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Computer tomography assessment of the subscapularis after reverse shoulder arthroplasty and subscapularis repair: reduction in subscapularis size do not affect clinical outcomes

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ABSTRACT

Background: Excellent Clinical and patient-reported outcome have been reported following Reverse Shoulder Arthroplasty (RTSA). However, outcomes in range of motion (ROM) remain variable. The role and importance of subscapularis repair during RTSA is a topic of intense debate and the long term-integrity of the subscapularis after repair remains poorly studied. Aims of this study were to radiologically evaluate pre- and postoperative condition of the subscapularis muscle in RTSA with concurrent subscapularis tendon repair using transosseous suture, and to investigate the correlation between clinical and radiological results.

Methods: Patients who had undergone RTSA with subscapularis repair in our Institute between January 2010 and November 2016 were included. Constant, UCLA, Simple Shoulder Test and Visual Analog Scale (VAS) pain questionnaires were administered pre- and post-operatively. Internal rotation ability was recorded on a 6-point scale. Pre - and postoperatively shoulder CT scans were performed by a blinded examiner from which subscapularis muscle cross-sectional area (SMCSA) and supraspinatus fossa cross-sectional area (SFCSA) were measured in square millimeters. The SMCSA/SFCSA ratio was employed to standardize values for individual anatomical differences between patients.

Results: The study included 32 patients (32 shoulders). Mean follow-up was 74.6 months ± 15.2 months (range 35−117 months). Statistically significant differences were found between pre- and postoperative VAS score, Constant Score, UCLA and Simple Shoulder Test scales ($P < .0001$). A postoperative SMCSA reduction of >35% was found in 38% of patients. Only 21% of patients maintained their preoperative SMCSA/SFCSA ratio. Overall, a statistically significant difference in pre and postoperative SMCSA/SFCSA ratios was found ($P < .001$). A correlation between radiological findings and clinical outcomes was not found.

Conclusion: Postoperative subscapularis size expressed as SMCSA and SMCSA/SFCSA ratio, was significantly reduced in the majority of patients treated with non-lateralized RTSA

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design and concurrent subscapularis tendon repair at final follow-up. A correlation between radiological findings and clinical outcomes was not found. RTSA with subscapularis tendon repair provides a high degree of patient satisfaction, as well as statistically significant improvements in clinical outcomes and internal rotation ROM. Being associated with several advantages, subscapularis repair may be routinely recommended.

Level of evidence: Level II; Prospective Cohort Design; Prognosis Study

Reverse total shoulder arthroplasty (RTSA) offers a biomechanical advantage to anatomic total shoulder arthroplasty (TSA) in patients with rotator cuff arthropathy. Since its introduction in 1987 by Grammont [10] et al and approval by the Food and Drug Administration (FDA) in 2004 [4], the number of RTSA operations performed annually has increased dramatically [17]. Currently, the rates at which RTSA is performed in the United States rivals those of the traditional TSA [29]. While patient reported outcomes of RTSA have proven excellent, there remains tremendous variability in range of motion (ROM) outcomes, particularly with respect to internal (IR) and external rotation (ER) [4,23].

In the context of anatomic TSA, the subscapularis tendon serves a critical role in stabilizing the implant, which necessitates its repair [1,20]. However, the role and relative importance of subscapularis repair during RTSA remains a topic of debate. Advocates of subscapularis repair maintain that doing so enhances the stability of the implant, improves internal rotation, and decreases dead space in the joint, which subsequently reduces related complications [5,9,24]. Conversely, detractors believe that repairing the subscapularis impairs glenohumeral ER and places increased demand on the deltoid muscle to perform arm elevation [14,15,24].

While several studies have examined the effects of subscapularis repair in the context of RTSA, most have been either cadaveric [2,3,12,16,19] or based on computer modeling [15,21,22]. However, the long term-integrity of the subscapularis after repair in vivo remains poorly studied. Dedy et al. [8] sonographically evaluated the subscapularis tendon in patients who underwent repair and found it to be absent in 23% of patients after a mean follow-up of 19 months. Similarly, De Boer et al [7] demonstrated only 40% of repaired tendons maintained sufficient integrity at a mean follow-up of 36 months.

We believe that a more accurate evaluation of the condition of the subscapularis after RTSA and concurrent subscapularis repair can be achieved utilizing high-accuracy imaging techniques such as computed tomography (CT). Furthermore, no previous investigation has delineated the impact of subscapularis condition after RTSA on clinical and functional outcomes. Therefore, the primary aim of this study was to evaluate, with pre- and postoperatively shoulder CT scans, the condition of the subscapularis muscle after RTSA with concurrent subscapularis tendon repair using transosseous suture. The secondary aim of this study was to investigate the correlation between conditions of the subscapularis and clinical as well as functional outcomes at mid-term follow-up.

