10. Hasil Uji similaritas Preoperative magnetic resonance imaging

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Preoperative magnetic resonance imaging rotator cuff tendon stump classification correlates with the surgical outcomes following superior capsular reconstruction

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Hypothesis: This study aimed to investigate the correlation between rotator cuff stump classification and postoperative outcomes after superior capsular reconstruction (SCR).
Methods: A total of 75 patients who underwent SCR between June 2013 and May 2021 were included in this study. Based on stump classification using the signal intensity ratio of the tendon rupture site to the deltoid muscle in the coronal view of preoperative T2-weighted, fat-suppressed magnetic resonance imaging scans, the patients were classified into types 1, 2, and 3 with ratios of <0.8, 0.8–1.3, and >1.3 (44, 17, and 14 patients, respectively). The American Shoulder and Elbow Surgeons (ASES), Constant, and visual analog scale (VAS) scores for pain and range of motion were evaluated at a minimum of 1 year of follow-up postoperatively. The acromiohumeral distance and rotator cuff arthropathy according to the Hamada classification were assessed on plain radiography. The graft integrity was evaluated by magnetic resonance imaging at 3 and 12 months postoperatively and annually thereafter.
Results: Clinical and radiological outcomes were significantly improved after SCR. In comparison with type 2 and 3 patients, type 1 patients had significantly higher ASES scores (type 1, 2, and 3 = 84 ± 10, 75 ± 15, and 76 ± 14; all $P = .014$), Constant scores (type 1, 2, and 3 = 65 ± 5, 61 ± 9, and 56 ± 13; all $P = .005$), and forward flexion (type 1, 2, and 3 = 155 ± 10, 154 ± 15, and 145 ± 13; all $P = .013$). However, these statistical differences between groups were below the established minimum clinically important difference values for the ASES and Constant scores after rotator cuff repair. The graft failure rate after surgery was lower in the type 1 group than that in the other 2 groups; however, the difference was not statistically significant ($P = .749$).
Conclusion: Patients with stump classification type 1 showed significantly better functional scores (ASES and VAS scores) and forward flexion; however, the clinical importance of these differences may be limited. Stump classification may be useful for predicting postoperative clinical outcomes.
Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Keywords: Superior capsular reconstruction; massive rotator cuff tear; stump classification; advanced glycation end-products; magnetic resonance imaging signal intensity of the stump; fascia lata autograft

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Rotator cuff (RC) injuries are the most common reason for shoulder pain and disability,[12] and most injuries are caused by age-related degeneration.[32] As introduced by Mihata et al in 2013, arthroscopic superior capsular reconstruction (SCR) has been developed for the treatment of irreparable RC tear (RCT).[22] In SCR, the superior capsule plays the role of a static stabilizer, allowing for the centering of the humeral head.[4] SCR has been demonstrated to restore the stability of the shoulder joint and contribute to improved outcomes.[2,21,37] However, patients are thought to have incomplete recovery of the dynamic function of the shoulder joint because the anatomy of the supraspinatus (SSP) tendon is not restored in conventional SCR.[29]

The SSP tendon dynamically stabilize the shoulder.[29] Cabarcas et al found that restoration of the dynamics of the SSP tendon during SCR could contribute to optimal shoulder function.[8] Recently, Li et al found that suturing the remnant SSP tendon to the fascia lata autograft during conventional SCR could restore the SSP tendon's dynamic force, which resulted in superior clinical outcomes compared with those of conventional SCR alone.[29] Previous studies also demonstrated that the quality of the remaining RC tissue could affect the shoulder muscle balance.[5-7,27] Furthermore, Kijowski et al reported that the preoperative severity of torn tendon degeneration on fat-suppressed T2-weight magnetic resonance imaging (MRI) was correlated with postoperative clinical outcomes.[23] Overall, the quality of the remnant SSP tendon appeared to affect clinical outcomes after SCR.

