Original Investigation

The Added Diagnostic Value of the Bright Rim Sign to Conventional MRI Assessment of Anterior Talofibular Ligament Disruption

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Rationale and Objectives: The bright rim sign (BRS) was used as a reliable indicator of anterior talofibular ligament (ATFL) disruption beside other well-known diagnostic criteria. Although this sign can improve accuracy of conventional magnetic resonance imaging (MRI) in diagnosis of ATFL disruption, it was not adequately discussed in the literature. This study aimed to confirm the added diagnostic value of BRS to conventional MRI assessment of ATFL disruption.

Materials and Methods: A prospective study included 62 patients (47 males and 15 females; mean age, 36.9 ± 12.1 years; range, 17−52 years) with clinically suspected ATFL disruption. All patients underwent MRI and arthroscopy of ankle. MRI images were evaluated for the presence of ligament disruption sign (LDS) and BRS. The patients were classified into 3 groups: group 1 included patients with acute lateral ankle ligament sprain; group 2 included patients with chronic ankle instability; and group 3 included patients with recurring ankle sprain. The diagnostic value of the BRS was evaluated using arthroscopy as reference standard.

Results: The diagnostic value of both signs together increased overall sensitivity in detecting ATFL disruption to 86.7% compared to 60% when considering LDS alone ($p < 0.0001$). In group 1 and 3, the sensitivity increased when both signs were considered together compared to LDS alone ($p = 0.004$ and 0.025, respectively). In group 2, there was a trend toward significance in sensitivity when both signs were considered compared to LDS alone ($p = 0.08$).

Conclusion: BRS is a very helpful diagnostic sign in assessment of ATFL disruption when considered conjointly with the LDS.

Key Words: Magnetic resonance imaging; Bright rim sign; Anterior talofibular ligament; Ankle sprain.

Abbreviations: ATFL Anterior talofibular ligament, **BRS** Bright rim sign, **ET** Echo train, **FOV** Field of view, **LDS** Ligament disruption sign, **MRI** Magnetic resonance imaging, **Mm** Millimeters, **Ms** Milliseconds, **PD** Proton density, **NPV** Negative predictive value, **PDFS** Proton density fat sat, **PPV** Positive predictive value, **SD** Standard deviation, **STIR** Short tau inversion recovery, **TE** Echo time, **TR** Repetition time

INTRODUCTION

Ankle sprain is a ligamentous disruption induced by an excessive range of motion at the ankle joint in the absence of fracture or dislocation (1). It is common and accounts for >90% of sport ankle injuries (2). Ankle inversion is the most common mechanism of disruption, with approximately 75% involving the lateral ligamentous complex (3,4). Being the weakest ligament in the lateral complex, the anterior talofibular ligament (ATFL) is the most commonly torn (5). Clinically, ATFL disruption may be acute, chronic, or acute on top of chronic when reinjury occurs (2,6).

Precise diagnosis of the acute ATFL disruption is essential not only to diminish the risk of recurring ankle sprain but also to avoid the development of chronic ankle instability or post-traumatic ankle osteoarthritis (7). Imaging plays an important role as an adjunct to the physical examination in the evaluation of ligamentous injuries of the ankle. Plain X-ray with ankle stress tests, ultrasonography, and magnetic resonance imaging (MRI) are to

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be considered when diagnosing ATFL disruption (8−10). MRI has proved to be an important tool for assessing lateral ankle instability and ATFL disruption owing to its excellent soft-tissue contrast resolution and multiplanar capabilities, allowing direct visualization and evaluation of the ATFL and showing associated intra-articular lesions as well as bone marrow edema (5). Moreover, the noninvasiveness of MRI help in the follow-up of sprained ankles (2)

Several authors have discussed and documented the changes in the MRI morphology of the ATFL for the diagnosis of the ligament sprain (11−14). However, considerable variation exists in the MRI accuracy, and the reliability of findings on MRI has not been established (15). Significantly various sensitivities and specificities for diagnosing ATFL were reported in the previous studies that assessed the lateral ankle ligamentous complex (13,14). This raises the demand for other supportive MRI signs for the evaluation of ATFL disruption. Lee et al. (16) in 2012 described a bright signal intensity focus at the talar or fibular attachment site of the ATFL on axial T2-weighted MRI of patients with an ankle injury. Lee et al. called this the "bright rim sign (BRS)" and used it as a reliable indicator of ATFL disruption beside the other well-known diagnostic criteria. Lee et al. attributed this sign to the chemical-shift artifact resulting from the exposure of the subcortical fat marrow to joint fluid, because of cortical disruption induced by a small avulsion injury at the fibular or talar attachment of the ATFL. Although this sign can improve the accuracy of conventional MRI in the diagnosis of ATFL disruption, it was not adequately discussed in the literature. Consequently, we conducted this prospective study to confirm the added diagnostic value of BRS to conventional MRI assessment of ATFL disruption using arthroscopy as a reference standard.

MATERIALS AND METHODS

Ethical Statement

Ethical approval was obtained from the local research ethical committee. All patients were informed of the study and provided written informed consent prior to MRI and arthroscopic examination. The study was performed in accordance with the ethical principles of the Declaration of Helsinki.

Study Population

This prospective study was carried out between May 2019 and January 2020. Initially, we collected 101 consecutive patients with an ankle sprain. Inclusion criteria were (1) patients with a history of a post-traumatic ankle sprain, (2)

