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A comparison of conventional 3.0-Tesla nonenhanced magnetic resonance imaging and arthroscopic findings of the anteroinferior capsulolabral complex in patients with traumatic anterior shoulder instability

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Background: This study aimed to evaluate the association between specific, reproducible findings of an anteroinferior capsulolabral complex obtained using conventional 3.0-Tesla nonenhanced magnetic resonance imaging (MRI) and pathologic arthroscopic findings and to assess the confidence level of the findings.

Methods: Of 125 cases of traumatic anterior instability surgery from January 2017 to November 2019, 66 patients (52 men, 14 women; 23.5 ± 7.9 year old) who underwent conventional 3.0-Tesla MRI at our hospital were reviewed. The following anteroinferior capsulolabral complex features were observed on the T2-star axial image: size difference of the labrum (swelling, diminished), difference in marginal and internal signals (irregularity), and capsule edema image (capsular thickening). We also reviewed fraying, flattening, cracking, and capsular hypertrophy as pathologic arthroscopic findings of the capsulolabral complex. These findings allowed for the simultaneous description of the MRI and arthroscopic evaluations. Three orthopedic surgeons and one radiologist measured the interobserver reliability. We investigated the correlation between the MRI and arthroscopic findings.

Results: The interobserver reliability of MRI irregularities was low ($\kappa = -0.16$), whereas reliability was moderate ($\kappa = 0.554$-0.595) for swelling in 22 cases (33%), diminished in 34 cases (52%), and capsular thickness in 40 cases (59%). Labral detachment was found in 26 patients (39%) and fluid collection in 24 patients (36%). The agreement of MRI findings with arthroscopic findings was $\kappa = 0.46$ (95% confidence interval [CI]: 0.268-0.654) for swelling to fraying; $\kappa = 0.42$ (95% CI: 0.202-0.638) for swelling to capsular hypertrophy; and 0.46 (95% CI: 0.268-0.654) for flattening to diminished.

Conclusion: The swelling and diminished findings of the anteroinferior capsulolabral complex on conventional MRI were moderately related to pathologic arthroscopic findings in patients with traumatic anterior shoulder instability. These findings contribute to achieving an accurate clinical diagnosis.

When assessing the pathologic findings of magnetic resonance imaging (MRI) of the anteroinferior capsulolabral complex (CLC) in traumatic anterior shoulder instability, visualizing the instability of the labrum has been emphasized.[7,9] However, conventional (noncontrast) MRI and actual arthroscopic (AS) findings often lead to different diagnoses.[6,9] Therefore, MRI arthrograms, which can use intra-articular contrast to visualize the location of the injured CLC, are reportedly more informative.[14,15] Furthermore, MRI arthrography in the abduction-external rotation (ABER) position is useful because it is performed in a pathogenesis-inducing posture.[3,22]

However, not all hospitals have access to MRI arthrography. Typically, conventional (nonenhanced) MRI is performed at a doctor's clinic, and patients often present the images to the

This study was performed in accordance with the Declaration of Helsinki and ethical approval was obtained from the Research Ethics Committee of St. Luke's International Hospital (Ref: 17-R086).

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hospital to receive surgical treatment. In these cases, the specialist has the option of continuing treatment using the conventional MR image or obtaining an MRI arthrogram; however, choosing the latter increases medical costs. It is also undeniable that arthrocentesis, which is performed at the time of arthrography, can potentially lead to complications.[7,8] In posterior shoulder instability, conventional MRI pathologic findings of the posterior labrum are diagnosed using not only the labrum cleft but also the labrum height.[10]

No studies have examined imaging characteristics by comparing conventional MRI to AS findings; by this comparison in traumatic anterior instability, 3.0-Tesla (3T) MR images that are expected to provide high signal contrast can reveal clinically useful abnormalities.[2,22] New positive findings may be identified on nonenhanced 3T MR images by comparing the findings with arthroscopic findings. In addition, assessing and understanding the diagnostic accuracy of conventional MRI is an important aspect of daily clinical practice. Furthermore, the invasiveness and additional medical costs associated with MRI arthrography can be avoided.