Ishitani et al developed a three-type stump classification using the signal intensity ratio between the torn tendon site and the deltoid muscle in the coronal view of T2-weighted, fat-suppressed (T2W-FS) MRI scans as an indicator of RC tendon degeneration.[18] This classification has also been demonstrated to positively correlate with advanced glycation end-product (AGE) accumulation and inflammation, which could reflect stump quality.[36]

Given the existing findings, the quality of the remnant SSP tendon, as indicated by the MRI classification, may be associated with clinical outcomes after suturing the remnant SSP tendon to the fascia lata autograft during conventional SCR. This study aimed to investigate the correlation between stump classification and clinical outcomes after SCR. A lower stump classification, which indicated better tendon quality, was hypothesized to be correlated with better clinical outcomes.

Methods

Patient enrollment

This retrospective case-control study investigated the correlation between stump classification and clinical outcomes after SCR, and institutional review board approval was obtained (No. 2022-1682) before this study was performed. From June 2013 to May 2021, data from patients who underwent arthroscopic SCR were retrospectively reviewed. Between June 2013 and September 2016, an isolated fascia lata autograft was used for the patients, and a fascia lata with mesh augmentation was used between September 2016 and May 2021. The graft preparation technique was altered according to the operating surgeon's investigation of the preliminary outcome.[22] A total of 124 consecutive patients underwent SCR performed by a single senior surgeon (I.H.J.). The inclusion criteria were as follows: (1) diagnosis of an irreparable RCT with (A) greatest tear size >5 cm, (B) complete tear of ≥2 tendons, or (C) ≥ Patte grade 3 retraction on a preoperative MRI scan[26]; (2) an irreparable RCT confirmed under arthroscopy as being irreducible to its anatomic footprint; and (3) available preoperative coronal view of T2W-FS MRI scans within 6 months. The exclusion criteria were as follows: (1) severe bone deformity (Hamada grade 5)[16]; (2) irreparable subscapularis tendon tear; (3) previous ipsilateral shoulder surgery; and (4) < 1 year of follow-up. The following patients were excluded: those without a preoperative coronal view of T2W-FS MRI scans (n = 18), those with time from preoperative MRI to surgery >6 months (n = 4), those with previous ipsilateral shoulder surgery (n = 11), and those lost to 1-year clinical and/or radiological follow-up (n = 16). Finally, 75 patients were included in the analysis.

Surgical technique and postoperative protocol

Surgical preparation

After general anesthesia, all patients underwent SCR in a beach chair position. The size and configuration of the massive RCT were confirmed through a lateral portal under diagnostic arthroscopy. After the RCT was confirmed to be irreparable, routine procedures were performed as follows: débridement, acromioplasty, measurement of the defect size, and long-head biceps tenotomy, if required.

Graft preparation

The RCT defect size was measured using an arthroscopic ruler under arthroscopy. The fascia lata was harvested from the ipsilateral thigh at least twice the length of the RCT and prepared on a back table by the assisting surgeon. A single-layer polypropylene mesh (Prolene Mesh; Ethicon Inc.) was fashioned between the folded fascia lata, and a running stitch was performed to seal the graft margin using a 2–0 polyester suture (Ethibond).[3]

Graft fixation

On the glenoid side, 3 suture anchors (1.9 mm Suturefix Ultra anchor; Smith & Nephew) were used to fix the graft. At the medial row of the footprint, 2 polyetheretherketone threaded suture anchors (4.5 mm Healicoil; Smith & Nephew) were used for graft fixation. The remaining RC tendon was partially fixed on top of the fascia lata autograft as a routine procedure for all cases, and the bursa tissue was fixed using the remaining sutures of each limb from the medial row. Finally, all sutures were fixed laterally in the humeral metaphysis using 2 lateral row anchors (4.5 mm FOOTPRINT Ultra; Smith & Nephew). All graft fixation procedures were performed at 30° of shoulder abduction.

Postoperative rehabilitation

A 30° abduction brace was used for immobilization for 6 weeks, and the patients were required to perform pendulum exercises for 3 weeks postoperatively. Under the supervision and instruction of a dedicated physical therapist, all patients started periscapular strengthening exercises 3 months postoperatively.