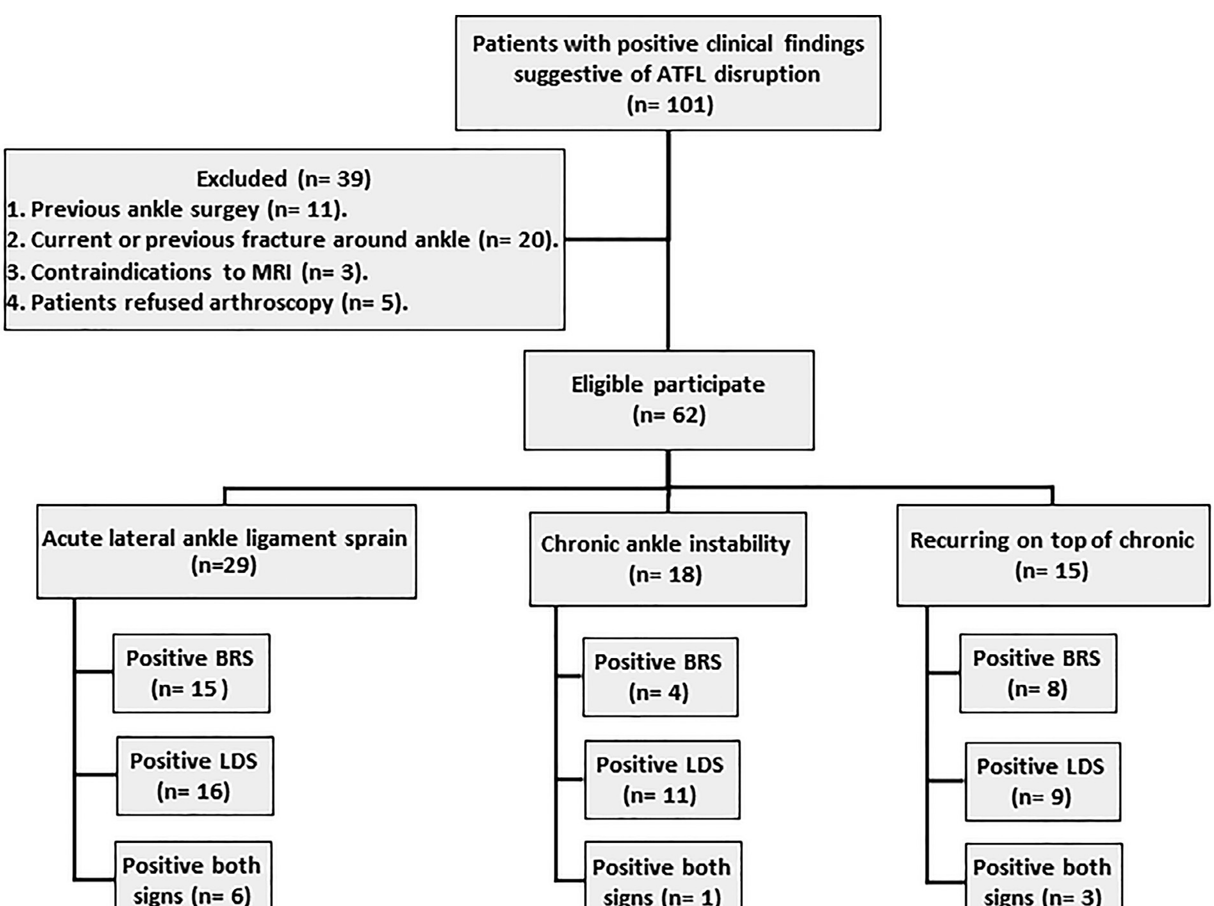

Figure 1. Flowchart of our study.

patients with persistent signs of pain, swelling, or instability after conservative management, and (3) patients with positive clinical findings indicating disruption of ATFL such as positive talar tilt test and/or anterior drawer test. Exclusion criteria included, (1) previous ankle surgery ($n = 11$), (2) current or previous fracture around the ankle on plain radiography ($n = 20$), (3) contraindications to MRI ($n = 3$), and (4) patients refused arthroscopy ($n = 5$). The final cohort was composed of 62 patients eligible for participation in the study. Once enrolled, all participants were subjected to MRI and arthroscopic examinations of ankle joint.

MRI Protocol

MRI was performed using 1.5-Tesla Toshiba Vantage Elan System. A Flex Speeder 16-channel (receiver only) coil is used. The MRI protocol consists of fat-suppressed and non-fat suppressed sequences. The patient was placed in the supine position with his feet were in a neutral position. Axial, sagittal, and coronal images were obtained. The protocol for the evaluation of the ATFL was axial T2-weighted images (T2), proton density (PD), PD fat sat (PDFS), and short tau inversion recovery (STIR) sequences. Axial T2 sequences had the following parameters: repetition time/echo time (TR/TE) of 4200−4600/110 milliseconds (ms), echo train (ET) of 15, section thickness of 3 millimeters (mm), interslice gap of 10%, matrix size of 356 × 286, field of view (FOV) of 18 × 18, and scan time of 3.25 minutes. Axial PD sequence had the following parameters: TR/TE of 2400−2800/36 ms, ET of 12, section thickness of 3 mm, interslice gap of 10%, matrix size of 284 × 224, FOV of 18 × 18, and scan time of 3.04 minutes. Axial PDFS sequence had the following parameters: TR/TE of 2400−2800/36 ms, ET of 12, section thickness of 3 mm, interslice gap of 10%, matrix size of 284 × 224, FOV of 18 × 18, and scan time of 3.40 minutes. Axial STIR sequence had the following parameters: TR/TE of 4800/60 ms, ET of 10, section thickness of 3 mm, interslice gap of 10%, matrix size of 288 × 256, FOV of 18 × 18, and scan time of 4.10 minutes.

Image Interpretation

All MRI data were transferred to the workstations, and image analysis was performed on the picture archiving and communication system (PACS) (PaxeraUltima- paxeramed). Two consultant radiologists with over 10 years of experience in musculoskeletal imaging independently read all MR images. The radiologists were blinded to patients' clinical data, but they evaluated all MR images for ligament disruption sign (LDS) or positive BRS. LDS appeared as torn or absent ligament. Positive BRS appeared as a dot-like or curvilinear high signal intensity overlying cortical disruption at ATFL attachment sites of the fibula or talus or both (kissing BRS) on axial T2 and PD images. BRS was differentiated from possible bone marrow edema by the persistence of the bright signal of bone marrow edema on STIR and PDFS images, and the absence of cortical disruption.

TABLE 1. Baseline Characteristics of All Studied Patients

Variable	Value
Total number	62
Demographic data	
Age (years), Mean ± SD (range)	36.9 ± 12.1 (17−52)
Males	47 (75.8)
Females	15 (24.2)
Groups	
Acute lateral ankle ligament sprain	29 (47)
Chronic ankle instability	18 (29)
Recurrent ankle sprain	15 (24)

SD, standard deviation.
Unless otherwise indicated, data represent the number with the percentage in parenthesis.