The current study hypothesized that reproducible, specific labrum findings from conventional 3T MRI can be obtained by comparison with pathologic AS labrum findings in patients with traumatic anterior shoulder instability. This study aimed to evaluate the association between conventional MRI findings and AS labral pathology and to assess the confidence level of the findings.

Materials and methods

We conducted a retrospective chart review of 125 patients who were surgically treated for traumatic anterior shoulder instability between January 2017 and October 2019. This study was performed in accordance with the Declaration of Helsinki and ethical approval was obtained from the institutional review board. Informed consent was obtained from all patients and relevant individuals before study initiation.

Clinical information included age, sex, number of dislocations or subluxations, and time from the recent injury to when the MRI data were examined. The glenoid bony lesions were evaluated using three-dimensional computed tomography.[21]

The inclusion criteria were as follows: cases diagnosed with anterior shoulder instability with a clear history of one or more traumatic events, experiencing anterior dislocation or subluxation at the time of injury, 3T conventional MRI performed at our institution, surgery performed at our hospital by a single surgeon (first author), and anteroinferior CLC adequately reviewed by AS imaging. The exclusion criteria were as follows: cases with MRI was taken at another hospital, revision surgery cases after failed surgical treatment, cases of humeral avulsion of glenohumeral ligament (HAGL) lesions, a glenoid bony defect of >3% diameter (excluding osseous Bankart lesions to focus on the evaluation of the CLC), and cases with insufficient clinical information.[11]

With respect to the MRI conditions, T2-star-weighted MR images were obtained in axial planes (TR/TE = 900/13, FOV 180 mm, section thickness 3 mm, 3T unit, Magnetom Verio; Siemens, Erlangen, Germany). Additionally, fat-suppressed proton density-weighted MR images were obtained in the diagonal–coronal and diagonal–sagittal planes (TR/TE = 2500/37, FOV = 180 mm, section thickness = 3 mm). After examining these 3-way MR images, the observed findings from the axial images were investigated.

Evaluation of MRI findings

Four specific findings of the anteroinferior CLC on MR axial images were recognized by comparing the morphology of the posterior labrum and capsule (Fig. 1 *A-D*)[1] and were defined as follows: 1) swelling: the labrum was enlarged; 2) diminished: the labrum was small, flat, and almost nonvisible; 3) irregular: the margins of the labrum were distorted and had an irregular signal; and 4) capsular thickening: the capsule adjacent to the labrum was thickened. These 4 findings can be used simultaneously to describe each MRI evaluation. Additional morphologic features that were defined included 1) detachment: a clear labral detachment from the rim of the glenoid; 2) fluid: fluid collection in the joint; and 3) Hill–Sachs Lesion: an edematous change in the posterior superior humerus. These four findings allowed for the simultaneous evaluation of the MRI findings.

Evaluation of AS findings

The following 4 abnormal findings of the anteroinferior CLC were observed on arthroscopy (Fig. 2 *A-D*): 1) fraying: the labral edge was frayed and disorganized; 2) flattening: the height of the labrum was inappreciable, including an anteroinferiorly displaced labrum; 3) crack: a cleft or fissure was noted on the surface of the labrum; and 4) capsular hypertrophy: the joint capsule adjacent to the labrum was erythematous and the synovial membrane was enlarged. These 4 findings allowed for the simultaneous description of the arthroscopic evaluations.

Assessing the reliability of MRI and AS findings

MRI findings were independently evaluated by an orthopedic consultant who was involved in all treatments, a board-certified orthopedic surgeon who was not involved in patient care, an orthopedic surgery resident, and a radiology musculoskeletal specialist. Three orthopedic surgeons independently evaluated the AS findings of the anteroinferior CLC. The interobserver reliability of each MRI and AS finding was assessed.

