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ORIGINAL ARTICLE

Volumetric Analysis of Subacromial Space After Superior Capsular Reconstruction for Irreparable Rotator Cuff Tears

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Abstract

Purpose Subacromial volume measurement on magnetic resonance images is relatively new. It has been shown that decreased subacromial volume increases after surgical repair of full-thickness rotator cuff tears. There is no study examining subacromial volume changes after superior capsular reconstruction (SCR). The purpose of this study was to compare subacromial volume changes on magnetic resonance images (MRI) after superior capsular reconstruction performed for primary irreparable rotator cuff tears.

Methods Patients who underwent an SCR procedure between 2017 and 2019 with a minimum 2-year postoperative follow-up were included in this retrospective study. Subacromial volume was measured on MRI using software. The preoperative and postoperative acromiohumeral distance, Constant Scores, graft thickness, and Hamada grades of the patients were evaluated.

Results A total of 18 patients with a mean age of 59.7 years (range: 49–74 years) underwent an SCR for massive irreparable cuff tear. The mean preoperative subacromial volume was 3.54 ± 0.39 cm^3 (range 2.88–4.36 cm^3), which increased to 4.46 ± 0.39 cm^3 (range 3.75–5.32 cm^3) postoperatively ($p = < 0.001$). The increase in subacromial volume and acromiohumeral distance did not correlate with Constant scores and graft thickness. We observed a significantly higher subacromial volume increase among Hamada grade 1 patients, compared to those with Hamada grade 2 ($p = 0.011$).

Conclusions We observed that subacromial volume significantly increased after superior capsular reconstruction. However, the increase in subacromial volume did not correlate with clinical scores, acromiohumeral distance changes, or graft thickness.

Level of evidence: Level III – Retrospective Cohort Study.

Keywords Rotator cuff tear · Massive · Irreparable · Superior capsular reconstruction · Fascia lata

Introduction

Rotator cuff tears are common in the elderly [1, 2]. Massive tears account for 10–40% of all rotator cuff tears in different reports [3]. A massive rotator cuff tear is defined as a tear with a diameter of ≥ 5 cm or the complete detachment of two or more tendons [4, 5]. Surgical treatment of massive rotator cuff tears is challenging. Advanced age, large tears, tendon retraction, and fatty degeneration are well-known risk factors for re-rupture after surgical repair

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of massive rotator cuff tears [6, 7]. In case of retraction of the rotator cuff tendons beyond the glenoid and fatty infiltration of the rotator cuff muscles more than Goutallier grade 2, the rotator cuff tear is more likely to be irreparable [8]. Burkhart et al. stated that if the rotator cuff tendon tear edges do not reach the humeral footprint after adequate releases and interval slides intraoperatively, the tear was considered irreparable [9].

There are several treatment options for irreparable rotator cuff tears, including arthroscopic debridement, partial repair, interval slides, allograft augmentation, muscle transfers and reverse total shoulder arthroplasty [3]. However, these techniques have several limitations. In 2013, Mihata et al. reported the clinical results of a novel joint sparing procedure called the "superior capsular reconstruction" (SCR) [10]. In this technique, a fascia lata autologous graft was taken from the patient's thigh and transferred to the patient's shoulder arthroscopically. The graft was fixed between the superior glenoid rim and the rotator cuff footprint tuberculum majus. From that date, the procedure gained popularity worldwide and several reports showed favorable outcomes [11–15].

The philosophy of SCR was mainly based on creating a biological barrier to prevent the superior migration of the humeral head [9]. This biological barrier was designed to stabilize the humeral head during the range of motion and optimize the force couples of the shoulder [16]. Furthermore, this construct was designed to increase the acromiohumeral distance (AHD) by depressing the humeral head [17]. It has been shown that AHD decreases after full-thickness rotator cuff tears [18]. In addition, many authors report that AHD increases after primary rotator cuff repair and may be used for clinical follow-up as a prognostic indicator [19–21]. In 2018, Pepe et al. measured subacromial volume on MRI images in three dimensions via software and showed an increase in subacromial volume after primary rotator cuff repairs [22]. However, Yi et al. could not find a correlation between rotator cuff tears and subacromial volume measurement [23]. Volumetric analysis of the subacromial space on MRI images is a relatively new topic and conflicting results of the previous studies may lead to a new debate. To the best of our knowledge, there is not a single study investigating subacromial volume changes after superior capsular reconstruction in the literature. In this study, we aimed to evaluate the volumetric changes in subacromial space after superior capsular reconstruction. Secondarily, we aimed to assess the relationship between subacromial volume increase and clinical scores, AHD changes, and graft thickness. We hypothesized that subacromial volume may increase after superior capsular reconstruction and this increase may be significantly related to clinical scores, AHD changes, and graft thickness.