The ligament was considered disrupted if the MRI revealed positivity for LDS or BRS or both signs.

The inter-reader agreement (IRA) was achieved between the two independent radiologists regarding the use of LDS, BRS, or both signs for diagnosing ATFL disruption. To estimate the diagnostic performance of using both signs together and using each sign alone for diagnosing ATFL disruption, a consensus reading was achieved by the two radiologists to reach the final diagnosis. In case of disagreement between radiologists, all parameters were discussed in detail until a final agreement was reached. The results of consensus reading were used to calculate the validity of BRS.

TABLE 2. MRI and Arthroscopic Findings in Studied Patients

Findings MRI	*n* (%)
Positive LDS	
Alone	26 (41.9)
With BRS	10 (16.1)
Total (alone and with BRS)	36 (58.1)
Positive BRS	
Alone	17 (27.4)
With LDS	10 (16.1)
Total (alone and with LDS)	27 (43.5)
Positive BRS	
At fibular side	15 (24.2)
At talar side	4 (6.5)
At both fibular and talar sides	8 (12.9)
T2 positive BRS	27 (43.5)
PD positive BRS	27 (43.5)
Positive bone marrow edema	3 (4.8)
Arthroscopy	
Complete ATFL tear	12 (19.4)
Partial ATFL tear	48 (77.4)
Intact ATFL	2 (3.2)

ATFL, anterior talofibular ligament; BRS, bright rim sign; LDS, ligament disruption sign; n, number; PD, proton density.

Reference Standard

Arthroscopy was performed to confirm the diagnosis based on the request of treating physicians. All arthroscopic examinations were performed within three weeks after MRI examinations (mean, 11.3 ± 3.7 days). Two orthopedic surgeons with 22 and 19 years of clinical experience performed all arthroscopic examinations. The ligament was considered partially injured if it showed an abnormal ligament course and/or reduced ligament tautness, while a complete ligament tear was diagnosed if there was an avulsion at either fibular or talar attachment or if there was a ligament discontinuity with or without fibrous tissue filling the gap (17).

Statistical Analysis

The collected data were revised, tabulated, and analyzed using Statistical Package for Social Science (IBM Corp., Released 2017, IBM SPSS Statistics for Windows, Version 25.0, Armonk, NY). Numerical data were presented as mean and standard deviation and analyzed using paired Student's *t* test and one-way analysis of variance. Non-numerical data were presented as numbers and percentages and were analyzed using the chi-square. Diagnostic performance characters included sensitivity, specificity, positive predictive value, negative predictive value (NPV), positive and negative likelihood ratios, and accuracy rate were calculated using the four-fold table test. McNemar test was used to analyze paired qualitative data. Regression analysis (Stepwise method) was used to define the highly significant predictor of MRI findings for the arthroscopic findings. The kappa statistics were used to calculate the IRA. The resulting κ values were interpreted as follows: 0.00−0.20 = poor agreement; 0.21-0.40 = fair agreement; 0.41−0.60 = moderate agreement; 0.61−0.80 = good agreement; and 0.81−1.00 = very good agreement. A p value of <0.05 indicated a significant difference.

RESULTS

Study Population

A total of 62 patients (47 males and 15 females; mean age, 36.9 ± 12.1 years; range, 17−52 years) with positive clinical findings suggestive of ATFL disruption and submitted to MRI and arthroscopic examinations were included in the final analysis. Figure 1 illustrates the flow diagram of our study. Patients were classified into three groups according to the time lag between injury and MRI examination. Group 1 (acute lateral ankle ligament sprain), included patients who had MRI examination within three months of injury (29 patients, 47%). Group 2 (chronic ankle instability), included patients who had MRI examination later than three months (18 patients, 29%). Group 3 (recurring ankle sprain), included patients who had repeated ankle sprain on top of chronic (15 patients, 24%) (Table 1 and Figure 1).

MRI Findings

LDS was positive in 36 patients (nine complete tears + 27 partial tears), while BRS was positive in 27 patients (nine complete tears + 17 partial tears + one false positive). Out of 27 positive

TABLE 3. Comparison Among Three Studied Groups

	Acute Lateral Ankle Ligament Sprain (n = 29)	Chronic Ankle Instability (n =18)	Recurring Ankle Sprain (n = 15)	p Value
Age (years), mean ± SD	33.2 ± 10.1	40.6 ± 12.9	39.7 ± 12.8	0.681
Sex				0.202
Males	19 (65.5)	15 (83.3)	13 (86.7)	
Females	10 (34.5)	3 (16.7)	2 (13.3)	
MRI findings				0.657
Positive LDS				
Alone	10 (34.5)	10 (55.6)	6 (40.0)	
With BRS	6 (20.7)	1 (5.6)	3 (20.0)	
Total (alone and with BRS)	16 (55.2)	11 (61.1)	9 (60.0)	
Positive BRS				
Alone	9 (31.0)	3 (16.7)	5 (33.3)	
With LDS	6 (20.7)	1 (5.6)	3 (20.0)	
Total (alone and with LDS)	15 (51.7)	4 (22.2)	8 (53.3)	
Arthroscopically approved ATFL tear				0.182
Complete ATFL tear	8 (27.6)	1 (5.6)	3 (20.0)	
Partial ATFL tear	20 (69.0)	16 (88.9)	12 (80.0)	
Total	28 (96.6)	17 (94.4)	15 (100.0)	
Arthroscopically intact ATFL	1 (3.4)	1 (5.6)	0	0.1316

ATFL, anterior talofibular ligament; BRS, bright rim sign; LDS, ligament disruption sign; n, number; PD, proton density; SD, standard deviation.

Unless otherwise indicated, data represent the number with the percentage in parenthesis.

BRS patients, BRS was observed in the fibular side in 15 patients, in the talar side in four patients, and in both fibular and talar sides in eight patients. Comparing the MRI pulse sequences in terms of the ability of each sequence to detect the BRS showed that all T2 positive-patients were also positive in PD images. Bone marrow edema was observed in three patients: one in the fibular side, one in the talar side, and one in both fibular and talar sides. The hyperintense signal of bone marrow edema was observed in T2, PD, PDFS, and STIR images (Table 2).

