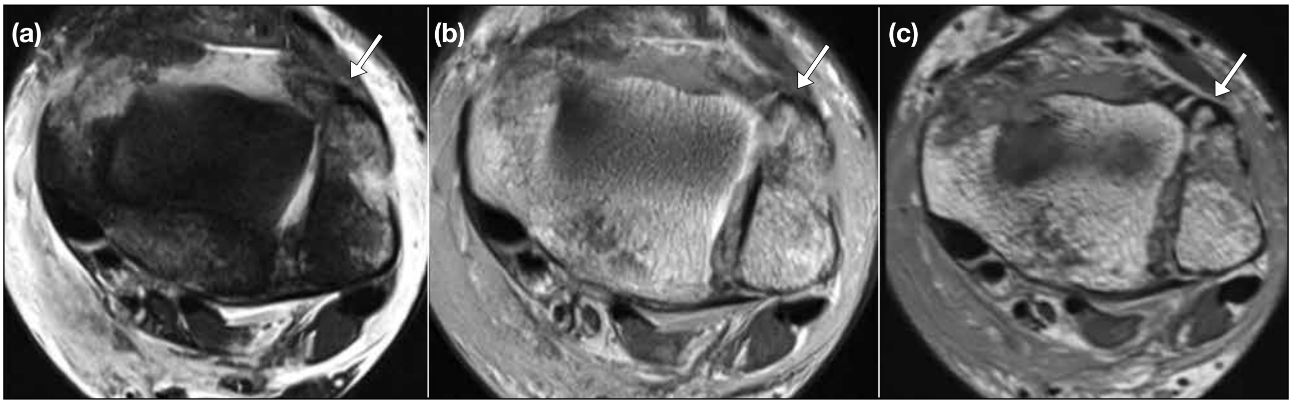

Figure 2. A 61-year-old woman with a left tibiofibular fracture; discordance was observed between two-dimensional (2D) and three-dimensional (3D) sequence images. (a) 2D fat-suppressed T2-weighted fast spin echo sequence and (b) 2D intermediate-weighted sequence showing uncertain continuity and delineation of the left anterior inferior tibiofibular ligament (AITFL) [arrows], suggesting a complete tear. (c) A 3D isotropic intermediate-weighted axial image showing a normal AITFL (arrow) attached to avulsion fragments of the distal fibula. Subsequent ankle arthroscopy showed a complete tear of the left AITFL.

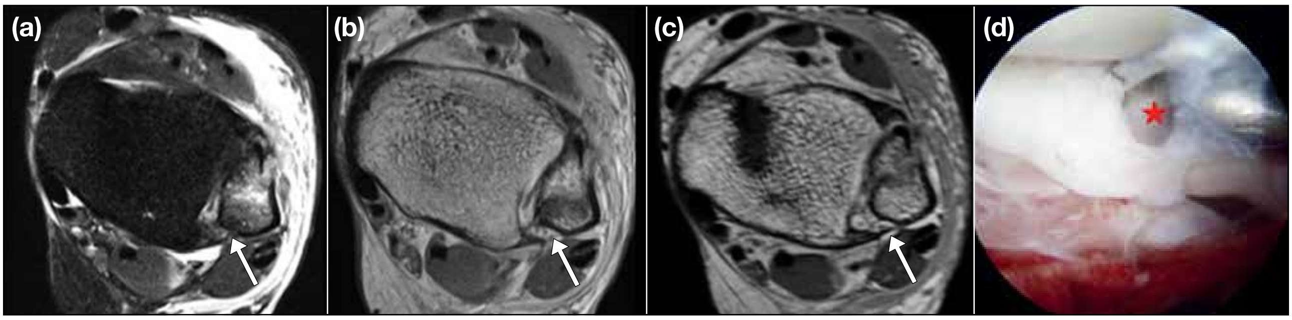

Figure 3. A 42-year-old woman with a left ankle fracture; concordance was shown between two-dimensional (2D) and three-dimensional (3D) sequence images. (a) 2D fat-suppressed T2-weighted fast spin echo sequence, (b) 2D intermediate-weighted sequence, and (c) 3D isotropic intermediate-weighted axial images showing a thinned contour of the PITFL (posterior inferior tibiofibular ligament), suggesting a tear (arrows). (d) An intrasubstance partial tear of the left PITFL is noted on arthroscopy (star).