Materials and Methods

Study Population

This retrospective study was performed under the approval of our institutions' ethical review board and conducted per the Declaration of Helsinki. Written consent was obtained for each patient. The clinical and radiographic data of patients who underwent an SCR between 2017 and 2019 were retrospectively reviewed. Patients with a minimum follow-up of 2 years and Hamada grades 1 and 2 who underwent primary SCR were included in this study. Patients who underwent a secondary SCR for failed rotator cuff repair, additional acromioplasty, and those with incomplete follow-up were excluded (Fig. 1).

The indication for SCR was an irreparable posterosuperior rotator cuff tear with an intact or reparable subscapularis tendon. We routinely did not perform SCR if the subscapularis tendon was not intact, and the patient had a Hamada grade 3, 4, or 5 shoulder. Arthroscopic SCR procedure with tensor fascia autograft was performed under general anesthesia as described by Mihata et al. [10] in their original article (Fig. 2).

Clinical and Radiographic Evaluation

An abduction brace was used for shoulder immobilization for 6 weeks. Pendulum and passive ROM exercises were started at the 2nd postoperative week. Patients were allowed to actively exercise at the 6th postoperative week. They were called for follow-up visits at the 2nd week, 6th week, 3rd month, 6th month, and the 12th month postoperatively and annually thereafter. Pseudoparalysis was noted preoperatively and during follow-ups. Constant scores were calculated by a physician preoperatively and at the latest follow-up. All complications were recorded.

The shoulder's Hamada and Goutallier classifications were evaluated through radiographs and MRIs, respectively. On plain anteroposterior x-ray images, AHD was measured as the narrowest distance between the acromion edge and the humeral head.

MRI Volume Measurement

MRI was performed with a 1.5 T MR-Scanner (Magnetom Aera, Siemens AG, Erlangen, Germany) with the patient in supine position with the arm at the side, hand palm facing upward to prevent shoulder motion. Coronal, sagittal, and axial T1-weighted images were acquired for structural assessment of the acromion and humeral head; T2-weighted images were acquired for qualitative