Evaluation of the relationship between MRI and AS findings

An orthopedic shoulder consultant and a radiology musculoskeletal specialist evaluated the specific MRI findings, and a consensus was used to confirm the results. In addition, AS findings of the anteroinferior CLC were determined after the consultant doctors and orthopedic surgeons came to a consensus.

Statistical analysis

Categorical variables were compared using Fisher's exact test, whereas continuous variables were compared between the two groups using the Mann–Whitney *U* test. Continuous nonparametric variables of 3 or more groups were subjected to the Kruskal–Wallis test, and Dunnett's test was used for subsequent comparisons. The MRI and AS findings were evaluated by calculating the Cohen's κ value with respect to the level of agreement. The level of correlation between MRI and AS findings was also evaluated using the Cohen's κ value. This value was interpreted as follows: 0.0 to 0.2 indicated a slight agreement, 0.21 to 0.40 indicated a fair agreement, 0.41 to 0.60 indicated a moderate agreement, 0.61 to 0.80 indicated a substantial agreement, and 0.81 to 1.0 indicated an almost unanimous or unanimous agreement.[12]

All statistical analyses were performed using the SPSS software (version 25.0; IBM Corp., Armonk, NY, USA). The significance level was set at $P = .05$.

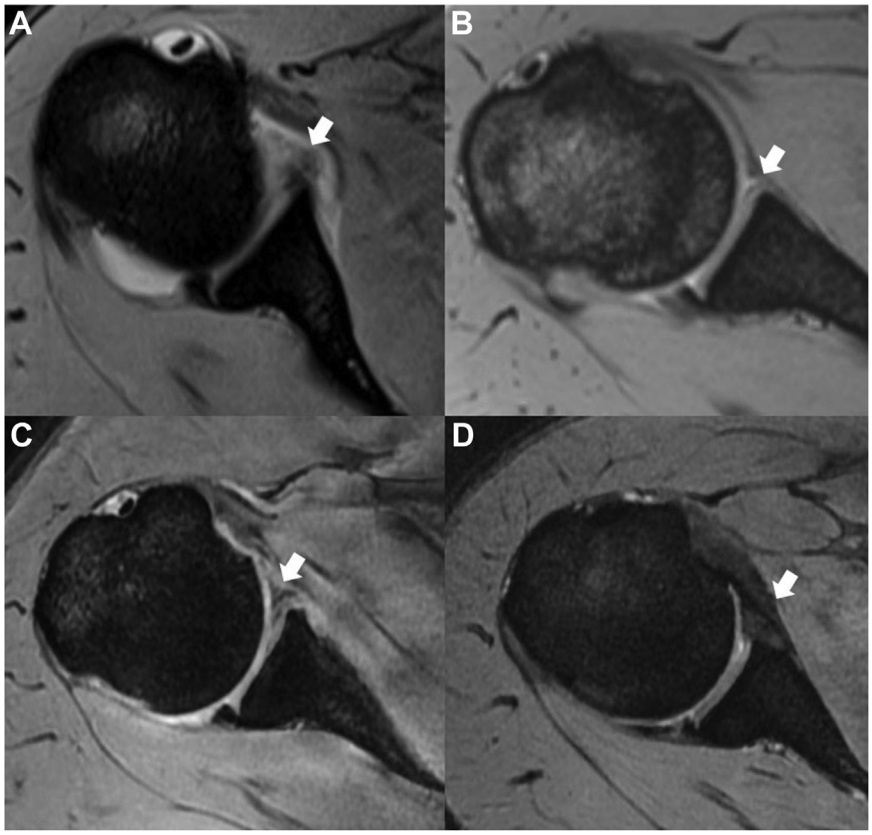

Figure 1 Specific findings of the anterior labrum, Right shoulder. T2-star axial-view images. Each arrow indicates the labrum. (**A**). A 21-year-old man with swelling and irregularity. (**B**). A 20-year-old man with diminished labrum and capsule. (**C**). A 21-year-old man with irregularity. (**D**). A 21-year-old man with swelling, irregularity, and capsular thickening.

