Archives of Orthopaedic and Trauma Surgery
https://doi.org/10.1007/s00402-023-04790-5

ARTHROSCOPY AND SPORTS MEDICINE

Is lesser tuberosity morphology related to subscapularis tears and anterior shoulder instability?

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Received: 2 June 2022 / Accepted: 22 January 2023

Abstract

Purpose Although the morphological relationship of the scapula and the humeral head has been claimed to be related to shoulder pathologies, few studies examined the relationship between subscapularis (Ssc) tears and lesser tuberosity (LT)—humeral head (HH) and between Ssc tears and HH—glenoid. This study aims to evaluate the relationship of LT with HH and glenoid in patients with Ssc tears and anterior shoulder instability (ASI). We hypothesized that the glenoid, HH, and their combined relationship with LT may impact Ssc tears and ASI.

Material and methods The study included 34 patients with ASI, 28 patients with isolated Ssc tears, and 40 patients as the control group. The radius of HH (Hr), the distance between the center of HH and LT (LTr), and the glenoid radius (Gr) were measured in shoulder magnetic resonance (MR) images. The LTr to Hr (LTr/Hr) ratio was defined as the lesser tuberosity-humeral head index (LTHHI), whereas the LTr to Gr (LTr/Gr) ratio was defined as the lesser tuberosity-glenoid index (LTGI). The three groups were compared regarding LTHHI, LTGI, LTr, Hr, and Gr.

Results There was a significant difference between each group concerning LTGI ($p < 0.001$). LTGI values below 1.99 showed 93.1% sensitivity and 93.3% specificity for Ssc tears, while values above 2.24 showed 86.7% sensitivity and 86.2% specificity for ASI. Also, there was a significant difference when the groups were compared for LTHHI ($p < 0.001$). This rate was lowest for Ssc tears, and LTHHI values below 1.17 showed 82.8% sensitivity and 80.1% specificity.

Conclusion LTGI may be a new predictive factor showing 93.1% sensitivity and 93.3% specificity for Ssc tears and 86.7% sensitivity and 86.2% specificity for ASI. In addition, LTHHI may be a new predictive factor showing 82.8% sensitivity and 80.1% specificity for Ssc tears.

Level of evidence III retrospective comparative study.

Keywords Lesser tuberosity · Humeral head · Glenoid · Subscapularis tear · Shoulder instability

Introduction

The etiology of rotator cuff tears is multifactorial and may be due to internal or external factors. External factors include impingement syndromes such as subacromial and subcoracoid impingement [5, 12]. Unlike supraspinatus tears, isolated subscapularis (Ssc) tears are rare and are often a part of anterior–superior rotator cuff tears [12, 15]. Ssc tears have been associated with the coracohumeral distance (CHD) measured in the axial plane, and it has been suggested that a coracohumeral distance less than 6 mm is also associated with subscapularis tendon tears [7, 24]. However, Tollemar et al. [23] suggested that the coracohumeral distance is not associated with Ssc tears. Most studies investigating CHD have involved measuring the relative position of the coracoid and humeral head, but this distance can vary with the position of the arm, which is not always controllable when acquiring the image [4, 24].

The glenohumeral joint (GHJ) is the most frequently dislocated joint in the body [8, 10]. Most of the GHJ dislocations are traumatic and anterior [1, 8, 17]. Traumatic ASI is associated with capsulolabroligamentous tears, glenoid margin fractures, and posterosuperior humeral head compression

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fractures [17]. Few studies have addressed osseous morphological factors other than lesions of the anteroinferior glenoid rim and lesions of the posterosuperior humeral head that may contribute to recurrent traumatic ASI [14, 16, 18]. Owens et al. [18] defined the coracohumeral distance as an independent risk factor for traumatic ASI, with a 20% increased risk of instability for every 1 mm increase in CHD. Besides, Lopez et al. [14] associated coracoacromial arch morphology with glenohumeral instability. Furthermore, Hong et al. [6] studied the glenoid-humeral head relationship in patients with ASI.

Although the morphological relationship of the scapula-humeral head in the literature focuses mostly on CHD, patient groups have been examined in different studies with Ssc tears and ASI, but the results are not consistent [5, 18]. There are few studies examining the relationship between Ssc tears and Lesser tuberosity (LT)—humeral head (HH) and between Ssc tears and HH-glenoid [6, 8, 21]. However, Saygi et al. [20] compared rotator cuff rupture, the axial and sagittal plane diameter of the humerus, the axial and sagittal diameter of the glenoid, subacromial distance, and coracohumeral distance in the ASI and control groups, but they did not detail the rotator cuff rupture and did not measure lesser tuberosity. Based on the demonstration of the effect of Ssc variations like multiple Ssc tendon sign (which have an effect on recurrence) on instability in operated ASI patients, we hypothesized that ASI may also be related to the LT, to which Ssc adheres, and the distance of the LT from the HH center (LTr). Therefore, we thought that Ssc tears may be related to LTr, which affects the rotational power of LT on HH rather than isolated LT morphology [5]. For this reason, we decided to compose the sample from patients with ASI and Ssc ruptures. Our literature scan showed no study examining shoulder pathologies comparing HH, LT, and glenoid together. This study aimed to evaluate the relationship of LT morphology with ASI and Ssc tears. Our hypothesis in this study is that the relationship of LT with HH and Glenoid may be related to Ssc tears and ASI.