Arthroscopic Findings

Being the standard reference in this study, the ankle arthroscopy findings confirmed that 60 out of 62 patients had ATFL disruption. Twelve patients had a complete tear, and 48 patients had a partial tear (Table 2). The arthroscopic reports showed intact ATFL in two patients: one in the first group which was falsely diagnosed by BRS (false positive), and the other patient in the second group which was diagnosed intact (true-negative) by both BRS and LDS; in this patient, the arthroscopic examination was done based on the clinical assessment only.

Comparison Among Three Studied Groups

Detailed data for comparison among the groups are presented in Table 3. No significant differences in baseline characteristics among studied groups ($p > 0.05$).

Diagnostic Value of LDS and BRS

As presented in Table 4, we have analyzed the diagnostic value of LDS and BRS compared to arthroscopy. For the total patients included in this study, the highest sensitivity and accuracy were noticed when both signs were considered together (86.7%, 85.5%, respectively), while the highest specificity and positive predictive value were obtained when LDS was considered alone (100%). The NPV was very low for LDS, BRS, and even when both were considered together (7.7%, 2.9%, and 11.1%, respectively).

We compared the diagnostic value of using both signs together to using each sign alone. Overall, using LDS and BRS together increased the sensitivity compared to using LDS alone ($p < 0.0001$). In group 1, the sensitivity increased to 85.7% when both signs were considered together compared to LDS alone ($p = 0.004$) and BRS alone ($p = 0.001$). Similarly, in group 3, the sensitivity increased when both signs were considered together in comparison to LDS alone ($p = 0.025$) and BRS alone ($p = 0.014$). In group 2, there was a trend toward significance in the sensitivity when both signs were considered together compared to LDS alone ($p = 0.08$), and significant sensitivity increased compared to BRS alone ($p = 0.001$). The NPV significantly increased when detecting both signs compared to BRS alone ($p = 0.003$), but showed a trend toward significance compared to LDS alone ($p = 0.08$).

TABLE 4. Diagnostic Value of LDS, BRS, and Both Signs in Comparison to the Arthroscopy

	Total (n =62)			Acute Lateral Ankle Ligament Sprain (n = 29)			Chronic Ankle Instability (n =18)			Recurring Ankle Sprain (n =15)		
	LDS	BRS	Both	LDS	BRS	Both	LDS	BRS	Both	LDS	BRS	Both
True positive	36	26	52	16	14	24	11	4	14	9	8	14
True negative	2	1	1	1	0	0	1	1	1	0	0	0
False positive	0	1	1	0	1	1	0	0	0	0	0	0
False negative	24	34	8	12	14	4	6	13	3	6	7	1
Sensitivity (%)	60	43.3	86.7[a]	57.1	50	85.7[b]	64.7	23.5	82.4[d]	60	53.3	93.3[c]
Specificity (%)	100	50	50	100	0	0	100	100	100	-	-	-
PPV (%)	100	96.3	98.1	100	93.3	96	100	100	100	100	100	100
NPV (%)	7.7	2.9	11.1[a]	7.7	0	0	14.3	7.1	25[e]	0	0	0
Accuracy (%)	61.3	43.5	85.5	58.6	48.3	82.8	66.7	27.8	83.3	60	53.3	93.3

BRS, bright rim sign; LDS, ligament disruption sign; n, number; NPV, negative predictive value; PPV, positive predictive value.

a Mcnemar test revealed enhanced sensitivity for using both signs with statistically significant difference versus using LDS ($p < 0.0001$) and BRS ($p < 0.0001$). Also, enhanced NPV compared to BRS ($p < 0.0001$) but not compared to LDS ($p = 0.6$).

b Mcnemar test revealed enhanced sensitivity for using both signs with statistically significant difference versus using LDS ($p = 0.004$) and BRS ($p = 0.001$).

c Mcnemar test revealed enhanced sensitivity for using both signs with statistically significant difference versus using LDS ($p = 0.025$) and BRS ($p = 0.014$).

d Mcnemar test revealed enhanced sensitivity for using both signs with statistically significant difference versus using BRS ($p = 0.001$) but showed a trend toward significance versus LDS ($p = 0.08$).

e Relative Predictive Values method revealed enhanced NPV for using both signs with statistically significant difference versus using BRS ($p = 0.003$) but showed a trend toward significance versus LDS ($p = 0.08$).

Inter-Reader Agreement

The IRA regarding the use of LDS for diagnosing ATFL disruption was very good ($\kappa = 0.81$, 95%CI= 0.66−0.95). The IRA for the use of BRS for diagnosing ATFL disruption was good ($\kappa = 0.71$, 95%CI = 0.54−0.88). The IRA regarding the use of both signs together for diagnosing ATFL disruption was good ($\kappa = 0.65$, 95%CI = 0.46−0.84).

Representative cases of our study are illustrated in Figures 2-6.

DISCUSSION

Adding the BRS to LDS significantly increased the MRI sensitivity for detecting ATFL disruption in acute ankle sprain from 57.1% to 85.7% ($p = 0.004$) by adding 9 more injured ATFL, which was missed if LDS was considered alone. Likewise, the MRI sensitivity significantly increased in the recurring sprain from 60% to 93.3% by adding 5 more injured ATFL ($p = 0.025$). In patients with chronic ankle instability, the sensitivity showed a trend toward significance from 64.7% if LDS is considered alone, to 82.4% when both signs considered together ($p = 0.08$), as it added three injured ATFL only. BRS alone was able to diagnose ATFL disruption in 16 out of the 60 patients (26.7%) who had arthroscopic proof of ATFL disruption, while LDS was negative.