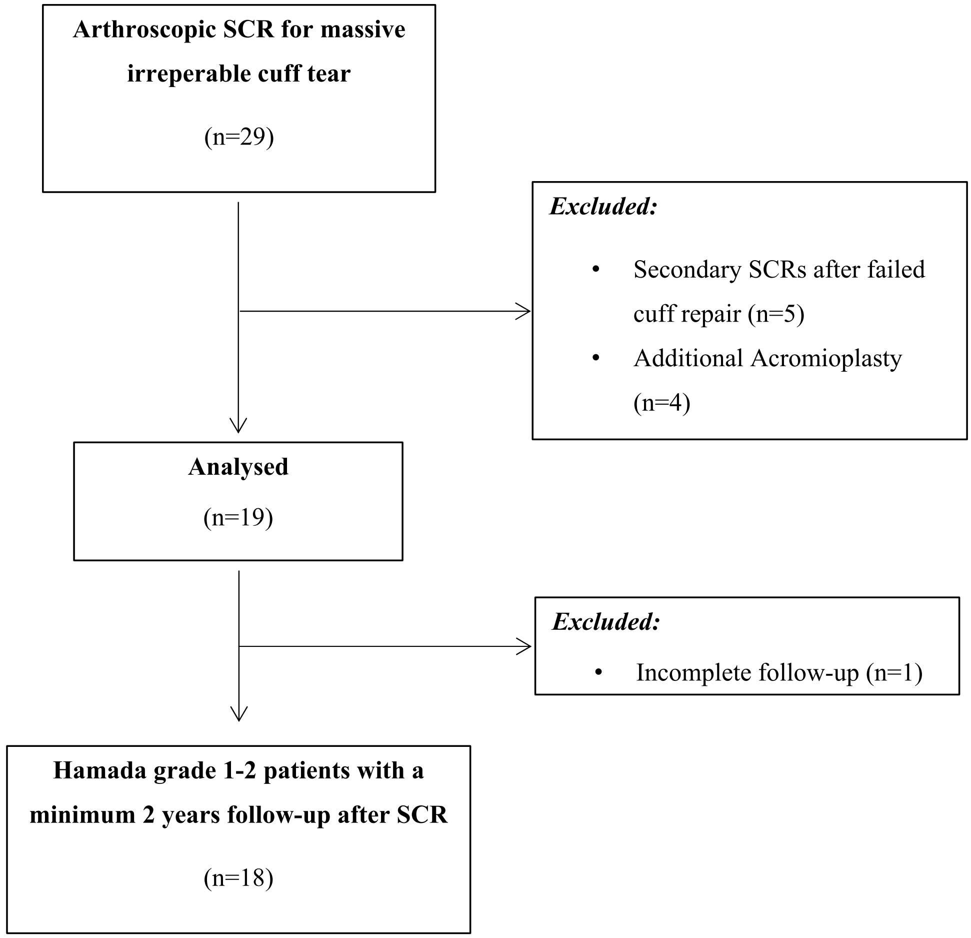

Fig. 1 Flowchart diagram of the study

assessment of the rotator cuff tendon. The slice thickness was 4 mm (Fig. 3).

Subacromial volume was calculated with the Osirix software (Pixmeo, Geneva, Switzerland). This is a specialized software that enables measurements like distance, area, and volume on radiologic images such as MRI. To measure subacromial volume, T1-weighted sagittal images, which better show the bony tissue borders, were used. The area between the acromion and the chondral surface of the humeral head was outlined using the pencil tool on serial sagittal T1-weighted images from the acromial tip to the acromioclavicular joint (Fig. 4). Then, the software computed the volume automatically in cm^3. Postoperative MRIs were performed 1 year after the surgery to evaluate graft integrity. Measurements were done by two authors and repeated by the same authors 1 week after the first measurement. Inter-rater reliability and intraclass coefficient correlations (ICCs) were used to assess reliability. Intra-observer and inter-observer correlation coefficient were 0937 and 0.906, respectively, for subacromial volume measurement and 0962 and 0945, respectively, for AHD.

Statistical Analysis

Statistical analyses were performed using the SPSS 26.0 (*SPSS Inc.*, Chicago, USA). The Kolmogorov–Smirnov test was used to determine whether the data were normally distributed. The paired sample t-test was used to compare continuous data. Bivariate correlation analysis was performed to compare the change in outcome scores with changes in subacromial volume and AHD. Linear regression analysis was utilized to compare the graft measurement with changes in outcome scores and AHD. A p-value lower than 0.05 was considered statistically significant.

Results

There were 18 patients (9 females, 9 males) with a mean age of 59.7 ± 7.5 (range: 49–74 years). Eleven patients were operated on the right and 7 patients, on the left. The mean follow-up time was 25.3 months (range: 24–29 months). The mean preoperative subacromial volume was 3.54 ± 0.39 cm^3 (range 2.88–4.36 cm^3), which increased to 4.46 ± 0.39