Material and methods

Ethical approval was obtained from the “Necmettin Erbakan University Ethical Committee” (IRB number: 2022/3574).

Among the 449 patients who underwent shoulder arthroscopy at Necmettin Erbakan University Meram Faculty of Medicine, Department of Orthopedics and Traumatology between 2018 and 2019, 34 patients with ASI and 28 isolated Ssc tears (Lafosse type 2–4, goutallier grade 1–3) were included in the study. Exclusion criteria were glenoid bone defects, Hill-Sachs lesion, neuromuscular diseases, epilepsy, multiple tendon sign findings, previous upper extremity surgeries and recurrent dislocations, os acromiale, posterior capsular contractures, scapular dyskinesia, subacromial spurs, acromioclavicular joint arthrosis, previous upper extremity surgeries, and congenital malformations. Forty patients, who consecutively applied to the orthopedics outpatient clinic due to shoulder pain and did not have any shoulder pathology in their imaging and physical examination, were included as the control group. Radiology department faculty evaluated the MRIs of patients in the control group as normal. Also, they had no findings suggestive of any specific shoulder pathology in their physical examination.

Conventional shoulder magnetic resonance (MR) imaging of 102 patients (60 men and 42 women) with a mean age of 41.57 ± 14.1 (16–65) years was retrospectively analyzed. Demographic information of the participants is summarized in Table 1.

The HH center is the center of the smallest circle covering the humeral head [6, 20]. Therefore, in shoulder MR images, the smallest circle covering the humeral head was drawn in the axial section, in which the humeral articular surface is seen widest, and the radius of this circle was determined as the radius of HH (Hr). Then, the projection of the circle’s center was marked where the LT was most prominent, and LTr, the distance between the apex of the LT and the center of the HH, was calculated (Fig. 1).

Gr was not measured in the axial section as it may be affected by the glenoid bone defect in patients with ASI; it was measured in sagittal sections using the circle method defined elsewhere [9, 11, 22] (Fig. 2).

Lesser tuberosity-humeral head index (LTHHI) was defined as the distance from the center of the HH to the LT type (LTr) and the ratio to the radius of the humeral head (Hr) (LTr/Hr).

The LTR to Gr ratio (LTr/Gr) was defined as the lesser tuberosity-glenoid index (LTGI).

Table 1 Demographic characteristics of the patients

	Number of patients (*n*)	Age ± SD (min–max)	Sex (M/F)
Subscapularis tear	28	55.69 ± 6.7 (42–65)	15/13
Anterior shoulder instability	34	23.8 ± 7.6 (16–41)	22/12
Control group	40	45.9 ± 10.7 (26–62)	23/17