Outcome measurements

The patients' active forward flexion and external rotation were assessed using a manual goniometer before and after SCR. For internal rotation, we determined the highest level that a patient could reach with the thumb and recorded it using a numbering method as previously described: 1 to 12 for the 1st to 12th thoracic vertebrae, 13 to 17 for the 1st to 5th lumbar vertebrae, and 18 for the level below the sacral vertebrae.[40] The preoperative and postoperative visual analog scale (VAS) scores,[45] American Shoulder and Elbow Surgeons (ASES) score,[34] and Constant score[11] were assessed before and after SCR. All outcomes were recorded at the latest follow-up.

The acromiohumeral distance (AHD) was calculated on anteroposterior plain radiographs,[43] and the stage of RC arthropathy was evaluated according to the Hamada classification.[27] Follow-up MRI was performed with a 3-T machine (Achieva; Philips Healthcare) at 3 and 12 months after surgery to assess healing and the integrity of the graft, and complete discontinuity of the graft was recorded as graft failure. The integrity of the connection between the stump and graft was evaluated according to the classification of Sugaya et al[39]; types IV and V were regarded as tears. On MRI, the global fatty degeneration index was used to assess the fatty infiltration of the RC muscles,[15] and the Patte classification was used to assess RC retraction.[45] Stump classification was assessed using the technique described by Ishitani et al[18] The signal intensity of the RC tendon stump (C) and deltoid muscle (D) was calculated on preoperative T2W-FS MRI using the oblique coronal image plan. The C/D ratio was calculated as the mean value for 3 slides on preoperative MRI to divide the patients into 3 groups with different types of stump classification. In type 1 ($C/D < 0.8$), the stump appeared darker than the deltoid. In type 2 ($0.8 \leq C/D \leq 1.3$), the stump was similar in color to the deltoid, and in type 3 ($C/D > 1.3$), the stump appeared whiter than the deltoid (Fig. 1). All the measurements were conducted by 2 fellowship-trained shoulder surgeons (H.B., J.G.) who were blinded to each other and the patients' information. One of them (H.B.) measured the data 3 months later. All of the imaging data were evaluated by a fellowship-trained shoulder surgeon (H.B.) who was blinded to the surgical and clinical outcomes.

Statistical analysis

Continuous data are presented as the mean ± standard deviation. The Kruskal–Wallis test was used to compare the differences among the groups, followed by the Bonferroni correction test for pairwise comparisons. The Wilcoxon signed-rank test was used for preoperative and postoperative comparisons. The chi-square test or Fisher's exact test was performed for comparisons between categorical data. The intraclass correlation coefficient was calculated to evaluate the interobserver and intraobserver agreements. Statistical analysis was conducted using SPSS (version 24.0; IBM Corp., Armonk, NY, USA). The statistical significance level was set at $P < .05$.

Results

Baseline characteristics

A total of 75 patients were included in this study. Based on stump classification, the patients were classified into types 1 (n = 44), 2 (n = 17), and 3 (n = 14). The mean clinical follow-up time was 19.9 ± 7.8 months. The numbers of patients treated with a fascia lata autograft with mesh augmentation were 31, 12, and 8 in the type 1, 2, and 3 groups, respectively ($P = .603$). The detailed baseline data are presented in Table I. All groups showed no significant differences in age, body mass index, affected side, diabetes mellitus, time from preoperative MRI to surgery, follow-up time, tear size, global fatty degeneration index, Hamada classification, or AHD. The intraclass correlation coefficient values for intraobserver and interobserver reliability were 0.793 and 0.711, respectively.