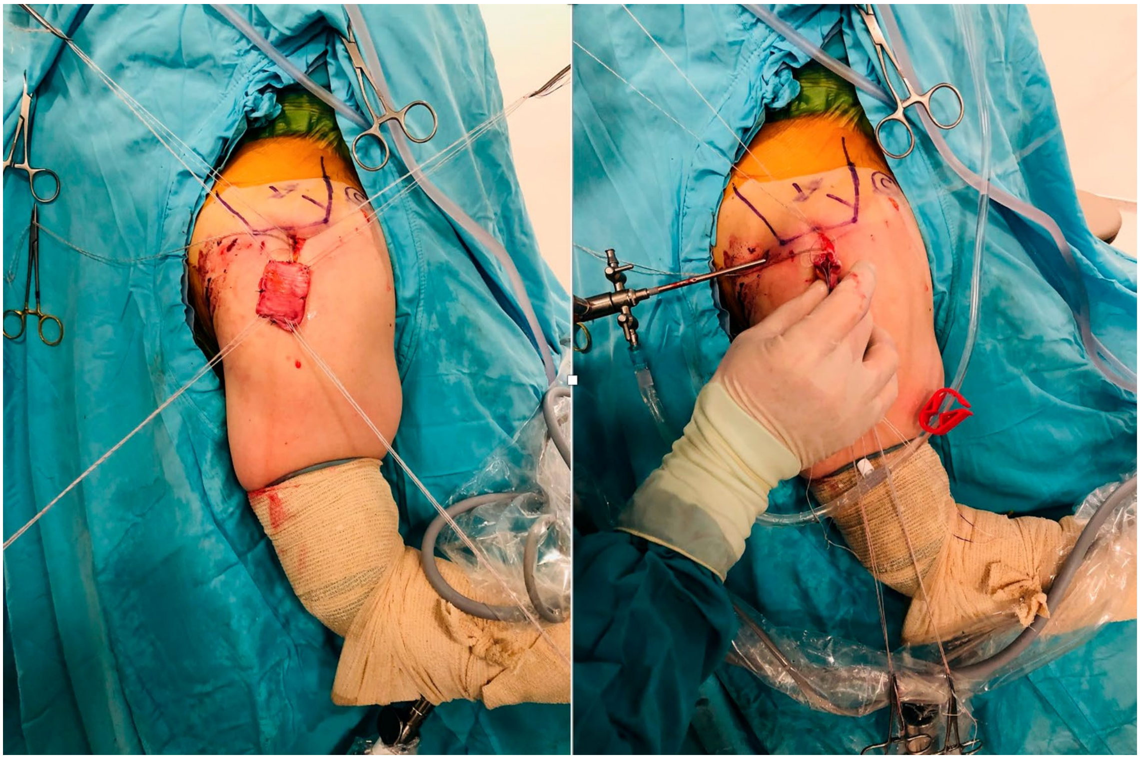

Fig. 2 Intraoperative images of the introduction of the fascia lata autograft into the subacromial space