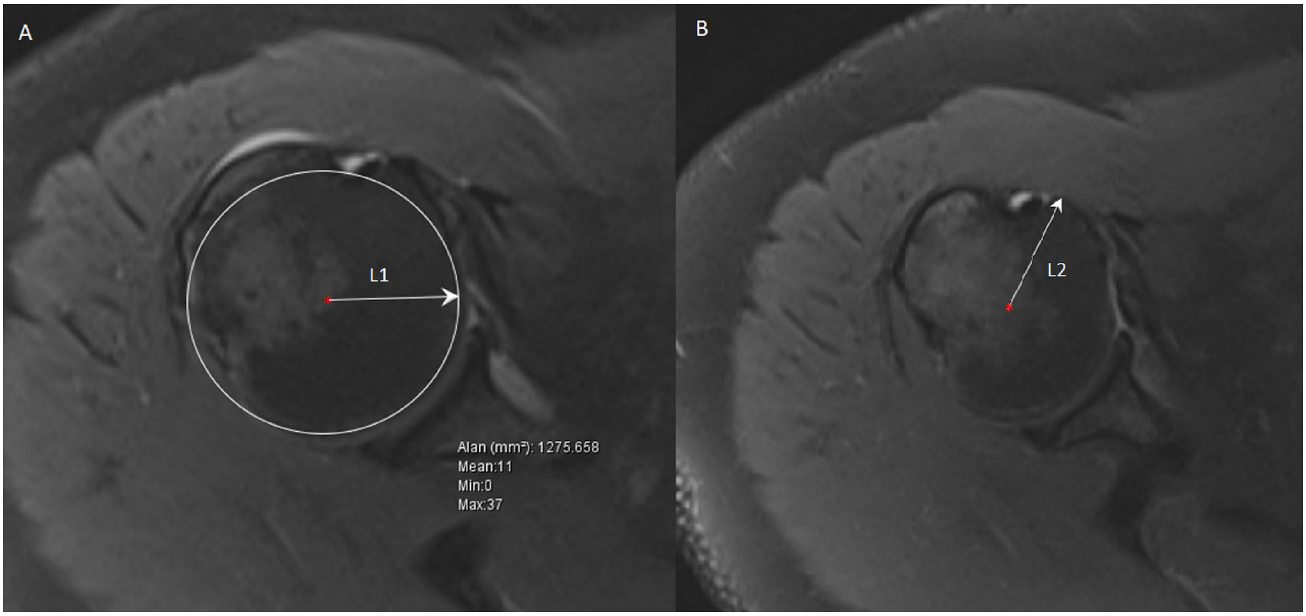

Fig. 1 **A** L1: In the axial section where the articular surface of the humerus is seen widest, the smallest circle covering the humeral head was drawn. It shows the radius of this circle (Hr). The center of the circle in this section is marked with the red dot. **B** L2: the projection of the circle center determined by the red dot is also marked on the section where LT is most prominent. The distance between the be point and the apex of the LT gives LTr

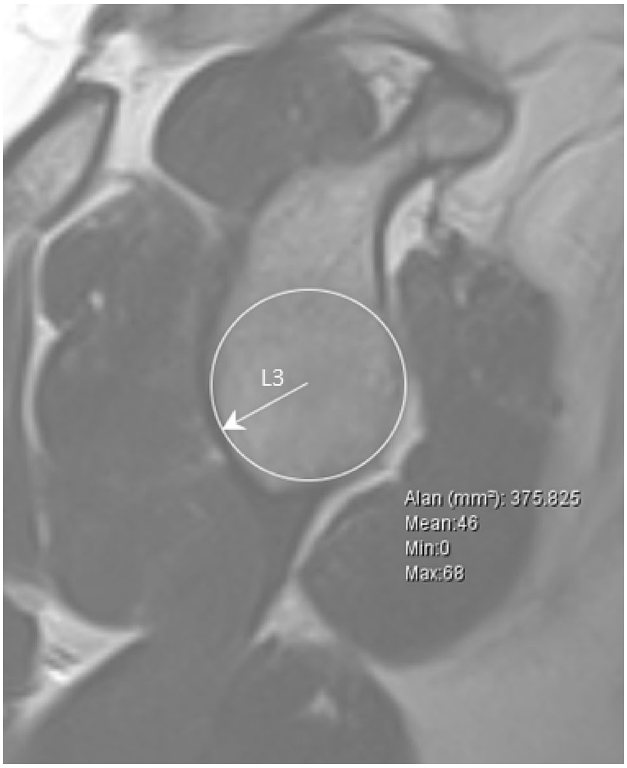

Fig. 2 Measurement of the radius of the glenoid in the sagittal section using the best fit circle method (L3)

On 102 patients with standard shoulder MR images, LTr, Hr, and Gr were measured by two different observers blinded to each other in two separate sessions.

Data analysis was performed using the SPSS software (IBM-SPSS 22.0, Armonk, NY, USA). Other than descriptive statistics and frequency analysis, the intragroup correlation coefficient (ICC) was used to evaluate the intra- and inter-class correlations between the measurements by the same observer in two separate sessions two weeks apart and the measurements of two different observers. The mean values and confidence intervals of the four measurements were calculated. Post hoc power calculations were performed using the G*Power software (version 3.1.9.4, Heinrich Heine University, Düsseldorf) taking alpha error as 0.05 with a two-tailed significance. Skewness of the data was checked with the Shapiro–Wilk test. One-Way ANOVA, independent sample T test, and Mann–Whitney U tests were used to compare independent variables. Receiver operating characteristic (ROC) analysis was done to calculate best diagnostic cut-off thresholds of the LTHHI and LTGI values. Calculations with $p < 0.05$ were considered significant. Post hoc (Bonferroni) tests were used for dual comparisons. When Bonferroni correction was made, $p < 0.0167$ (0.05/3) was considered significant.

Results

The ICC ranged from 0.83 to 0.92 for all measurements, indicating high within-observation reliability.

When the groups were compared with Hr, no significant difference was found ($p = 0.109$) (Table 2). The mean Hr in patients with Ssc rupture was 21.18 ± 2.27 mm (min: 18, max: 24.9) (95% CI 19.92–22.43), while it was 20.26 ± 2.25 mm (min: 17.5, max: 23.5) (95% CI 18.96–21.56) in the control group, and 21.94 ± 1.72 mm (min: 18.4, max: 24) (95% CI 20.99–22.89) in the ASI group (Table 3). Post hoc power analysis for Hr between Ssc rupture and ASI was < 80%.