Clinical outcomes

Pain

No significant difference was detected in the preoperative VAS score among the 3 groups (Table I). After surgery, all 3 groups showed a statistically significant decrease in the VAS score (Type 1, 6 ± 2 vs. 1 ± 1, $P < .001$; Type 2, 6 ± 2 vs. 2 ± 2, $P = .001$; Type 3, 6 ± 2 vs. 1 ± 1, $P = .001$; Table II). Moreover, there was no difference in the VAS score among the 3 groups after surgery ($P = .078$).

Functional score

There was no difference in the preoperative ASES and Constant scores among the 3 groups (Table I). The ASES score was improved significantly after surgery in all 3 groups (Type 1, 49 ± 18 vs. 84 ± 10, $P < .001$; Type 2, 50 ± 16 vs. 75 ± 15, $P = .002$; Type 3, 46 ± 14 vs. 76 ± 14, $P = .001$; Table II). The differences in Type 1, 2, and 3 all exceeded the minimum clinically important difference (MCID) (15.2) for the ASES score after SCR.[31] However, a significant difference in the Constant score was only found in the type 1 group (54 ± 11 vs. 65 ± 5, $P < .001$) and the difference was below the MCID (10.4) for the Constant score after RC repair.[25] After surgery, patients in the type 1 group had significantly higher ASES and Constant scores than those in the type 2 and 3 groups ($P = .014$ and .005, respectively); however, no difference was found between the type 2 and 3 groups. For the postoperative ASES score, the difference between type 1 and 2 was 9 and the difference between type 1 and 3 was 8, which were both below the MCID for the ASES score (15.2).[31] For the postoperative Constant score, the difference between type 1 and 2 was 4 and the difference

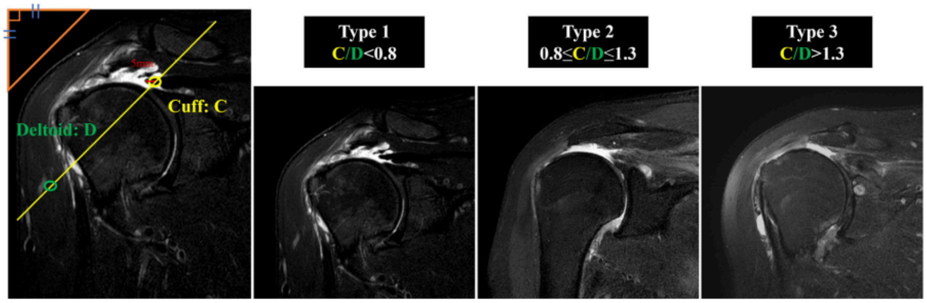

Figure 1 Signal intensity was evaluated using a 10 mm^2 circle located 5-8 mm from the edge of the stump and 45° from the deltoid. (D), deltoid signal intensity; (C), rotator cuff stump signal intensity.

Table I Baseline characteristics for different types*

Variables	Type 1 (n = 44)	Type 2 (n = 17)	Type 3 (n = 14)	*P* value
Sex, male: female (n)	16:28	4:13	6:8	.496
Age, yrs	66 ± 6	63 ± 11	65 ± 7	.701
BMI, kg/m^2	25.4 ± 3.3	26.5 ± 4.0	26.0 ± 2.5	.439
Affected side, right: left (n)	37:7	14:3	5:9	.353
Diabetes mellitus, n (%)	10 (22.7)	3 (17.6)	2 (16.7)	.760
Graft, FL: FL/M (n)	13:31	5:12	6:8	.603
Time from PreOP MRI to surgery (months)	2 ± 1	2 ± 1	2 ± 1	.617
Follow-up time, mos	20 ± 7	17 ± 6	24 ± 10	.093
Tear size (the Patte classification), n				.455
I: Greater tuberosity	0	0	0	
II: humeral head exposed	1	0	0	
III: Glenoid	22	5	6	
IV: Medial to glenoid	21	12	11	
GFDI	2 ± 1	2 ± 1	2 ± 1	.682
Hamada classification, n				.624
Grade 1	18	9	6	
Grade 2	24	8	7	
Grade 3	1	0	0	
Grade 4a	1	0	0	
Grade 4b	0	0	1	
Grade 5	0	0	0	
AHD, mm	5.4 ± 2.5	6.2 ± 3.8	5.6 ± 2.8	.954

BMI, body mass index; *FL*, fascia lata; *FL/M*, fascia lata with mesh augmentation; *PreOP*, preoperative; *MRI*, magnetic resonance imaging; *ROM*, range of motion; *GFDI*, global fatty degeneration index; *AHD*, acromiohumeral distance.