Results

Of the 125 patients who underwent AS stabilization surgery for traumatic anterior shoulder instability, 59 were excluded: 52 cases with 3% of the glenoid osseous demonstrating a defect on CT scans, 5 revision surgery cases, and 2 cases with inadequate images. The remaining 66 patients (median age, 23 years) were included in this study (Table I). There were 52 males (78.8%), 55 cases (83.3%) with multiple injuries (dislocation or subluxation), and 15 cases with < 3% glenoid bone defects. The mean time from injury to MRI was 2 months. No cases with an HAGL lesion or capsular midsubstance tears were identified through arthroscopy in this series.

Demographics of MRI-specific findings

Irregularities were seen on MR images in nearly all cases (65 cases, 98%). Swelling was observed in 22 patients (34%), diminishing in 34 patients (52%), and capsular thickening in 40 patients (59%) (Table II). In terms of sex, age, dominant or nondominant, number of injuries, and occurrence of glenoid bony defects (<3%), no differences in the patient demographics were observed among the findings. With respect to AS findings, fraying was observed in 4 cases (52%), flattening in 20 cases (30%), a crack in 55 cases (83%), and capsular hypertrophy in 28 cases (42%).

Interobserver reliability of MRI and AS findings

In the analysis of interobserver reliability of MRI findings, the swelling category had the highest agreement level, with a median κ value of 0.595 (Table III). Diminished capsular thickening showed a moderate level of agreement. In contrast, agreement on observed irregularities was low. In the same analysis of AS findings, flattening (20 cases) showed the highest agreement with a median κ value of 0.703. Fraying (34 cases), cracking (55 cases), and capsular hypertrophy (28 cases) showed moderate agreement.

Agreement between MRI and AS findings

After excluding the findings of irregularity attributed to a low κ value, correlations between MRI and AS findings are summarized in Table IV. The overall accuracy for assessing swelling to fraying (73%), swelling to capsular hypertrophy (73%), and diminished to flattening (73%), was found to be high.

From these results, the MRI findings moderately correlated with AS findings were swelling to filling ($\kappa = 0.461$, 95% confidence interval [CI]: 0.268-0.654), swelling to capsular hypertrophy ($\kappa = 0.42$, 95% CI: 0.202-0.638), and diminished to AS flattening ($\kappa = 0.461$, 95% CI: 0.268-0.654) (Table V). Kappa values for all combinations are presented in the Supplementary Materials.

Other MRI findings: labrum detachment, fluid collection, and Hill–Sachs lesions

Labrum detachment was found in 26 cases (39%), and fluid collection was found in 24 cases (36%). In 16 cases of detachment, fluid was simultaneously found. The time from injury to MRI (median: one month; interquartile range [IQR]: 1, 2) in 24 patients with fluid collection was significantly shorter than that in the 42 patients without fluid collection (median: 2; IQR: 1, 3) ($P < .001$). A high-intensity change in Hill–Sachs lesions was observed in 57 cases (86%), and the median time until an MRI was performed was