The hypothesis is that RTSA with concurrent subscapularis repair allows for excellent clinical results in patients treated with a non-lateralized RTSA and that clinical outcomes are expression of subscapularis muscle conditions.

Material and methods

Study population

After receiving approval by the University Ethics Committee, 142 consecutive patients who were scheduled to undergo RTSA and who provided their informed consent were enrolled into this prospective study between January 2010 and November 2016. Inclusion criteria consisted of: 1) age greater than 60; 2) painful rotator cuff arthropathy clinically established and confirmed by shoulder X-Ray and MRI; and 3) absence of neurological disease or cognitive dysfunction. Exclusion criteria included: 1) patients undergoing RTSA for concentric osteoarthritis; 2) humeral fractures; 3) osteonecrosis; 4) history of rheumatoid arthritis; 5) presence of a dysplastic glenoid (i.e. Walch classification type A2 or B2 and C) [30]; 6) presence of neurological disease or cognitive dysfunction and 7) an intra-operative finding of a degenerated or irreparable tendon. Several exclusion criteria were adopted in order to focus the attention on the effect of the subscapularis repair, eliminating any confounding factor which may affect results interpretation.

Surgical technique

All patients were treated with the same non-lateralized RTSA design SMR-system (Lima Corporate, Italy). The same orthopedic surgeon performed all the operations. The delto-pectoral approach was performed in every case. In all cases, a tenotomy of the subscapularis tendon at the level of the anatomical neck was performed. In addition, a tendon release was performed in order to allow adequate mobility of the tendon stump. The tendon was considered reparable if it could be reattached to its native location with mild force at 20° of ER and neutral abduction. When possible, the subscapularis tendon was reattached with transosseous suture to its original insertion. The prostheses were implanted as described by the manufacturing company (Lima Corporate®). The humeral stem was placed at 10° of retroversion and the base plate was placed at 10° of inferior tilt.

Clinical evaluation

A different orthopedic surgeon who was not involved in surgical procedures, collected a detailed clinical history and performed a thorough physical examination of the shoulder for all patients. ROM was assessed by a comparison with the contralateral side. IR was recorded on a 6-point vertebral-segments related scale [6].

Grade 1: hand positioned at lateral thigh
Grade 2: at the buttock
Grade 3: at the lumbosacral junction
Grade 4: at lumbar spine
Grade 5: at lumbothoracic junction
Grade 6: at interscapular level

Pre- and postoperative dynamometric evaluation of IR strength with a comparison to the contralateral side was performed. ER ROM was measured postoperatively both with the arm in abduction and adduction and successively compared with the contralateral side. Constant Score, UCLA Scale, Simple Shoulder Test and Visual Analog Scale (VAS) pain questionnaires were administered to each patient at pre- and postoperative timepoints. Patient satisfaction, measured on a scale of 1 to 4 (poor, sufficient, good and excellent), was evaluated postoperatively.

Radiographic evaluation

Pre- and postoperatively shoulder CT scans were performed and evaluated by the same musculoskeletal radiologist. Images were obtained with a Toshiba Aquilion 16-slice CT scanner using the same protocol and calibration technique for all patients. The scanning parameters were 120 kVp, 125 mAs, field of view 250 mm, and a detector pitch of 15. A soft-tissue filter and raster artifact suppression tool were used, producing a 512 matrix of 1-mm-thick slices (slice overlap: 0.5 mm). The sagittal-oblique CT slice was reconstructed in this exact plane from original CT data sets, producing the typical Y-shaped image [25]. Evaluation was performed at the most lateral section on which the scapular spine was still in continuity with the body of the scapula. The subscapularis muscle cross-sectional area (SMCSA) and supraspinatus fossa cross-sectional area (SFCSA) were measured in square millimeters (Fig. 1). The SFCSA was not subject to variations during the degenerative process of the massive rotator cuff tear. Thus, the SMCSA/SFCSA ratio was employed to standardize the SMCSA as it is a validated method for accounting for individual anatomical differences between patients [26]. Patients were divided into three groups according to their SMCSA/SFCSA ratio: <1.5, 1.5−2 or >2.0. Postoperative reduction in subscapularis size was evaluated at final follow-up, according to both the SMCSA/SFCSA ratio groups and the absolute SMCSA reduction (i.e. <25%, 25-35% and >35% reduction) compared to their preoperative values.