When the groups were compared in terms of humeral head center-tuberculum minor distance (LTr), there was a significant difference ($p = 0.022$) (Table 2). LTr was significantly lower in patients with Ssc tears than in patients with ASI ($p = 0.004$). LTr values of the control group were between those of the Ssc tear and ASI groups, and no significant correlation was observed ($p = 0.084$, $p = 0.85$, respectively) (Table 2). The mean LTr value of the patients with Ssc tears was 23.58 ± 0.52 mm (min: 21, max: 26.7) (95% CI 22.45–24.72), while it was 25.26 ± 0.81 mm (min: 22.1, max: 30.1) (95% CI 23.51–27.01) in the control group, and 26.04 ± 0.48 mm (min: 22.5, max: 29) (95% CI 24.99–27.08) in the patients with ASI (Table 3). Post hoc power analysis for LTr between Ssc rupture and ASI groups was 99.8% (effect size *d*: 4.73).

When the groups were compared in glenoid radius (Gr), there was a significant difference ($p < 0.001$) (Table 2). The glenoid radius of patients with Ssc tear was significantly higher than the control group and patients with anterior shoulder instability ($p = 0.016$, $p = 0.001$, respectively), but there was no significant difference ($p = 0.066$). The mean Gr value of patients with Ssc tears was 12.98 ± 1.35 (min: 10.8, max: 15) (95% CI 12.22–13.73), while it was 11.8 ± 1.19 (min: 9, max: 13.7) (95% CI 11.11–12.48) in the control group, and 10.86 ± 0.59 (min: 10.1, max: 12) (95% CI 10.52–11.19) in patients with anterior shoulder instability (Table 3). Post hoc power analysis for LTr between Ssc rupture and anterior shoulder instability was 99.4%. (effect size *d*: 1.57).

When the groups were compared regarding Hr/Gr ratio, there was a significant correlation ($p < 0.001$) (Table 2). ASI patients had significantly higher Hr/Gr ratios compared to Ssc tear and control group patients ($p < 0.001$), but there was no significant difference between Ssc tear and control groups ($p = 0.185$). The mean Hr/Gr value in the patients with Ssc tears was 1.63 ± 0.091 (min: 1.49, max: 1.76) (95% CI 1.58–1.68), while it was 1.72 ± 0.127 (min: 1.52, max: 1.94) (95% CI 1.64–1.79) in the control group, and 2.02 ± 0.162 (min: 1.72, max: 2.26) (95% CI 1.93–2.11) in patients with anterior shoulder instability (Table 3). Post hoc power analysis for LTr between Ssc rupture and anterior shoulder instability was 100% (effect size *d*: 1.57).

When the three groups were compared in terms of LTGI, a significant difference was found between the three groups ($p < 0.001$) (Tables 2, 3). This LTGI rate was lowest in patients with Ssc tears, and mean LTGI in patients with Ssc tear was 1.82 ± 0.1 (min: 1.66, max: 2.05) (95% CI 1.76–1.88), while it was 2.14 ± 0.2 (min: 1.86, max: 2.61) (95% CI 2.02–2.26) in the control group, and 2.4 ± 0.16 (min: 2.2, max: 2.74) (95% CI 2.3–2.49) in patients with

Table 2 Mean values of Hr, LTr, Gr, Hr/Gr, LTHHI, and LTGI

Parameter	Groups			
	Subscapularis tear	Anterior shoulder instability	Control group	p value
Mean Hr ± SD	21.18 ± 2.27 mm	21.94 ± 1.7 mm	20.26 ± 2.25 mm	0.109
(min–max)	(18–24.9)	18.4–24	17.5–23.5	
(95% CI)	(19.92–22.4)	20.99–22.89	18.96–21.56	
Mean LTr ± SD	23.58 ± 0.52 mm	26.04 ± 0.48 mm	25.26 ± 0.81 mm	0.022*
(min–max)	21–26.7	22.5–29	22.1–30.1	
(95%CI)	22.45–24.72	24.99–27.08	23.51–27.01	
Mean Gr ± SD	12.98 ± 1.35 mm	10.86 ± 0.59 mm	11.8 ± 1.19 mm	0.001*
(min–max)	10.8–15	10.1–12	9–13.7	
(95% CI)	12.22–13.73	10.52–11.19	11.11–12.48	
Mean Hr/Gr ± SD	1.63 ± 0.091	2.02 ± 0.16	1.72 ± 0.127	< 0.001*
(min–max)	1.49–1.76	1.72–2.26	1.52–1.94	
(95% CI)	1.58–1.68	1.93–2.11	1.64–1.79	
Mean LTHHI ± SD	1.13 ± 0.05	1.18 ± 0.06	1.24 ± 0.04	< 0.001*
(min–max)	1.01–1.21	1.11–1.27	1.16–1.34	
(95% CI)	1.1–1.16	1.16–1.20	1.22–1.27	
Mean LTGI ± SD	1.82 ± 0.1	2.4 ± .16	2.14 ± 0.2	< 0.001*
(min–max)	1.66–2.05	2.2–2.74	1.86–2.61	
(95%CI)	1.76–1.88	2.3–2.49	2.02–2.26	