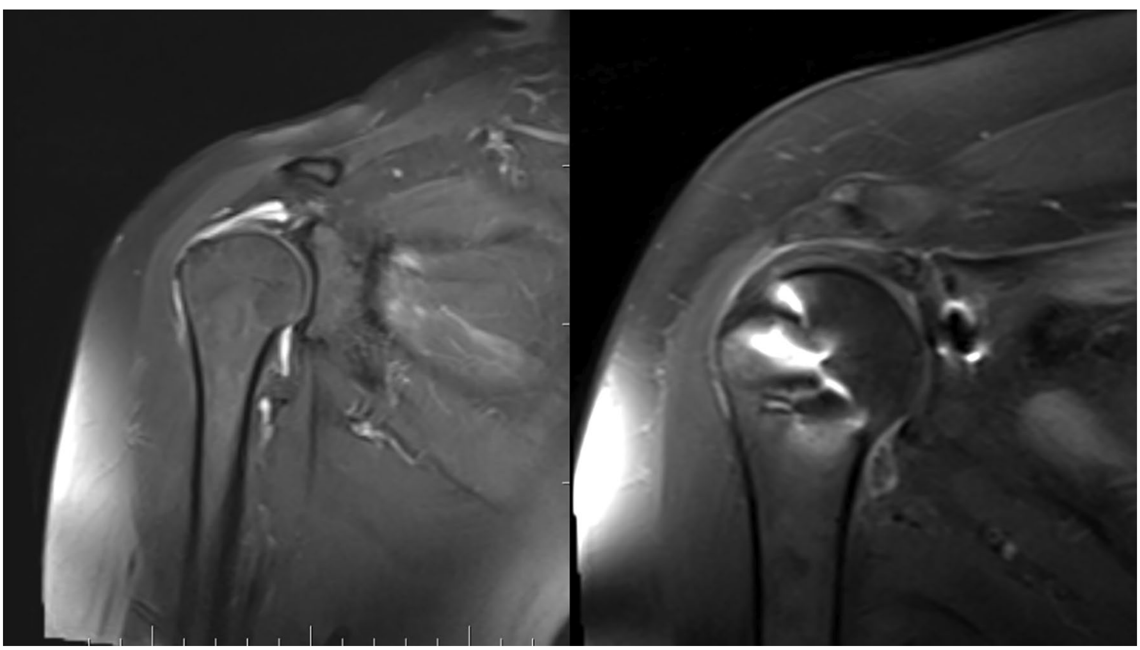

Fig. 3 Preoperative (left) and postoperative (right) MRI of the patient who underwent an SCR procedure

cm^3 (range 3.75–5.32 cm^3) at 2 years postoperatively ($p = < 0.001$). The pre-and postoperative mean AHDs were 6.11 ± 2.35 mm (range: 3–11 mm) and 10.3 ± 1.88 mm (range: 7–13 mm), respectively ($p = < 0.001$). The mean change in AHD was 4.22 ± 1.51 mm (range: 2–6 mm). The preoperative and postoperative mean Constant scores were

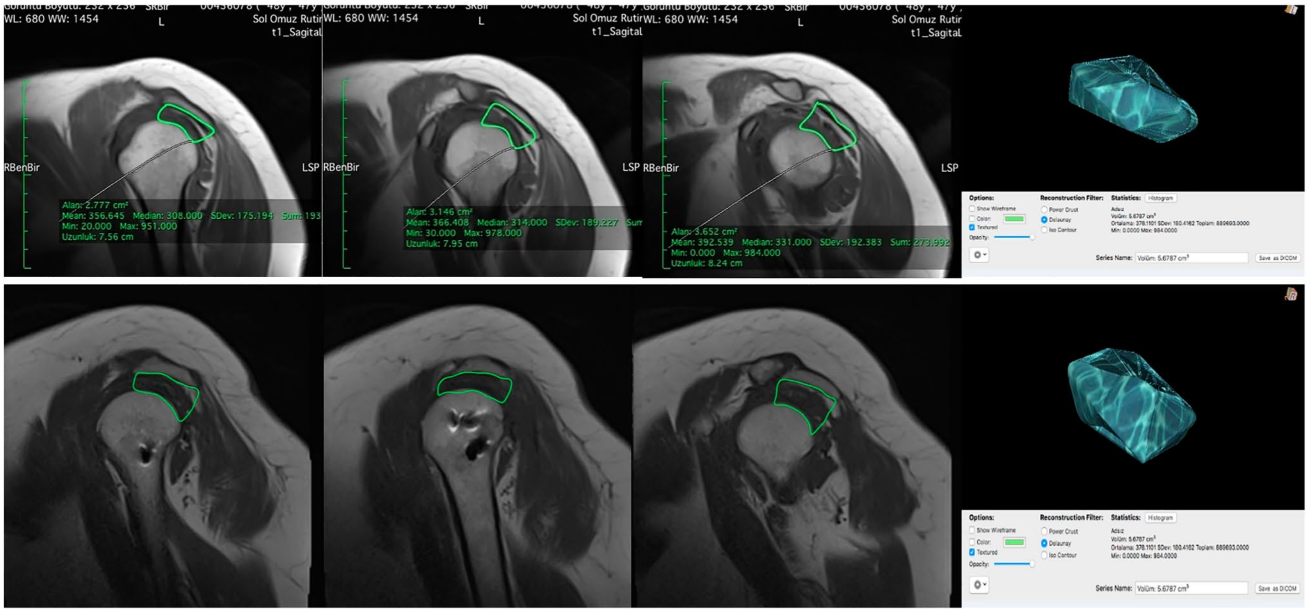

Fig. 4 Subacromial volume measurement technique on MRI. The images demonstrate the subacromial volume measurements on the preoperative (upper row) and postoperative (bottom row) MRIs

39.5 ± 10.6 points (range: 21–55 points) and 83.3 ± 7.4 points (range: 72–93 points), respectively ($p = < 0.001$) (Table 1).