Lee et al. evaluated 34 patients for the BRS sign; the BRS was observed in 58.8−73.5% of the patients and the MRI sensitivity increased from 60.6% to 66.7% when considering

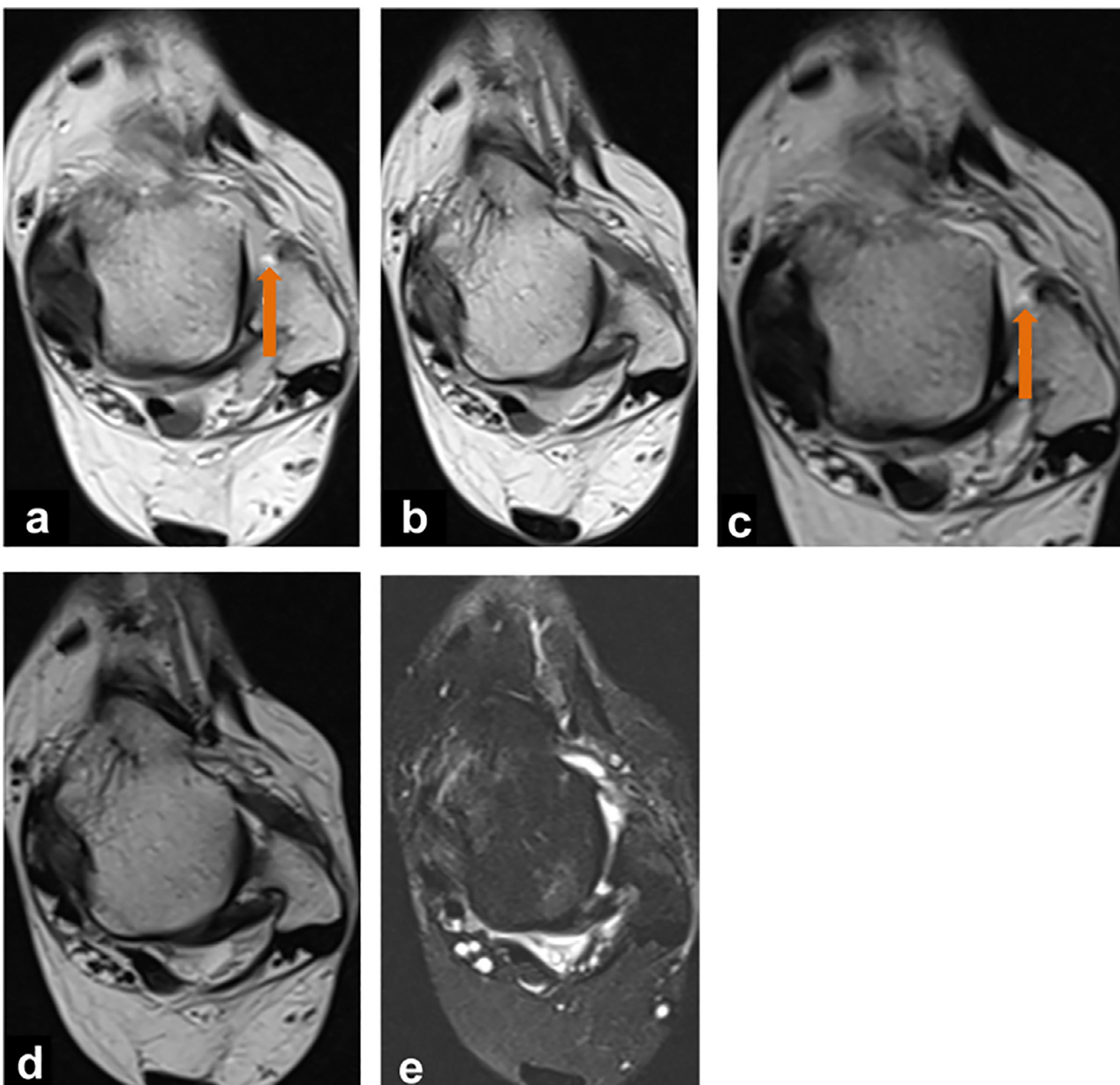

Figure 2. A 35-year-old woman with acute left lateral ankle instability and partial ATFL tear which was confirmed by arthroscopy. (a) and (b) Axial PD images, and (c) and (d) Axial T2WIs show BRS in the fibula with cortical disruption (arrows) and thickened ATFL. (e) Axial STIR image at the same level shows absent BRS. ATFL, anterior talofibular ligament; BRS, bright rim sign; PD, protein density; STIR, short tau inversion recovery.