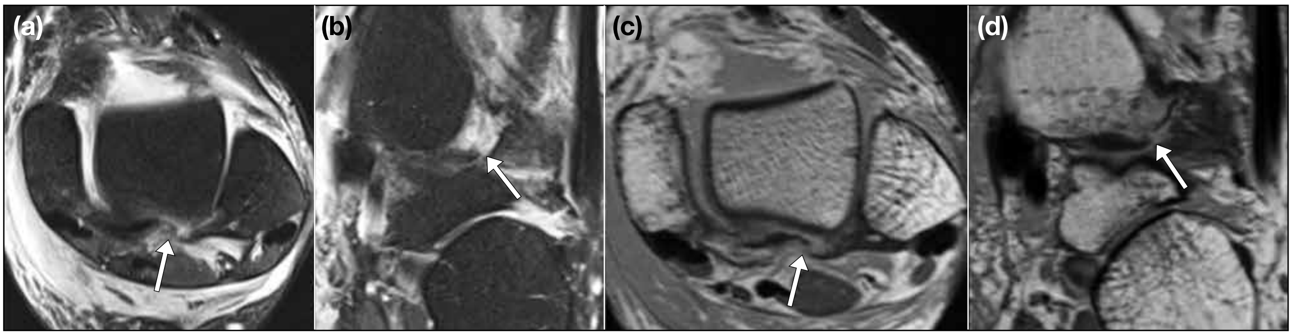

Figure 4. A 44-year-old woman with a left ankle fracture; concordance is observed between two-dimensional (2D) and three-dimensional (3D) sequence images. (a) 2D fat-suppressed T2-weighted fast spin echo axial and (b) coronal, and (c) 3D isotropic intermediate-weighted axial and (d) coronal images showing waviness and uncertain continuity of the left transverse tibiofibular ligament (TrTFL) [arrows], indicating a possible complete tear. Subsequent ankle arthroscopy showed a complete tear of the left TrTFL.

Table 4. Sensitivity, specificity, and accuracy for each syndesmotic ligament injury.

Ligament	Images	Sensitivity (%)		Specificity (%)		Accuracy (%)	
		Reader 1	Reader 2	Reader 1	Reader 2	Reader 1	Reader 2
AITFL	3D intermediate-weighted FSE	100%	96.8%	66.7%	50%	94.6%	91.9%
	Conventional 2D FSE	100%	96.8%	33.3%	66.7%	89.2%	89.2%
PITFL	3D intermediate-weighted FSE	60%	60%	71.9%	71.9%	70.3%	70.3%
	Conventional 2D FSE	60%	60%	71.9%	68.8%	70.3%	67.6%
TrTFL	3D intermediate-weighted FSE	60%	52%	83.3%	83.3%	67.6%	62.2%
	Conventional 2D FSE	68%	52%	83.3%	83.3%	73%	62.2%

Abbreviations: 2D = two-dimensional; 3D = three-dimensional; AITFL = anteroinferior tibiofibular ligament; FSE = fast spin echo; PITFL = posteroinferior tibiofibular ligament; Reader 1 = musculoskeletal radiologist with 15 years of experience; Reader 2 = radiologist with 3 years of experience; TrTFL = transverse tibiofibular ligament.

Table 5. Diagnostic performance for syndesmotic ligament injury.

Images	AUC					
	AITFL		PITFL		TrTFL	
	Reader 1	Reader 2	Reader 1	Reader 2	Reader 1	Reader 2
3D intermediate-weighted FSE	0.833	0.734	0.659	0.659	0.752	0.677
Conventional 2D FSE	0.667	0.817	0.659	0.644	0.757	0.677
p value	0.114	0.588	1.000	0.317	0.417	1.000

Abbreviations: 2D = two-dimensional; 3D = three-dimensional; AITFL = anteroinferior tibiofibular ligament; AUC = area under the receiver operating characteristic curve; FSE = fast spin echo; PITFL = posteroinferior tibiofibular ligament; TrTFL = transverse tibiofibular ligament.

Conventional 2D FSE ankle MRI sequences include separate orthogonal scan planes, which increases the scan time. Recently, high-resolution 3D FSE sequences have improved soft tissue contrast and allowed 3D reformation in arbitrary orientations. Previously, 3D MRI could not replace 2D MRI because its soft tissue contrast was unsatisfactory. In this study, we confirmed that 3D images are not inferior to 2D images when diagnosing ruptures of the syndesmotic ligaments of the ankle. If further studies continue to reveal that 3D images are comparable to 2D images for other ligaments or ankle injuries, it will be possible to substitute 3D MRI for 2D MRI, which will reduce the scan time.

A previous study by Kim et al[13] reported that the performance of MRI with 3D SPACE (sampling perfection with application-optimised contrasts using different flip angle evolution) sequences was better than that of 2D axial and coronal proton density-weighted magnetic resonance images for the diagnosis of acute and chronic syndesmosis injuries, including the AITFL and PITFL. Previous studies examining the anterior talofibular ligament[14] and calcaneofibular ligament[15] have also shown comparable diagnostic performance of 3D and 2D MRI.