The mean fascia lata graft thickness was 6.55 ± 1.29 mm (range: 5–8 mm). According to the linear regression analysis, there was no significant correlation between graft thickness and Constant score difference ($p = 0.057$, $r = 0.209$). However, there was a moderately significant correlation between graft thickness and AHD change ($p = 0.04$, $r = 0.473$). According to the bivariate correlation analysis, Constant score and subacromial volume ($p = 0.836$), Constant score and AHD change ($p = 0.190$), and subacromial volume change and AHD change ($p = 0.419$) were not correlated.

The mean changes in AHD in Hamada grade 1 and grade 2 patients were 4.00 ± 1.59 mm and 4.66 ± 1.36 mm, respectively ($p = 0.396$). There were no significant differences between the Hamada grade 1 and grade 2 patients in terms of Constant score changes ($p = 0.802$), as well. However, the mean change in subacromial volume in Hamada grade 1 patients was significantly higher than that of Hamada grade 2 patients (116 vs 0.46 cm3, $p = 0.011$).

We did not observe any graft failures after the SCR procedure and none of the patients required revision procedure. One patient had chronic seroma formation at the 2nd postoperative week and was treated with debridement. Pseudoparalysis was evident in six patients before the surgery. All patients with pseudo-paralysis recovered and achieved forward flexion more than 90° during the first postoperative 10 weeks.

Discussion

The subacromial volume was significantly increased in patients who underwent SCR procedure for irreparable rotator cuff tear, which was the most significant finding of this study. However, the increase in subacromial volume is not correlated with graft thickness or the patients' clinical scores. Our null hypothesis can be partially accepted since we observed a significant increase in subacromial volume; however, this increase was not correlated with patients' clinical scores, AHD distances, and graft thickness. Yi et al. measured subacromial volume using MRIs and compared the results between the patients with partial, complete, or intact (control group) rotator cuffs [23]. The authors reported that there was no significant difference between the control group and patients with partial or full-thickness tears. Pepe et al. evaluated the subacromial volumetric changes after primary rotator cuff repairs [22]. They found that subacromial volume increases after primary single-row rotator cuff repairs and clinical scores are not related to the change in subacromial volume.

Graft type and thickness are issues of controversies for superior capsular reconstruction in the literature [24]. Mihata et al. originally described this technique using large fascia lata grafts. In their biomechanical study on cadaver shoulders, the authors observed that both 4 mm and 8 mm fascia lata grafts decreased subacromial peak contact pressure, but only 8 mm grafts decreased superior translation of the humeral head [25]. To date, there is no study evaluating clinical outcomes with different fascia lata graft thicknesses

Table 1 Clinical and radiographic data of the patients

Patient	Age	Gender	Hamada classification	Goutallier classification	Preop volume (cm3)	Postop volume (cm3)	Preop constant score	Postop constant score	Preop pseudo-paralysis	Postop pseudo-paralysis	Graft thickness (mm)	Preop AHD (mm)	Postop AHD (mm)
1	51	F	1	3	288	533	37	78	(−)	(−)	8	6	10
2	61	M	1	4	333	468	29	75	(+)	(−)	7	6	11
3	53	F	1	3	310	453	53	88	(−)	(−)	5	11	13
4	50	F	1	4	368	508	21	90	(+)	(−)	5	8	10
5	60	M	2	3	344	424	34	72	(+)	(−)	8	3	8
6	61	F	2	4	357	375	45	87	(−)	(−-)	7	4	7
7	61	M	2	3	357	402	39	89	(−)	(−)	6	4	10
8	74	F	1	2	376	497	43	78	(−)	(−)	8	6	12
9	68	M	1	3	302	414	55	93	(−)	(−)	5	7	12
10	51	F	1	3	313	447	37	78	(−)	(−)	8	6	10
11	61	M	1	4	357	403	29	75	(+)	(−)	7	6	11
12	53	F	1	3	415	497	53	88	(−)	(−)	5	11	13
13	49	M	1	4	359	476	21	90	(+)	(−)	5	8	10
14	60	M	2	3	337	422	34	72	(+)	(−)	8	3	8
15	61	F	2	4	398	412	45	87	(−)	(−)	7	4	7
16	61	F	2	3	437	471	39	89	(−)	(−)	6	4	10
17	72	M	1	2	347	437	43	78	(−)	(−)	8	6	12
18	68	M	1	3	379	404	55	93	(−)	(−)	5	7	12