* Data are presented as the mean ± standard deviation or number. Statistical significance is indicated in bold.

between type 1 and 3 was 9, which were both below the MCID (10.4) for the Constant score.[25]

ROM

There was no difference in the preoperative forward flexion, external rotation, and internal rotation among the 3 groups. After surgery, type 1 and 2 patients showed significantly better forward flexion compared with type 3 patients (155 ± 10 vs. 145 ± 13; *P* = .022 and 154 ± 15 vs. 145 ± 13; *P* = .023,); however, there was no difference between type 2 and 3 patients (Table II).

Radiological outcomes

As shown in Table III, only the AHD was significantly increased (between pre- and postoperative AHD) in the type

Table II Clinical outcomes*

	Type 1 (n = 44)	P value	Type 2 (n = 17)	P value	Type 3 (n = 14)	P value	P value between 3 types
ASES score							
PreOP	49 ± 18		50 ± 16		46 ± 14		**.639**
PostOP	84 ± 10	**<.001**	75 ± 15	**.002**	76 ± 14	**.001**	**.014 (1 > 2 = 3)**
Constant score							
PreOP	54 ± 11		56 ± 7		48 ± 13		**.113**
PostOP	65 ± 5	**<.001**	61 ± 9	.083	56 ± 13	.133	**.005 (1 > 2 = 3)**
VAS score							
PreOP	6 ± 2		6 ± 2		6 ± 2		**.870**
PostOP	1 ± 1	**<.001**	2 ± 2	**.001**	1 ± 1	**.001**	**.078**
Active ROM, degrees							
Forward flexion							
PreOP	146 ± 28		142 ± 20		143 ± 31		**.309**
PostOP	155 ± 10	.180	154 ± 15	.062	145 ± 13	.751	**.013 (1 = 2 > 3)**
External rotation							
PreOP	43 ± 19		42 ± 26		41 ± 29		**.933**
PostOP	47 ± 16	.430	42 ± 14	.977	36 ± 17	.609	**.108**
Internal rotation							
PreOP	13 ± 3		12 ± 2		12 ± 3		**.553**
PostOP	12 ± 3	.347	12 ± 3	.856	12 ± 3	.798	**.928**

ASES, American Shoulder and Elbow Surgeons; *VAS*, visual analog scale; *ROM*, range of motion; *PreOP*, preoperative; *PostOP*, postoperative.
* Data are presented as numbers or the mean ± standard deviation. Statistical significance is indicated in bold.

1 group (5.4 ± 2.5 vs. 8.0 ± 2.4; $P < .001$). There was no difference in the pre- and postoperative AHD or the Hamada classification among the groups. No difference was observed in the graft failure rate after surgery (12/44 vs. 6/17 vs. 5/14; $P = .749$). A total of 7 patients were found to have graft tears before 12 months postoperatively. However, patients treated with the fascia lata autograft had a significantly higher graft failure rate (12/24) than that of patients treated with the fascia lata autograft with mesh augmentation (11/51) ($P = .017$). A significant difference was found in the integrity of the connection between the stump and graft among the groups (36/44 vs. 7/17 vs. 7/14; $P = .003$).

Discussion

The most important finding of this study was that patients with type 1 stump on preoperative MRI had better outcomes in terms of the ASES score, Constant score, ROM, and AHD, and stump classification could be used to predict postoperative clinical outcomes after suturing the remnant SSP tendon to the fascia lata autograft during conventional SCR.