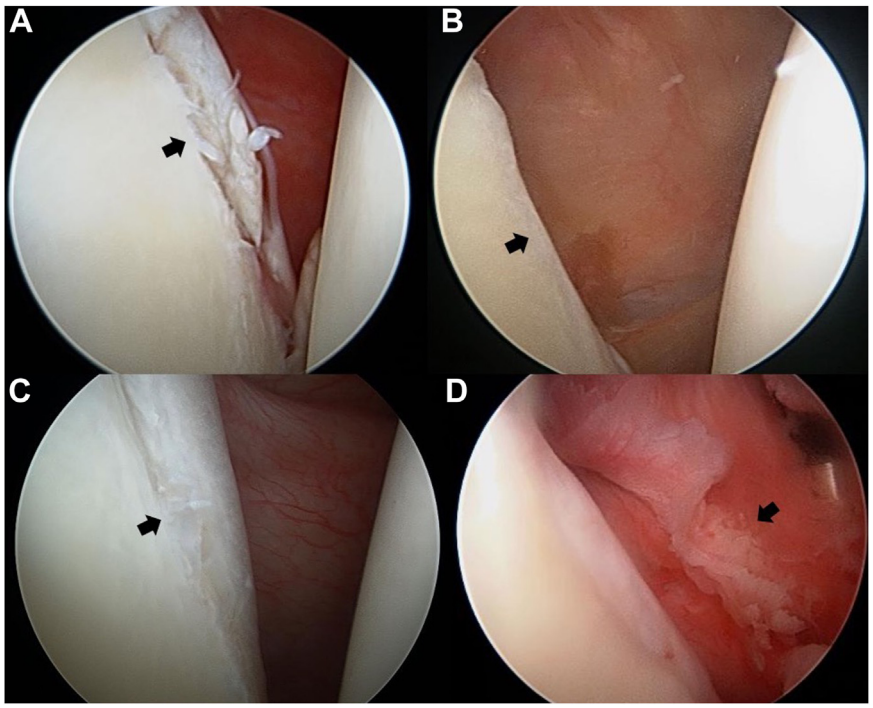

Figure 2 Pathologic findings of the anterior to anteroinferior labrum, viewed from the posterior portal with 45 degrees scope. The arrows in each figure indicate pathologic findings. Patients labelled as (**A-D**) correspond to the same patients labelled (**A-D**) in Fig. 1. (**A**). A 21-year-old man with fraying. (**B**). A 20-year-old man with flattening. (**C**). A 21-year-old man with a crack. (**D**): A 21-year-old man with capsular hypertrophy.

Table I
Patient demographics.

Age (years: Median, min-max)	20 (16-45)
Gender (N)	
Male	52 (78.8%)
Female	14 (21.2%)
Number of injuries (N)	
1	11 (16.7%)
2	20 cases (30.3%)
>3	35 cases (53.0%)
<3% Glenoid bone defect (N))[13]	15 (22.7%)
Time from recent injury to MRI (months: median, min-max))	1 (1-10)

SD, Standard deviation; *min*, minimum; *max*, maximum; *MRI*, magnetic resonance imaging.

one month (IQR: 1, 2). In contrast, no significant differences were found in 9 patients without Hill–Sachs lesions ($P = .12$). No cases of HAGL lesions were observed.

Discussion

Specific findings of the anteroinferior CLC on conventional MR images of patients with traumatic anterior shoulder instability were found with moderate interobserver reliability by evaluating the size of the anteroinferior labrum with respect to the posterior labrum. Signal irregularities detected in the labrum MRI showed high sensitivity to pathologic AS findings, but specificity was extremely low. Swelling visible on the MRI was associated with fraying and capsular hypertrophy with moderate agreement, while a diminished labrum was moderately associated with flattening. The time from recent injury to MRI was significantly shorter in patients with fluid collection than in those without.

We evaluated the inter-observer reliability of conventional MR images. In this study, we found differences in the size of the anteroinferior and posterior labrum to be specific findings, which were, at minimum, moderately agreed upon by the observers. This is in accordance with Kim et al's study on using the height of the posterior labrum as a method for diagnosing posterior shoulder instability with imaging.[10] Previous 3T MRI arthrogram studies have shown that the interobserver reliability of the cleft in the CLC had an approximate κ value of 0.5,[15] which is close to the value reported in our study. However, interobserver agreement on irregular MRI signals was extremely low, showing a signal difference in the margins and internal parts of the labrum. 3T MRI has a high signal-to-noise ratio and increased ability to detect differences in internal signals[2,20]; however, the results of the current study suggest that the presence of irregular signals is not as clinically useful as conventional MRI related to the pathologic findings of CLC.