Table 3 Statistical analysis results of Hr, LTr, Gr, Hr/Gr, LTHHI, and LTGI parameters between binary groups

Parameter	Groups		
	Subscapularis tear—anterior shoulder instability	Subscapularis tear-control group	Anterior shoulder instability-control group
Hr			
p value	$p=0.58$	$p=0.47$	$p=0.09$
Mean difference ± SD	− 0.76	0.91	1.68
95% CI of mean difference	− 2.67/1.14	− 1.02/2.85	− 0.26/3.62
p value	$p<0.001$*	$p=0.016$*	$p=0.066$
Gr			
Mean difference ± SD	2.12	1.18	− 0.94
95% CI of mean difference	1.12/3.11	0.16/2.19	− 1.95/0.07
p value	$p=0.004$*	$p=0.084$	$p=0.85$
LTr			
Mean difference ± SD	− 2.45	− 1.67	0.77
95% CI of mean difference	− 4.6/− 0.29	− 3.86/0.51	− 1.41/2.96
p value	$p<0.001$*	$p=0.185$	$p<0.001$*
Hr/Gr			
Mean difference ± SD	− 0.39	− 0.08	0.3
95% CI of mean difference	− 0.50/− 0.27	− 0.20/0.03	0.18/0.42
p value	$p=0.005$*	$p<001$*	$p=0.004$*
LTHHI			
Mean difference ± SD	− 0.05	− 0.11	− 0.05
95% CI of mean difference	− 0.09/− 0.01	− 0.15/− 0.07	− 0.10/− 0.01
p value	$p<0.001$*	$p<0.001$*	$p=0.001$*
LTGI			
Mean difference ± SD	− 0.57	− 0.32	0.25
95% CI of mean difference	− 0.72/− 0.42	− 0.47/− 0.17	0.10/0.40

anterior shoulder instability. Low LTGI showed 93.1% sensitivity and 93.3% specificity for Ssc tears (cut-off: 1.99, positive likelihood ratio: 13.44, AUC: 0.977) (Fig. 3). It was highest in patients with anterior shoulder instability, and a high LTGI showed 86.7% sensitivity and 86.2% specificity for anterior shoulder instability (cut-off: 2.24, positive likelihood ratio: 6.28, AUC: 0.922). The range of safe LTGI values indicating normal patients was between 1.99 and 2.24. Post hoc power analysis for LTGI between Ssc rupture and anterior shoulder instability was 99.9%. (effect size *d*: 1.57).

When the groups were compared regarding LTHHI (lesser tuberosity-humeral head index), there was a significant difference between all three groups ($p<0.001$) (Tables 2, 3). This rate was lowest in Ssc tears, and the mean LTHHI value was 1.13 ± 0.05 (min: 1.01, max: 1.21) (95% CI 1.1–1.16) in patients with Ssc tears, 1.24 ± 0.4 (min: 1.16, max: 1.34) (95% CI 1.22–1.27) in the control group, and 1.18 ± 0.03 (min: 1.11, max: 1.27) (95% CI 1.16–1.20) in patients with anterior shoulder instability. Post hoc power analysis for LTHHI was 97% (effect size:1). Low LTHHI showed 82.8% sensitivity and 80.1% specificity for Ssc tears (cut-off: 1.17, positive likelihood ratio: 4.13, AUC: 0.893) (Fig. 3).

Discussion

The most important finding of this study is that it shows the relationship of lesser tuberosity with the humeral head and glenoid among patient groups with Ssc tear and anterior shoulder instability. It also reveals that low values of LTGI (Ltr being relatively small compared to Gr) are associated with Ssc tears, high values (Ltr being relatively large compared to Gr) are associated with ASI, and low values of LTHHI (Ltr being relatively small compared to HH) are associated with Ssc tears. To the best of our knowledge, this is the first study investigating these aspects.

In the study of Seo et al. [21], patients with Ssc tears and patients without shoulder pathology were compared. Their study defined the lesser tuberosity height (LTH) as the distance between the line from the anterior cartilage border of the humeral head to the beginning of the biceps groove and the anterolateral farthest point of the lesser tuberosity. They did not find a significant difference when comparing patients with Ssc tears and the control group for LTH [21]. In our study, we hypothesized the rotation force applied by the Ssc tendon while internally rotating by attaching to the