Several systematic reviews have shown that arthroscopic SCR improves patient-reported outcomes and shoulder ROM significantly during follow-up.[1,38,42] In the current study, almost all functional outcomes and pain scores were improved significantly after SCR regardless of the stump classification. The ASES and VAS scores were significantly improved in all groups after surgery, whereas the Constant score was only significantly improved in the type I group. This result may be attributed to differences in the evaluation of these scores as the ASES score places more weight on pain, and the Constant score places more weight on strength.[19] Additionally, the active forward flexion, ASES score, and Constant score were significantly higher for patients with type 1 stump. However, these statistical differences between groups were below the established MCID values for the ASES (15.2)[31] and Constant (10.2) scores[25] after RC repair, which may limit the clinical importance. However, the MCID values used in this study were derived from the reparable RCT. The clinical benefit of stump classification for an irreparable RCT needs further investigation after SCR.

MRI changes in the RC have been demonstrated to be associated with findings from arthroscopy[35] and histological evaluation.[24] Kjellin et al demonstrated that increased signal intensity on MRI and an indistinct margin at the SSP tendon corresponded to eosinophilic, fibrillar, and mucoid degeneration and scarring using cadaver shoulders.[24] Severe degeneration of the SSP tendon was found to correlate with areas of increased signal intensity on MRI T2-weighted images.[24] Gagey et al[14] and Williams et al[44] also reported that MRI abnormalities of the RC corresponded to histological changes consistent with tendon degeneration. Kijowski et al found that lower preoperative T2 signal within the tendon stump on MRI was associated with better postoperative clinical outcomes.[23] Shinohara et al demonstrated that stump classification reflected the degeneration of the torn SSP stump.[36] A better quality of the remnant SSP tendon in a type 1 stump has been suggested to restore the superior stability and dynamics of the

Table III Radiological outcomes*

Variables	Type 1 (n = 44)	Type 2 (n = 17)	Type 3 (n = 14)	*P* value between 3 types
Hamada classification				.085
Grade 1	32	10	6	
Grade 2	8	6	7	
Grade 3	0	0	0	
Grade 4a	1	0	0	
Grade 4b	0	1	0	
Grade 5	0	0	1	
AHD, mm				
PreOP	5.4 ± 2.5	6.2 ± 3.8	5.5 ± 2.4	.954
PostOP	8.0 ± 2.4	7.0 ± 3.3	7.0 ± 2.6	.248
P value	**<.001**	.298	.221	
Graft integrity, n (%)				.749
Success	32 (72.7)	11 (64.7)	9 (64.3)	
Failure	12 (27.3)	6 (35.3)	5 (35.7)	
Time of failure				.849
<12 mo	3	2	2	
≥12 mo	9	4	3	
Integrity of the connection between the stump and graft				.003
Intact	36	7	7	
Torn	8	10	7	

PreOP, preoperative; *PostOP*, postoperative; *AHD*, acromiohumeral distance; *SD*, standard deviation.
* Data are presented as numbers or the mean ± SD. Statistical significance is indicated in bold.

shoulder joint. The results are consistent with those of a previous study suggesting that the strain from the SSP muscle may cause angiogenic changes, contributing to better fascia-to-bone healing and outcomes.[30] In this study, compared with type 2 and 3 stumps, type 1 stumps showed a significantly higher healing rate with grafts. This may explain the superior clinical outcomes of patients with type 1 stump. However, no difference was found among the 3 groups in the fatty degeneration of the RC muscles, as indicated by GFDIs. The findings are consistent with those of a previous study showing no difference in GDFIs among groups; however, type 3 stumps showed a significantly higher retear rate after RC repair.[18] Future studies with a larger sample size are needed to investigate the relationship between the quality of the stump and muscle.