F female, *M* male, *AHD*:acoromio-humeral distance in the literature. In our study, graft thickness was not correlated with clinical outcomes. However, we have a small patient population, and this issue should be investigated in larger cohorts. On the other hand, dermal and newer fascia lata allografts are being employed for superior capsular reconstruction; however, there is not enough evidence favoring any graft type or diameter [26].

Acromiohumeral distance was believed to be a predictor and prognostic factor for rotator cuff tears [18]. However, there was no correlation between clinical scores and AHD changes despite the significant improvement in AHD. In addition, AHD was not correlated with subacromial volume changes. We only demonstrated a mild correlation between graft thickness and AHD changes. AHD measurement was performed on two-dimensional X-ray images, however, subacromial volume measurement was performed on three-dimensional MRI images. This may be the reason why we were unable to reveal a correlation between AHD and subacromial volume changes. This may also explain why there were no clinical differences between Hamada grade 1 and 2 patients, because the Hamada grading involves AHD. The fact that there was not a correlation between Constant scores, AHD, and volumetric changes may be explained by the fact that radiographic measurements were performed under an immobile joint position. However, the fascia lata graft may work as a dynamic stabilizer of the shoulder joint and the true effect of superior capsular reconstruction may be demonstrated with shoulder motion. Several studies revealed that there was no evidence for the reliability of radiographic methods for measuring AHD with non-standardized anteroposterior radiographs [27, 28]. Gruber et al. showed that a standardized anteroposterior radiograph technique is required for reliable measurement of the AHD [29]. These findings led the researchers to investigate more reliable methods for measuring the AHD. Many authors employed MRI, computerized tomography, and ultrasound for measuring the AHD. In our study, inter-rater and intra-rater correlation coefficients were above 0.70 for both AHD and subacromial space volume measurements. The high correlation coefficients in the current study may demonstrate that the measurement of subacromial volume with a software may be an easy and reliable method for measuring changes.

In our study, we observed an increase in subacromial volume and AHD after superior capsular reconstruction. However, the amount of the increase in subacromial volume and AHD was not related to the functional outcomes. This may be attributed to the fact that subacromial volume and AHD measurements were performed at a certain shoulder position. However, superior capsular reconstruction may mainly influence the dynamic stability of the humeral head. The dynamic stability effect of superior capsular reconstruction and its relationship with clinical outcomes may be investigated with further studies.

The major limitation of this study was its small patient population. However, we evaluated a relatively specific and homogeneous patient population that was treated by the same team and by the same protocol. Other limitations included its retrospective design and the lack of a control group. Ours is the first study evaluating subacromial volume with a simple and reliable method after the SCR procedure, and the first study in the literature investigating the relationship between graft thickness, clinical scores, and subacromial volume. Further well-designed studies in larger cohorts are needed to reach a higher level of evidence about the effect of subacromial volume and graft thickness and its relationship with clinical and radiographic outcomes.

Conclusions

According to our results, subacromial volume significantly increased after superior capsular reconstruction. However, the increase in subacromial volume was not correlated with clinical scores, acromiohumeral distance change, or graft thickness.

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Data availability The data that support the findings of this study are available on request from the corresponding author, [Y.O.K.]. The data are not publicly available due to (restrictions e.g. their containing information that could compromise the privacy of research participants).

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical approval This study was performed under the approval of Ankara Education and Research Hospital Ethical Review Board. (ID number: E-20/427-01.10.2020).

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