Statistical analysis

Parametric variables were expressed as medians. Frequencies and percentages were used to assess the distribution of non-parametric variables. The Wilcoxon signed rank sum tests and Chi-square tests were used to analyze differences between pre- and postoperative results in clinical and radiographic outcomes. Correlations among parametric and non-parametric variables were assessed with Pearson and Spearman correlations, respectively. Clinical correlations with the absolute reduction in SMCSA were performed using the Wilcoxon-Mann-Whitney test. Statistical analysis was performed using IBM SPSS Statistics 24 (Armonk, NY, USA) and JMP Pro 12 (Cary, NC, USA). Statistical significance was defined as $P < .01$.

Results

Demographics

Of the 142 patients enrolled into this study, 110 met at least one of the exclusion criteria and were subsequently

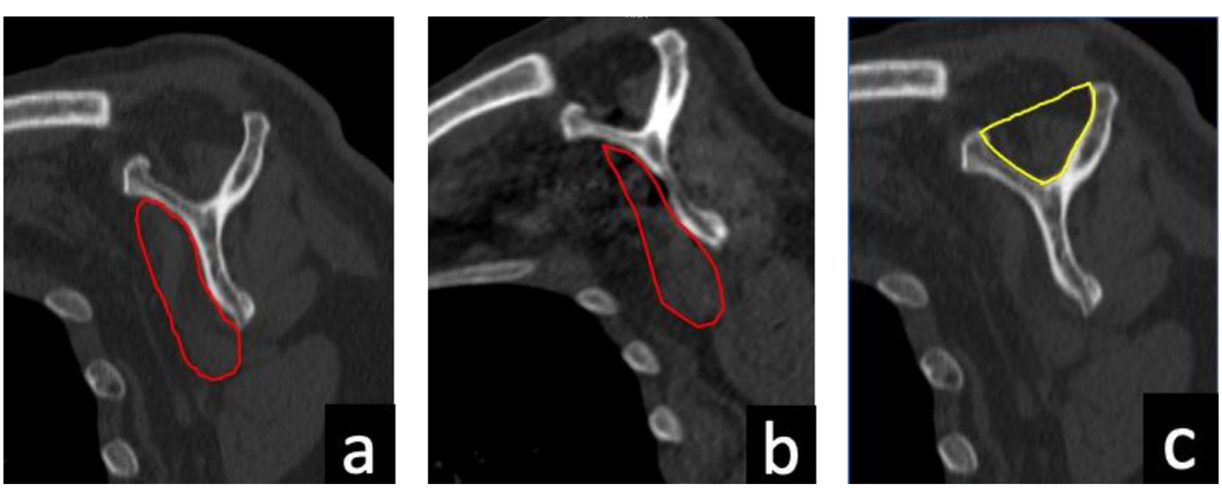

Figure 1 – Subscapularis muscle cross-sectional area (SMCSA) and Supraspinatus fossa (SFCSA) were measured in square millimeters in a standardized sagittal-oblique CT slice. Evaluation was performed at the most lateral section on which the scapular spine was still in continuity with the body of the scapula. (a) Preoperative delineation of SMCSA. (b) Postoperative delineation of SMCSA. (c) Delineation of SFCSA.

excluded. Of the 110 patients excluded, 19 suffered concentric osteoarthritis, 30 presented for humeral fractures, 8 had a diagnosis of rheumatoid arthritis, in 9 a dysplastic glenoid was found and 6 suffered from neurological diseases or cognitive dysfunctions. Nine patients were lost to follow-up and an additional 29 were excluded due to an intra-operative finding of a degenerated or irreparable subscapularis tendon.

The study population included 32 patients: 8 men (25%) and 24 women (75%). The mean age at the time of surgery was 72.2 ± 5.1 years (range 63–88 years). Thirty were right-hand-dominant (93.7%) and 2 were left-hand-dominant (6.2%). The operative shoulder was the right in 20 subjects (62.5%) and the left in 12 (37.5%). The mean follow-up was 74.6 ± 15.2 months (range 35–117 months). No cases of periprosthetic joint infection, periprosthetic fracture, dislocation or axillary nerve palsy were reported. Two cases of acromion stress fractures were reported in the first three months but none affected clinical results at the time of the study.