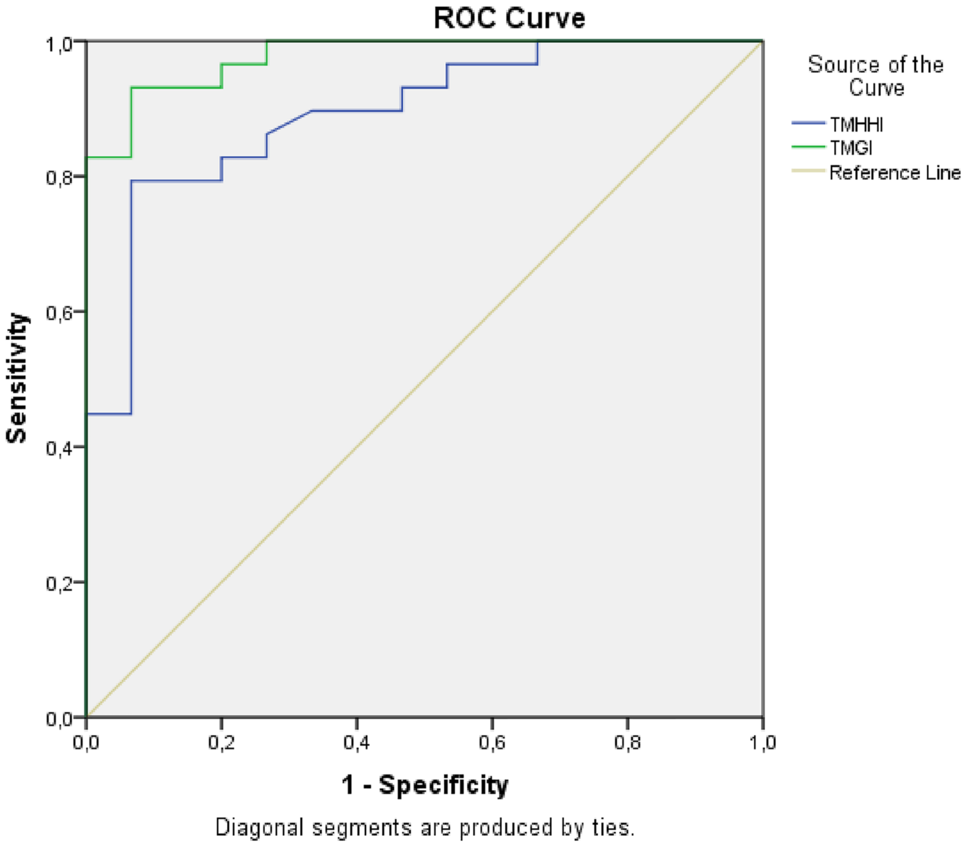

Fig. 3 ROC graph of LTHHI and LTGI parameters

tuberculum minus is not only related to LTH but also related to the distance of the lesser tuberosity from the center of the humeral head (LTr), the radius of the humeral head (Hr), and LTHHI, which is the ratio of the two to each other. As LTr decreases relative to Hr, the Ssc arm gets shorter. Since the force arm of Ssc is shortened, the force it will apply for humeral head rotation should increase. For this reason, we hypothesize that a tear may occur with the overload in the Ssc tendon. LTHHI (defined as LTr/Hr) below 1.17 showed Ssc tears with 82.8% sensitivity and 80.1% specificity, supporting our hypothesis.

It has been shown in previous studies that progressive subacromial impingement can cause pathologies such as subacromial bursitis and supraspinatus rupture [3]. Although it is thought that subcoracoid impingement may also cause Ssc tears, this issue has not been clarified yet [13]. Radas et al. [19] found no correlation between CHD and Ssc ruptures. Similarly, Bergin et al.[2] could not find a significant relationship between the subcoracoid space and the severity of Ssc pathologies. One reason for obtaining significant results regarding the relationship between the coracohumeral distance and subscapularis tear may be the effect of MR imaging acquisition position and joint rotation in the measurement of CHD. Another reason for the results may be that the most lateral point of the coracoid and the apex of the tuberculum minus are not located in the same cross section in the axial sections of the MR imaging. As a third reason, the MR imaging of the shoulder may be taken in the supine position, and factors such as increased thoracic kyphosis affecting the biomechanics of the shoulder may have been ignored. Since the parameter measurements required for LTHHI in our study were performed only at the humeral head, they were not affected by joint rotation or soft tissue pathologies influencing its relative position to the scapula. Therefore, we think that LTHHI is more consistent in terms of the measurement technique.

Leite et al. [12] reported CHD as a good predictor factor for Ssc tears. Rotator cuff muscles coordinate to keep the humeral head centralized in the glenoid. However, when Ssc ruptures, the power balance will change in favor of the infraspinatus and teres minor, and the humeral head will be displaced anteriorly relative to the glenoid center, which will reduce the coracohumeral distance. Therefore, the decrease in the subcoracoid distance may not be a predictive factor of Ssc tears but a result of Ssc tears. In line with the data obtained in our study, we think that the relationship of the tuberculum minus with the humeral head rather than the coracoid process is more effective in Ssc tears.

In our study, there was no significant relationship between the three patient groups regarding Hr. Gr was higher in patients with Ssc tears and significantly lower in patients with ASI. On the other hand, while LTr was low in patients with Ssc tears, it was high in patients with ASI. We defined LTGI to express these two parameters opposite to each other in terms of Ssc tear and ASI, with a single ratio. A low LTGI showed 93.1% sensitivity and 93.3% specificity for Ssc tears, while a high LTGI showed 86.7% sensitivity and 86.2% specificity for ASI. In healthy patients, the LTGI was between 1.99 and 2.24.