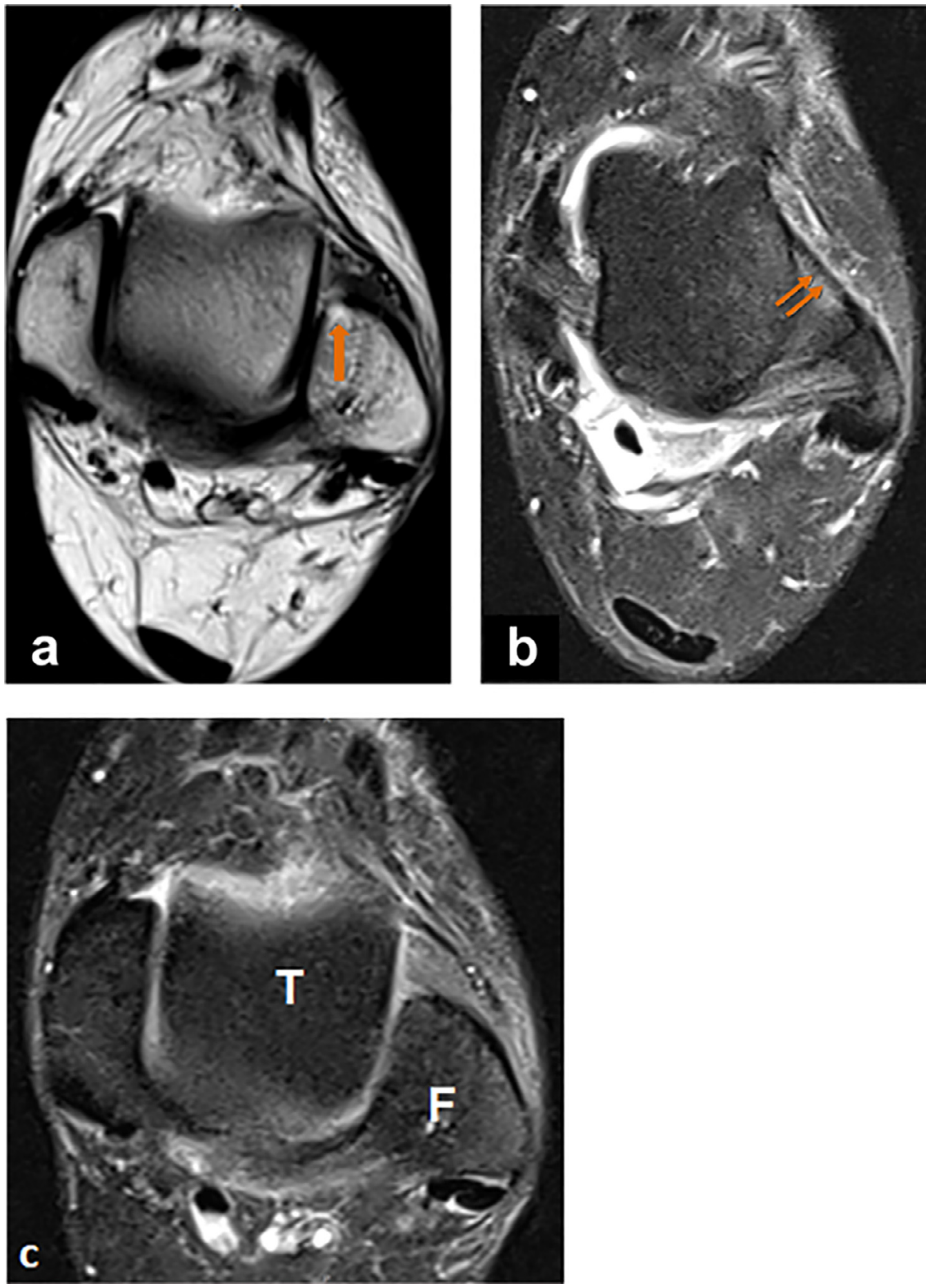

Figure 3. A 49-year-old man with recurring right ankle sprain and partial ATFL disruption which was confirmed by arthroscopy. (a) Axial T2WI shows positive BRS (arrow). (b) Axial STIR at the same level shows absent BRS (arrows). (c) Axial PDFS at the distal level shows intact ATFL. ATFL, anterior talofibular ligament; BRS, bright rim sign; PDFS, protein density fat sat; STIR, short tau inversion recovery.

LDS alone to 90.9% to 96.9% when considering both LDS and BRS. In comparison to our study, we found that the BRS and LDS separately showed a sensitivity of 43.3% and 60% respectively, while when both sigs were considered together, the sensitivity increased to 86.7% ($p < 0.0001$). The higher sensitivity in Lee et al. study may be explained by two facts; first, they scanned the patients by three-Tesla MRI scanner with better resolution and capability. Second, we included the second group of patients (chronic ankle sprain), which was scanned after three months of the trauma incident. There was a chance for possible healing of the cortical defect and elimination of the BRS. However, positive BRS in chronic cases in our study mostly attributed to non-union of the avulsed fragment.

In Lee et al. (16) study, the MRI examination was performed using three-Tesla MRI, and axial T2 parameters were applied as TR/TE = 4000/55, which in our opinion was PD rather than T2 sequence. In our study, the ATFL was evaluated by using a 1.5-Tesla MR scanner and both T2 and PD parameters were applied in addition to STIR and PDFS axial images.