However, no study has compared the performance of 3D isotropic intermediate-weighted FSE imaging with that of conventional 2D MRI of the syndesmotic ligaments for the diagnostic evaluation of ankle fractures, including AITFL, PITFL, and TrTFL. We found no statistically significant difference in the diagnostic performance of the 3D isotropic intermediate-weighted FSE sequences compared with that of the conventional 2D FSE sequences with regard to syndesmotic ligament injuries associated with ankle fracture. These results, although similar to those of previous studies, will be helpful in shaping future ankle MRI protocols.

The present study has some limitations. First, selection bias may have occurred. This study included surgically confirmed cases of ankle fracture and excluded patients with mild injuries. In addition, we did not include a control group without ankle joint problems. However, it was necessary to exclude healthy volunteers because healthy people cannot be subjected to invasive ankle arthroscopy. Second, this is a retrospective study, and the surgeons were not blinded to the MRI features prior to surgery. Third, the present study showed relatively low sensitivity and accuracy for PITFL and TrTFL. There were few PITFL injuries, most likely because PITFL is a thick, strong ligament. TrTFL is a thin structure and is difficult to evaluate on MRI.

CONCLUSION

3D isotropic intermediate-weighted FSE MRI of the ankle resulted in no statistically significant difference in diagnostic performance compared to 2D T2-weighted FSE MRI when evaluating the syndesmotic ligaments. The 3D MRI sequences can be considered for syndesmotic ligament injury instead of 2D images, with shortened acquisition time.

REFERENCES

1. Fong DT, Man CY, Yung PS, Cheung SY, Chan KM. Sport-related ankle injuries attending an accident and emergency department. Injury. 2008;39:1222-7.
2. Porter DA, Jaggers RR, Barnes AF, Rund AM. Optimal management of ankle syndesmosis injuries. Open Access J Sports Med. 2014;5:173-82.
3. Waterman BR, Belmont PJ, Cameron KL, Svoboda SJ, Alitz CJ, Qwens BD. Risk factors for syndesmotic and medial ankle sprain: the role of sex, sport and level of competition. Am J Sports Med. 2011;39:992-8.
4. Press CM, Gupta A, Hutchinson MR. Management of ankle syndesmosis injuries in the athlete. Curr Sports Med Rep. 2009;8:228-33.
5. Jung JY, Jee WH, Park MY, Lee SY, Kim YS. Supraspinatus tendon tears at 3.0 T shoulder MRI arthrography: diagnosis with 3D isotropic turbo spin echo SPACE sequence versus 2D conventional sequences. Skeletal Radiol. 2012;41:1401-10.
6. Kijowski R, Davis KW, Woods MA, Lindstrom MJ, De Smet AA, Gold GE, et al. Knee joint: comprehensive assessment with 3D isotropic resolution fast spin-echo MR imaging diagnostic performance compared with that of conventional MR imaging at 3.0 T. Radiology. 2009;252:486-95.
7. Stevens KJ, Busse RF, Han E, Brau AC, Beatty PJ, Beaulieu CF, et al. Ankle: isotropic MR imaging with 3D-FSE-cubedinitial experience in healthy volunteers. Radiology. 2008;249:1026-33.
8. Gold GE, Busse RF, Beehler C, Han E, Brau AC, Beatty PJ, et al. Isotropic MRI of the knee with 3D fast spin-echo extended echo-train acquisition (XETA): initial experience. AJR Am J Roentgenol. 2007;188:1287-93.
9. Subhas N, Kao A, Freire M, Polster JM, Obuchowski NA, Winalski CS. MRI of the knee ligaments and menisci: comparison of isotropic-resolution 3D and conventional 2D fast spin-echo sequences at 3 T. AJR Am J Roentgenol. 2011;197:442-50.
10. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics. 1988;44:837-45.
11. Park SH, Goo JM, Jo CH. Receiver operating characteristic (ROC) curve: practical review for radiologists. Korean J Radiol. 2004;5:11-8.
12. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33:159-74.
13. Kim M, Choi YS, Jeong MS, Park M, Chun TJ, Kim JS, et al. Comprehensive assessment of ankle syndesmosis injury using 3d isotropic turbo spin-echo sequences: diagnostic performance compared with that of conventional and oblique 3-T MRI. AJR Am J Roentgenol. 2017;208:827-33.
14. Yi J, Cha JG, Lee YK, Lee BR, Jeon CH. MRI of the anterior talofibular ligament, talar cartilage and os subfibulare: comparison of isotropic resolution 3D and conventional 2D T2-weighted fast spin-echo sequences at 3.0 T. Skeletal Radiol. 2016;45:899-908.
15. Park HJ, Lee SY, Choi YJ, Hong HP, Park SJ, Park JH, et al. 3D isotropic T2-weighted fast spin echo (VISTA) versus 2D T2-weighted fast spin echo in evaluation of the calcaneofibular ligament in the oblique coronal plane. Clin Radiol. 2017;72:176.e1-7.