Graft healing has been demonstrated to be essential in achieving optimal shoulder function.[22] Hasegawa et al found that a fascia lata autograft could regenerate the fibrocartilaginous insertion after SCR using rabbit and rat models.[17,30] Suturing the remnant SSP tendon to the fascia lata autograft was reported to transmit the contractile force of the SSP to the graft and the humerus, which contributed to the higher maturity of the histologic structure across the fascia-to-bone interface.[29] An appropriate muscle contracture force was found to promote the fascia-to-bone healing of the fascia lata autograft.[29] However, elevated levels of AGEs were also demonstrated to impair tendon healing,[33] bone regeneration,[28] and wound healing.[9] Furthermore, severe inflammation was reported to affect tendon-bone healing[9] with a strong correlation with poor outcomes after RC repair.[10] During surgery, the remnant tendon and bursa tissue on the graft were fixed on top of the graft for biological augmentation.[20] As higher classifications were found to have higher degrees of AGEs and inflammation at the RC site,[36] the effect of this biological augmentation on graft healing may differ between the 3 types of stumps. However, this was a retrospective clinical study with no histological or biomechanical examination; thus, this should not be overemphasized except for its importance in the classification. The better clinical outcomes of type 1 patients may be attributed to differences in graft healing associated with low AGEs and inflammation and higher strain from the SSP muscle. Furthermore, the graft integrity rate was the highest among type 1 patients; however, there was no statistically significant difference among the different types. Further research with a larger sample size is required to clarify the findings. Graft technical variations may also influence the results. The graft failure rate of patients treated with the fascia lata autograft was significantly higher than that of patients treated with the fascia lata autograft with mesh augmentation, which is consistent with a previous study.[22] As no difference was observed in the distribution of the grafts among the 3 groups, this would likely not influence the results. However, the percentage of patients treated with grafts with mesh in the type 3 group (58%) was lower than that in the type 1 and 2 groups (70%), which may be a potential reason for inferior outcomes in the type 3 group.

A previous study demonstrated that the loss of superior stability after irreparable RCT led to the excessive upward migration of the humeral head.[13] Li et al found that SCR with the suturing of the SSP tendon remnant to the fascia lata autograft could restore superior stability, resulting in significant AHD improvement compared with the outcome of conventional SCR. In the current study, radiological results showed that only patients with type 1 stump had a significant improvement in the AHD after SCR. Therefore, compared with type 2 and 3 stumps, type 1 stumps may be the best for restoring the stability of the shoulder joint and exerting better compression on the humeral head.

The strengths of the current study were as follows: (1) the stump classification determined on preoperative MRI was found to have a negative correlation with postoperative clinical outcomes, which was beneficial for choosing the most appropriate surgical technique and predicting postoperative outcomes and (2) this classification could allow surgeons to evaluate the signal intensity (color) at a glance, and the measurement could be performed within 5 minutes[18], which would strengthen its value for clinical practice. Ishitani et al raised the concern of whether stump classification is replicable in other institutions because MRI settings could vary between devices and institutions.[18] However, a multicenter study reported similar results that stump classification type 3 could predict retear after RC repair.[41] The findings suggest that MRI stump classification based on a T2-weighted fat-suppressed sequence may be universally reproducible in different devices and institutions.

There are some limitations in this study. First, the number of type 2 and 3 patients was relatively small, and further studies with a larger sample size are required to confirm the results. Second, the follow-up time was relatively short, and the relationship between stump classification and long-term follow-up remains unknown. However, this was the first study to investigate the relationship between stump classification and clinical outcomes after SCR. Future studies with a long-term follow-up are required to strengthen the clinical relevance of this MRI classification. Third, the surgical technique of suturing the remaining SSP stump to the graft was not widely used, which may limit generalization. Fourth, post-hoc power analysis was conducted in this study, which may introduce bias. Fifth, 2 types of grafts (with/without mesh) were used in this study, which may introduce bias. However, the graft preparation technique was changed based on the operating surgeon's investigation of the preliminary outcome, which was proposed to avoid selection bias of the graft types.

Conclusion

Patients with stump classification type 1 showed significantly better functional scores (ASES and VAS scores) and forward flexion; however, the clinical importance of these differences may be limited. Stump classification may be useful for predicting postoperative clinical outcomes.

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