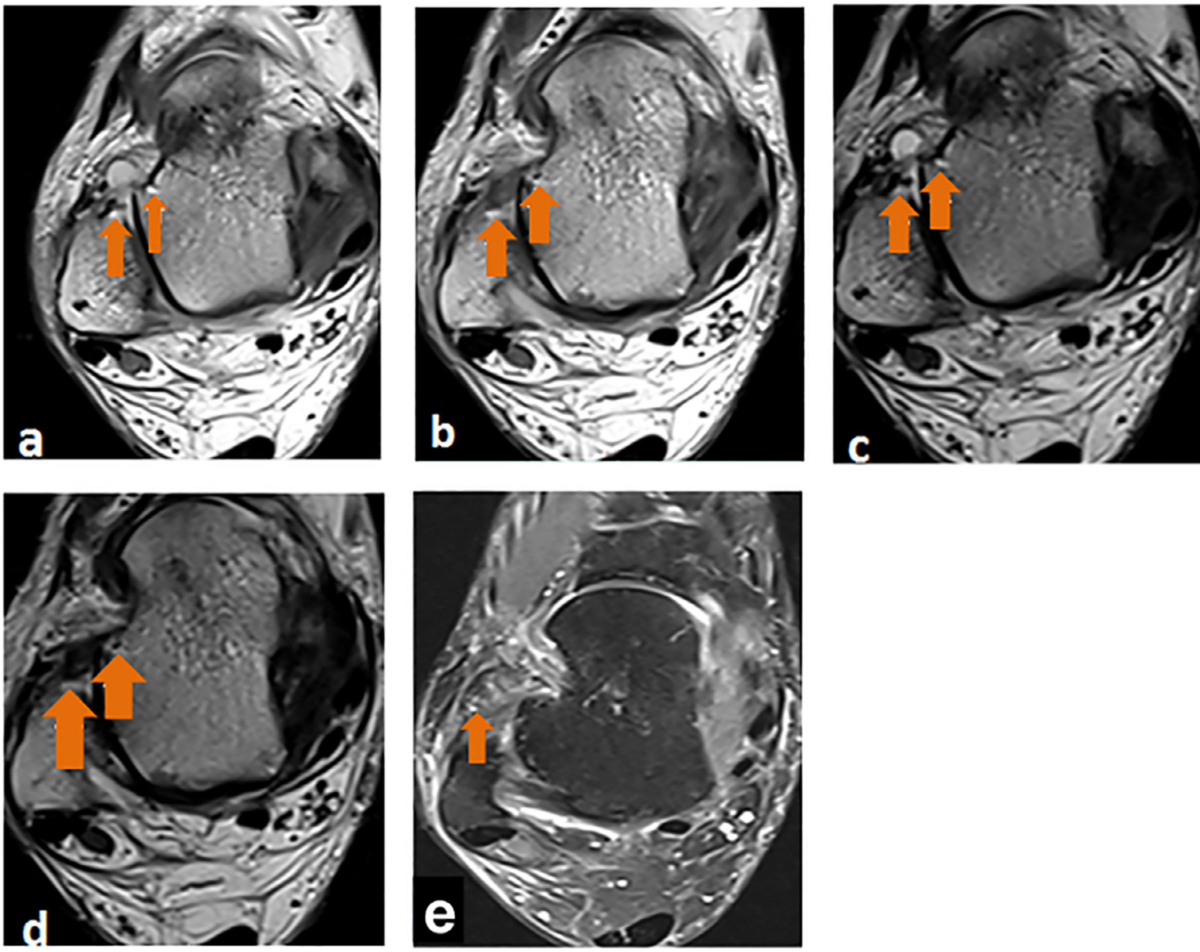

Figure 4. A 38-year-old man with chronic right ankle instability and partial ATFL tear. (a) and (b) Two consecutive axial T2WI, and (c) and (d) Axial PD images demonstrate BRS in both talus and fibula (arrows) with thickened ATFL. (e) PDFS axial image at a more caudal section shows thickened ATFL with increased intraligamentous signal intensity indicative of intrasubstance edema (arrow). ATFL, anterior talofibular ligament; BRS, bright rim sign; PD, protein density; PDFS, protein density fat sat.

Khan et al. (18) reported that ATFL disruption could be missed by MRI due to the formation of pseudo-band made up of granulation and/or scar tissue, which covers the tear gap. Takao et al. (19) added that false-negative MRI reports could be attributed to the partial volume effect induced by the use of 3-mm thickness obscuring the subtle ligament morphological changes. In our study, the BRS was observed either above or at the level of the ATFL in 27 out of 62 included patients. In 16 out of 27 patients with disrupted ATFL, the BRS was positive while the ligament itself was morphologically normal using the LDS sign. Using both signs together significantly increased the accuracy from 61.3% for LDS alone to 85.5% ($p < 0.0001$).

Using the LDS only, the previous studies (13−15) reported sensitivity for detecting ATFL disruption ranged from 44% to 87%. In contrast, a sensitivity of 60% was found when using LDS only in the total group of patients included in this study. This difference is not surprising because we included patients with a chronic and recurrent ankle sprain in our study. MRI of acutely injured ankle ligaments may show swelling of soft-tissue over the lateral malleolus, haemorrhage in the joint space, and high signal intensity at ligament avulsion sites, which may be absent in patients with chronic or recurrent ankle sprain (19). When using both BRS and LDS in our study, the sensitivity increased to 86.7%, which was comparable to that of previous qualitative studies.

Importantly, in our study, the BRS was more common on the fibular side (55.6%), compared to 14.8% on the talar side and 29.6% on both sides. The BRS was more associated with a complete tear when compared to partial tear (75% versus 35.4%, $p = 0.014$).

The chemical shift is more frequently visible on T2 sequences and is more intensive where the magnetic field is stronger and is usually eliminated in the fat suppression technique, including inversion-recovery imaging (20,21). In this study, both T2 and PD images showed equal sensitivity and accuracy for detecting BRS, while it was negative in STIR and PDFS images. Bone marrow edema signal was observed in 3 patients. It appeared to be more diffuse and wider than the dot-like or curvilinear high signal intensity of the BRS with the absence of the focal disruption of the overlying cortex. In these patients, the edema signal was more obvious in the PDFS and STIR images compared to the PD and T2 images.