Hong et al. [6] defined the humeral containing angle. They accepted this angle as the angle between the lines drawn from the center of the humeral head to the anterior and posterior points of the glenoid in the axial section and showed that the angle was significantly lower in patients with anterior instability. Factors leading to a narrower angle are a low glenoid radius and high humerus radius. One of the problems related to the humeral containing angle described by Hong et al. is that in patients with anterior instability, there may be a bone defect in the anterior of the glenoid, and the humeral containing angle may be lower than in the control group because the glenoid anterior–posterior distance will decrease in the axial sections. In our study, the glenoid radius was measured with the most appropriate circle method in the sagittal plane. MRI measurements made using the circle method in calculating an accurate glenoid width and glenoid bone defects are as accurate as computed tomography (CT) evaluations, and for this purpose, MRI may even replace CT [11]. The second reason is that the angle was measured in a single slice, and in the patient's MR imaging acquisition position, the widest section of the humeral head and the section where the glenoid is widest may not be the same. In our study, the glenoid radius was measured in the sagittal section, and it was noted that the bone defect in patients with ASI did not have a reducing effect on the glenoid radius. We think that the measurement methods of Gr, Hr, and LTr are more reliable in terms of being performed on a single bone independently of each other in different sections.

Patients with Ssc tears and ASI are heterogeneous regarding age. We believe that in order to evaluate LTGI and LTHHI within homogeneous age groups, it is necessary to examine both pathologies individually in different studies. However, evaluating these pathologies together may provide a more understandable presentation of the effect of lesser tuberosity morphology on Ssc tears and ASI. The effect of increased LTGI due to decreased glenoid radius in patients with recurrent dislocations and glenoid bone defect on ASI recurrence or surgical treatment success in ASI patients may be the subject of further studies.

Although power and ROC analyses indicate sufficient sample sizes, the relatively low number of patients due to the wide exclusion criteria is a limitation. The control group being selected from patients with normal radiological images, having no loss of shoulder function on examination, and nonspecific shoulder pain that did not show a specific shoulder pathology, such as rotator cuff rupture and ASI, can be regarded as a limitation too. Another limitation is that the study was retrospective despite the prospective data collection. Future studies investigating the relationships between shoulder pathologies and tuberculum minus, humeral head, and glenoid distance measurements using 3D imaging may reveal better results.

Conclusion

LTGI may be a new predictive factor showing 93.1% sensitivity and 93.3% specificity for Ssc tears at values less than 1.99, and 86.7% sensitivity and 86.2% specificity for anterior shoulder instability at values greater than 2.24. In addition, LTHHI may be a new predictive factor providing 82.8% sensitivity and 80.1% specificity for Ssc tears at values less than 1.17.

Funding No funding was obtained for this study.

Declarations

Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval Ethical approval was obtained from "Necmettin Erbakan University Ethical Committee" (Ref no: 2022-3574)

Informed consent Informed consent was obtained from all patients that their radiological images would be used for scientific purposes in accordance with the decision of the university ethics committee.

References

1. Altan E, Adas M, Tonbul M, Orman O (2011) Functional results of arthroscopic bankart repair of traumatic recurrent shoulder instability patients. Selcuk Med J 27(4):219–220
2. Bergin D, Parker L, Zoga A, Morrison W (2006) Abnormalities on MRI of the subscapularis tendon in the presence of a full-thickness supraspinatus tendon tear. Am J Roentgenol 186(2):454–459. https://doi.org/10.2214/ajr.04.1723
3. Bigliani LU, Ticker JB, Flatow EL, Soslowsky LJ, Mow VC (1991) Relationship of acromial architecture to rotator cuff disease. Clin Sports Med 10:823–838
4. Brunkhorst JP, Giphart JE, Laprade RF, Millett PJ (2013) Coracohumeral distances and correlation to arm rotation: an in vivo 3-dimensional biplane fluoroscopy study. Orthop J Sports Med 1:23–23. https://doi.org/10.1177/2325967113496059
5. Çetinkaya M, Ataoglu MB, Ozer M, Ayanoglu T, Kanatlı U (2017) Subscapularis tendon slip number and coracoid overlap are more related parameters for subcoracoid impingement in subscapularis tears: a magnetic resonance imaging comparison study. Arthroscopy 33:734–742. https://doi.org/10.1016/j.arthro.2016.09.003
6. Hong J, Huang Y, Ma C, Qu G, Meng J, Wu H et al (2018) Risk factors for anterior shoulder instability: a matched case-control