Previous reports have stated that only obvious detachments or tears should be diagnosed to detect pathologic findings of the labrum in patients with traumatic anterior shoulder instability.[16,23] In the current study, labral detachment was detected in only 39% of cases. The current study indicated that conventional MRI conducted within 2 months from the time of injury to MRI imaging could also yield intra-articular contrast effects, making it more likely to obtain typical findings of detachment. A diminished labrum and capsule, observed in 52% of all cases on MRI, was moderately correlated with AS flattening in the current study. Since we excluded patients with obvious glenoid bone lesions, this finding was not affected by glenoid bone defects. Although the detachment results are credible and significant, it is noteworthy that this is uncommon in conventional MRIs.

Shoulder joint dislocation causes substantial glenohumeral ligament tears; therefore, traumatic changes in the soft tissues should be visible.[18] Swelling seen on the MRI showed moderate agreement with the AS findings, specifically with respect to

Table II
Demographics of MRI findings.

	MRI findings (N)				*P* value
	Swelling (20)	Diminished (34)	Irregular (65)	Capsular thickening (40)	
Gender					.75*
Male 52	16	26	51	33	
Female 14	4	8	14	7	
Age					
Median (IQR)	19.5 (18, 28.5)	20.5 (17, 29)	20.0 (18, 28)	20.5 (17.5, 23)	.31†
Time from recent injury to MRI (months)					
Median (IQR)	1 (1, 1.5)	2.3 (1.6)	1 (1, 3)	1 (1, 3)	.50†
Number of injuries					
1	6	3	11	6	.64*
>2	14	31	54	34	
Glenoid bony defect (<3%)					
+ (28)	7	18	27	16	.52*
– (38)	13	16	38	24	
Arthroscopic findings					
Fraying					
+ (34)	18	11	33	21	
– (30)	2	23	32	19	
Flattening					
+ (20)	2	18	19	10	
– (44)	18	16	46	30	
Crack					
+ (55)	17	28	55	36	
– (11)	3	6	10	4	
Capsular hypertrophy					
+ (28)	15	10	28	20	
– (38)	5	24	37	20	

MRI, magnetic resonance imaging; *SD*, standard deviation; *IQR*, interquartile range.
*Fisher exact test.
†Kruskal–Wallis test and Dunnett test.

Table III
Inter-observer reliability of MRI and arthroscopic findings.

MRI findings	Kappa value (mean)	95% confidence interval
Swelling 20 cases (30%)	0.595	0.481-0.703
Diminished 34 cases (52%)	0.579	0.463-0.680
Irregularity 65 cases (98%)	−0.016	−0.098 to 0.096
Capsular thickening 40 cases (59%)	0.554	0.435-0.669
Arthroscopic finding		
Fraying 34 cases (52%)	0.523	0.380-0.654
Flattening 20 cases (30%)	0.703	0.593-0.795
Crack 55 cases (83%)	0.428	0.279-0.574
Capsular hypertrophy 28 cases (42%)	0.586	0.451-0.705

MRI, magnetic resonance imaging.

fraying and capsular hypertrophy. In the latter, it is speculated that 3T MRI was able to sensitively detect edematous changes after traumatic stress. It should be noted that capsular hypertrophy may be a response to traumatic stress on the capsule. In this series, an MRI was performed on an average of 2 months from the time of injury, and it is likely that changes in the acute phase are depicted in the images. In the current study, the time from injury to MRI was shorter in patients with joint fluid collection than in those without. In addition, 86% of high signal intensity changes in Hill–Sachs lesions were also observed in the current study. Recognizing that traumatic effects appear sharply on 3T MR images may be useful for correctly interpreting the imaging results.

The ABER position has been recommended to depict detachment.[1,4] As such, there are limitations to using conventional MRI in the diagnosis of anteroinferior CLC. In contrast, physical tests have shown high diagnostic accuracy for traumatic anterior shoulder instability.[2] Therefore, in the case of MRI for traumatic anterior instability, it is important to delineate labral lesions and search for other comorbid trauma.[1] For orthopedic surgeons taking medical histories and conducting physical examinations, understanding the significance of conventional MRI is practical for detecting characteristic findings and deciding on a treatment plan.