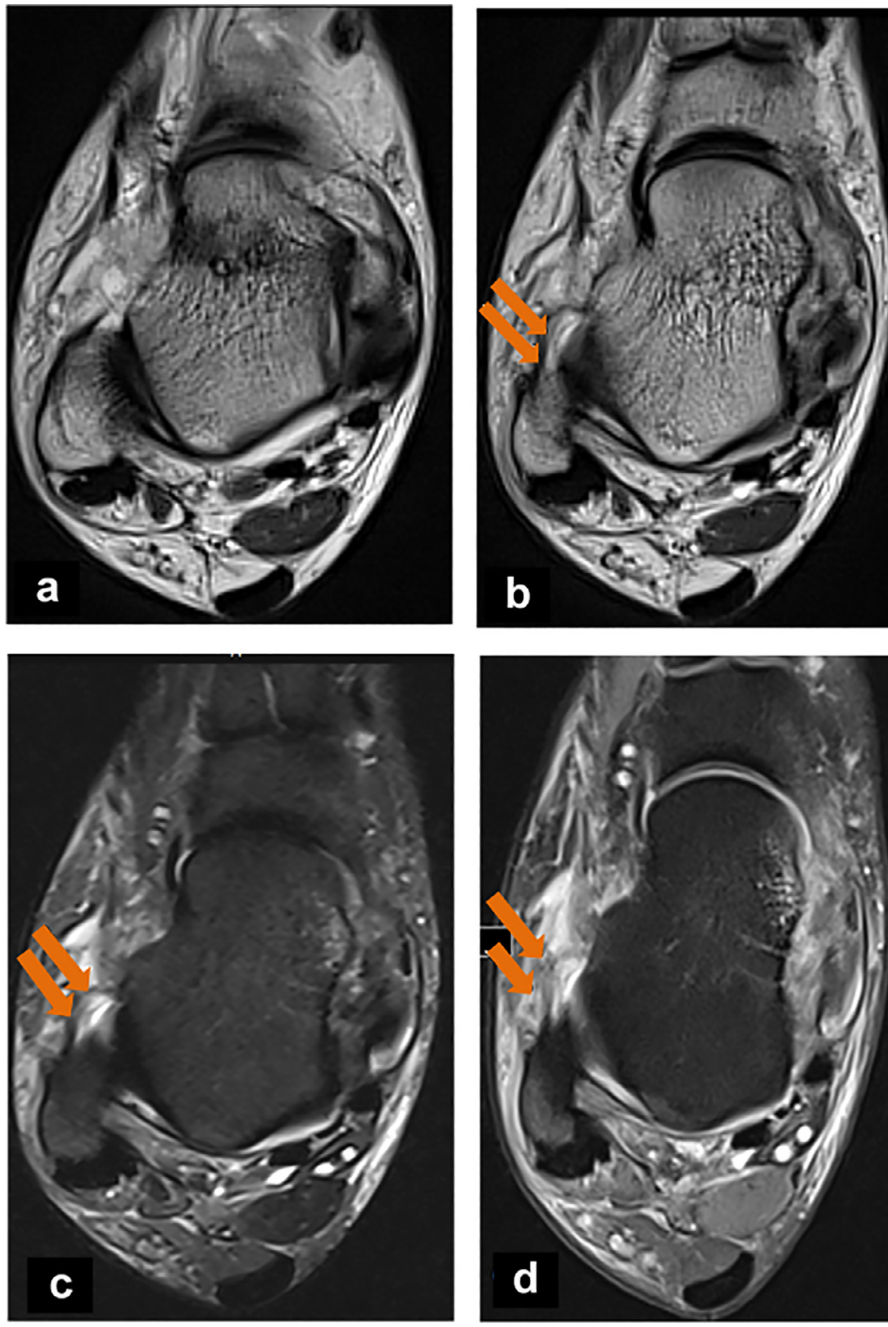

Figure 5. A 31-year-old man with acute right lateral ankle instability and complete ATFL tear which was confirmed by arthroscopy. (a) Axial T2WI demonstrates negative BRS. (b) Axial T2WI, (c) STIR and (d) PDFS images show thin and redundant ATFL (arrows). ATFL, anterior talofibular ligament; BRS, bright rim sign; PDFS, protein density fat sat; STIR, short tau inversion recovery.

Without better evidence for reproducibility of BRS, the results of the study become unusable for clinical practice, and we remain uncertain whether this is sign we should be used or not. So, we performed the inter-reader reproducibility in our study. The overall results were considered highly satisfactory. Our reporting regarding the use of BRS alone for diagnosing ATFL disruption was good ($k = 0.71$).

This study had some limitations. First, the lack of a control group with normal ATFL. However, it was very difficult to control because performing arthroscopy on healthy controls does not seem ethical. Second, there was no adequate number of patients with normal ATFL in our study, which could represent a limitation in the estimation of the specificity. Third, we included only patients who underwent ankle arthroscopy, which is different from the daily practice in investigating the ATFL disruption and could be a potential source of case-selection bias. However, we intended to compare our results with physical proof documenting the ligament disruption.

In conclusion, the BRS is a very useful and helpful diagnostic sign in the assessment of ATFL disruption when

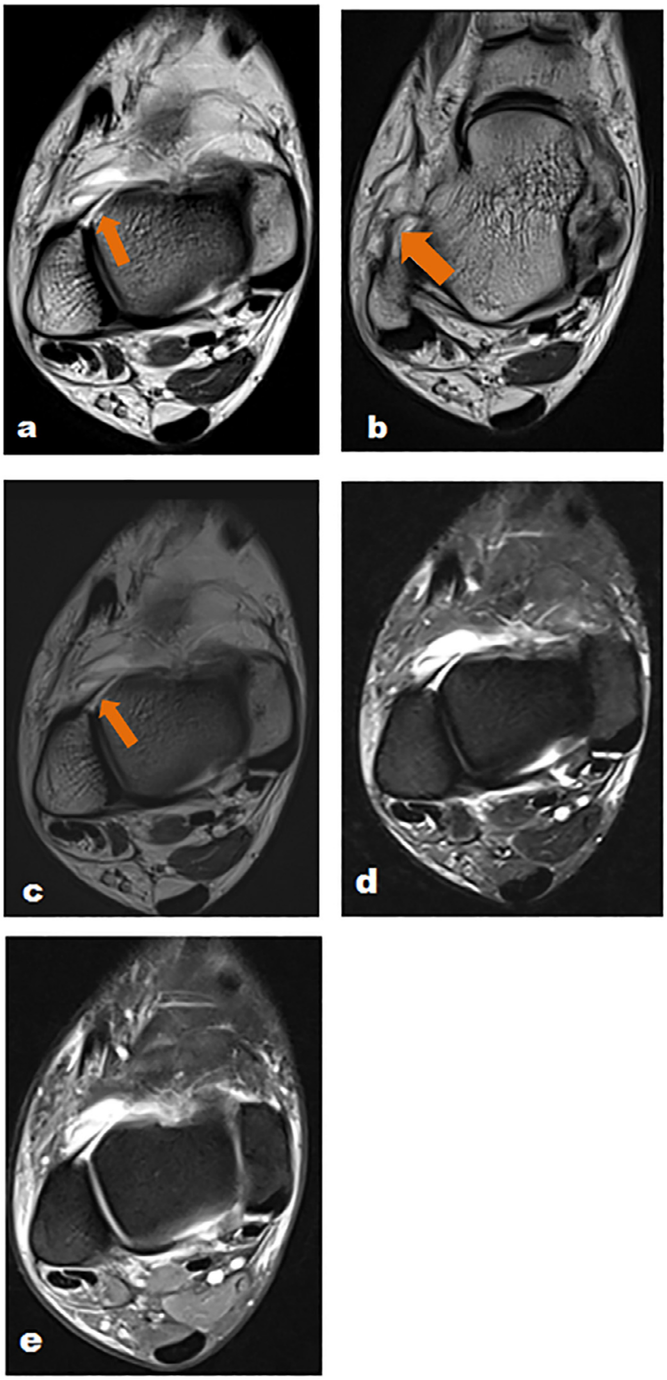

Figure 6. A 42-year-old man with recurring right ankle sprain and complete ATFL tear which was confirmed by arthroscopy. (a) Axial T2WI demonstrates BRS (arrow) in the talar side. (b) Axial T2WI at a more caudal level shows a complete ATFL tear (arrow). (c) PD axial image shows positive BRS in the talar side (arrow). (d) Axial STIR image and (e) PDFS image show negative BRS. ATFL, anterior talofibular ligament; BRS, bright rim sign; PDFS, protein density fat sat; STIR, short tau inversion recovery.

considered conjointly with the LDS as it increases diagnostic sensitivity of MRI significantly, especially in the acute and recurring ligament sprain. It is imperative to include T2 or PD axial images in the MRI protocol when assessing ATFL disruption.

GUARANTOR

The scientific guarantor of this publication is the corresponding author: Mohammad Abd Alkhalik Basha

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ETHICAL APPROVAL

Institutional review boards' approval were obtained.

INFORMED CONSENT

Written informed consent was obtained from all patients.

STATISTICS AND BIOMETRY

The corresponding author has great statistical expertise.

METHODOLOGY

- Prospective.
- Diagnostic or prognostic study.
- Performed at single center.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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