study. J Shoulder Elb Surg 28:869–874. https://doi.org/10.1016/j.jse.2018.09.014

7. Ide J, Tokiyoshi A, Hirose J, Mizuta H (2007) Arthroscopic repair of traumatic combined rotator cuff tears involving the subscapularis tendon. J Bone Jt Surg Am 89:2378–2388. https://doi.org/10.2106/jbjs.g.00082
8. Jacxsens M, Elhabian SY, Brady SE, Chalmers PN, Tashjian RZ (2019) Henninger HB coracoacromial morphology: a contributor to recurrent traumatic anterior glenohumeral instability? J Shoulder Elb Surg. 28(7):1316-1325.e1. https://doi.org/10.1016/j.jse.2019.01.009
9. Kompel AJ, Li X, Guermazi A, Murakami AM (2017) Radiographic evaluation of patients with anterior shoulder instability. Curr Rev Musculoskelet Med 10(4):425–433. https://doi.org/10.1007/s12178-017-9433-4
10. Kroner K, Lind T, Jensen J (1989) The epidemiology of shoulder dislocations. Arch Orthop Trauma Surg 108:288–290. https://doi.org/10.1007/bf00932317
11. Lee RK, Griffith JF, Tong MM, Sharma N, Yung P (2013) Glenoid bone loss: assessment with MR imaging. Radiology 267:496–502
12. Leite MJ, Sa MC, Lopes MJ, Matos RM, Sousa AN, Torres JM (2019) Coracohumeral distance and coracoid overlap as predictors of subscapularis and long head of the biceps injuries. J Shoulder Elb Surg 28(9):1723–1727. https://doi.org/10.1016/j.jse.2019.01.012
13. Lo IK, Burkhart SS (2003) The etiology and the assessment of subscapularis tendon tears: a case for subcoracoid impingement, the roller-wringer effect, and TUFF lesions of the subscapularis. Arthroscopy 19:1142–1150. https://doi.org/10.1016/j.arthro.2003.10.024
14. Lopez CD, Ding J, Bixby EC, Lobao MH, Heffernan JT, Levine WN et al (2020) Association between shoulder coracoacromial arch morphology and anterior instability of the shoulder. JSES Int 4(4):772–779. https://doi.org/10.1016/j.jseint.2020.07.013
15. MacMahon P, Taylor D, Duke D, Brennan D, O'Brienj D, Eustace S (2007) Contribution of full-thickness supraspinatus tendon tears to acquired subcoracoid impingement. Clin Radiol 62:556–563. https://doi.org/10.1016/j.crad.2007.01.004
16. Moroder P, Ernstbrunner L, Pomwenger W, Oberhauser F, Hitzl W, Tauber M, Resch H, Moroder R (2015) Anterior shoulder instability is associated with an underlying deficiency of the bony glenoid concavity. Arthroscopy 31:1223–1231. https://doi.org/10.1016/j.arthro.2015.02.009
17. Owens BD, Campbell SE, Cameron KL (2014) Risk factors for anterior glenohumeral instability. Am J Sports Med 42:2591–2596. https://doi.org/10.1177/0363546514551149
18. Owens BD, Duffey ML, Nelson BJ, DeBerardino TM, Taylor DC, Mountcastle SB (2007) The incidence and characteristics of shoulder instability at the United States Military Academy. Am J Sports Med 35(1168–73):10. https://doi.org/10.1177/0363546506295179
19. Radas CB, Pieper HG (2004) The coracoid impingement of the subscapularis tendon: a cadaver study. J Shoulder Elb Surg 13:154–159. https://doi.org/10.1016/j.jse.2003.12.007
20. Saygi B, Karahan N, Karakus O, Demir AI, Ozkan OC, Soylu-Boy FN (2018) Analysis of glenohumeral morphological factors for anterior shoulder instability and rotator cuff tear by magnetic resonance imaging. J Orthop Surg (Hong Kong) 26(2):2309499018768100. https://doi.org/10.1177/2309499018768100
21. Seo JB, Kim SJ, Ham HJ, Kwak KY, Yoo J (2020) New predictors for subscapularis tear: coraco-lesser tuberosity angle, lesser tuberosity angle, and lesser tuberosity height. OrthopTraumatol Surg Res 106(1):45–51. https://doi.org/10.1016/j.otsr.2019.10.017
22. Sugaya H, Moriishi J, Dohi M, Kon Y, Tsuchiya A (2003) Glenoid rim morphology in recurrent anterior glenohumeral instability. J Bone Jt Surg Am 85-A:878–884. https://doi.org/10.2106/00004623-200305000-00016
23. Tollemar VC, Wang J, Koh JL, Lee MJ (2020) Shi LL Coracoid morphology is not associated with subscapularis tears. J Shoulder Elb Surg 29:1162–1167. https://doi.org/10.1016/j.jse.2019.11.008
24. Watson AC, Jamieson RP, Mattin AC, Page RS (2019) Magnetic resonance imaging based coracoid morphology and its associations with subscapularis tears: a new index. Shoulder Elb 11:52–58. https://doi.org/10.1177/1758573217744170