Limitations

This study had several limitations. First, although consecutive patients visiting the shoulder clinic at our hospital were enrolled to minimize selection bias, it is possible that confounding factors were not comprehensively examined because of the retrospective nature of the medical records. Second, the current study did not explore which type of finding necessitates specific treatments. All cases in this series were uniformly treated with arthroscopic Bankart repair. Third, the current study included both complete dislocation and subluxation as causes of traumatic anterior instability. It is important to note that the physical impact of each condition differs, potentially leading to variations in MRI and arthroscopic findings. However, due to the challenge of accurately distinguishing between the two based on clinical information, they are mixed in the current study. Lastly, regarding the correlation between MRI and AS findings, the obtained κ values were approximately 0.5. Values of κ which are less than 0.5 may indicate that the results are not better than those achieved by chance alone.[13] Nevertheless, the κ values of other clinical measures, such as the Glasgow coma scale, Babinski sign, and digital rectal examination for prostate cancer, are all less than 0.5, which is similar to our results.[5,17,19] However, these clinical measures have been established as diagnostic tools in clinical practice by combining them with diagnostic imaging, physical examinations, and patient history evaluations. In the case of surgical treatment for traumatic anterior shoulder instability, even if only

Table IV
The correlation between the MRI findings and the arthroscopic findings.

MRI findings	s AS findings			
	Fraying	Flattening	Crack	Capsular hypertrophy
Swelling	Sensitivity: 53% Specificity: 94% PPV: 90%, NPV: 65% Overall accuracy: 73%	Sensitivity: 10% Specificity: 61% PPV: 10%, NPV: 61% Overall accuracy: 45%	Sensitivity: 30% Specificity: 70% PPV: 85%, NPV: 15% Overall accuracy: 36%	Sensitivity: 54% Specificity: 87% PPV: 75%, NPV: 72% Overall accuracy: 73%
Diminished	Sensitivity: 32% Specificity: 28% PPV: 32%, NPV: 28% Overall accuracy: 30%	Sensitivity: 90% Specificity: 65% PPV: 53%, NPV: 94% Overall accuracy: 73%	Sensitivity: 50% Specificity: 40% PPV: 82%, NPV: 13% Overall accuracy: 48%	Sensitivity: 36% Specificity: 37% PPV: 29%, NPV: 44% Overall accuracy: 36%
Capsular thickening	Sensitivity: 62% Specificity: 41% PPV: 53%, NPV: 50% Overall accuracy: 52%	Sensitivity: 50% Specificity: 35% PPV: 25%, NPV: 62% Overall accuracy: 39%	Sensitivity: 64% Specificity: 60% PPV: 90%, NPV: 23% Overall accuracy: 64%	Sensitivity: 71% Specificity: 47% PPV: 50%, NPV: 69% Overall accuracy: 58%

PPV, positive Predict Value; *NPV*, negative Predict Value; *MRI*, magnetic resonance imaging.

Table V
Relationship between MRI and arthroscopic findings.

MRI findings	Arthroscopic findings	Sensitivity (%)	Specificity (%)	Kappa value	95% CI	
					Min	Max
Swelling	Fraying	53	94	0.461	0.268	0.654
Swelling	Capsular hypertrophy	54	87	0.420	0.202	0.638
Diminished	Flattening	90	65	0.461	0.268	0.654

MRI, magnetic resonance imaging; *CI*, confidence interval.

conventional MRI is available, further invasiveness and cost by additionally performing MRI arthrography, can be avoided as seen in our findings.

Conclusion

The conventional MRI revealed a moderate association between the swelling and diminished findings of the anteroinferior CLC and the pathologic AS findings in patients suffering from traumatic anterior shoulder instability. These findings hold significance in accurately diagnosing the condition in a clinical setting.

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Supplementary data

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