Clinical assessment

Patients reported a statistically significant improvement across all patient-reported outcome measures at final follow-up (Table 1). Statistically significant differences were found between pre- and postoperative VAS score, Constant Score, UCLA and Simple Shoulder Test scales ($P < .0001$). At final follow-up, patient satisfaction was reported as poor in 2 patients (6.25%), sufficient in 2 (6.25%), good in 7 (21.9%) and excellent in 21 (65.6%). A statistically significant difference between pre-and postoperative dynamometric evaluation of internal rotation was reported ($P < .1$).

Range of motion

Patients demonstrated a statistically significance improvement in their preoperative IR ROM at final follow-up ($P < .001$). With respect to the 6-point vertebral-segments scale, preoperatively, 1 patient (3.1%) presented a grade 1, 5 patients (15.5 %) a grade 2, 15 patients (46,9%) a grade 3 and 11 patients (34.5%) a grade 4. Postoperatively, grade 1 to 5 were found in 2 (6,25%), 2 (6.25%), 10 (31,25%), 16 (50%) and 2 (6,25%) respectively. Patients demonstrated a statistically significance improvement in their preoperative ER ROM at final follow-up ($P < .001$). ER ROM in adduction improved from 5° pre- operatively to 20° postoperatively and in abduction improved from 10° pre- operatively to 45° postoperatively. Furthermore, a statistically significant postoperative reduction in ER ROM ($P < .001$) was found compared to the contralateral side with the arm both in abduction (45° in the operated vs 65° in the contralateral side) and in adduction (20° in the operated vs 47.5° in the contralateral side) (Table 2).

Table 1 – Median pre- and post-operative clinical outcome measures for patients undergoing medialized RTSA with subscapularis repair.

Variable	Pre-op	Post-op	P value
Vas (0–100)	72.5	15	<.01
Constant	42	80	<.01
UCLA Score	10	32	<.01
Simple shoulder test	3	10	<.01
Dynamometric evaluation of IR (kg)	6.75	6.0	<.01

Radiographic results

Preoperative assessment of the SMCSA/SFCSA ratio revealed a ratio of <1.5 in 4 patients (12.5%), a ratio of 1.5–2.0 in 13 patients (40.6%) and a ratio of >2.0 in 15 patients (46.9%). Postoperative SMCSA/SFCSA ratio demonstrated a ratio of <1.5 in 21 patients (65.6%), 1.5–2.0 in 9 patients (28.1%) and >2.0 in 2 patients (6.5%) ($P < .01$) (Table 3). Globally, 21% of patients maintained their preoperative SMCSA/SFCSA ratio. Of patients with a preoperative of 1.5-2-0, 92% demonstrated an inferior SMCSA/SFCSA ratio postoperatively. Of patients with a preoperative of >2.0, 87% demonstrated an inferior SMCSA/SFCSA ratio postoperatively. Overall, a statistically significant difference in pre and postoperative SMCSA/SFCSA ratios was found ($P < .001$) (Table 4). Furthermore, 11 patients (34%) demonstrated a postoperative SMCSA reduction of <25%, 9 (28%) demonstrated a 25-35% reduction and 12 (38%) demonstrated a reduction of >35% (Fig. 2).

Correlation between radiographic and clinical outcomes

No statistically significant correlation was found between postoperative VAS score, Constant Score, UCLA and Simple Shoulder Test scales improvement and the percentage of SMCSA reduction ($P > .01$). A significant negative correlation was found between VAS score and UCLA Score and Simple Shoulder Test ($P < .0001$), but not between VAS and Constant Score. Higher preoperative SMCSA were correlated with greater reductions in postoperative SMCSA. Patients with the highest preoperative SMCSA values were most likely to demonstrate postoperative SMCSA reductions >35%. However, radiographic findings did not correlate with clinical results ($P > .01$), except for IR strength reduction. In patients with SMCSA reductions >35% a significant greater IR strength reduction was found than in patients with a lower SMCSA

Table 2 – Pre- and post-operative range of motion for patients undergoing medialized RTSA with subscapularis repair ($P < .001$). ER values are presented as median.

Internal Rotation	Pre-operative (% of patients)	Post-operative (% of patients)
Lateral side of thigh	1 (3.1)	2 (6.25)
Buttock	5 (15.5)	2 (6.25)
Lumbosacral junction	15 (46.9)	10 (31.25)
Lumbar spine	11(34.5)	16 (50)
Lumbothoracic junction	0	2 (6.25)
External Rotation	**Operative Shoulder**	**Non-op Shoulder**
ER in Abduction	45°	65°
ER in Adduction	20°	47.5°
	Pre-operative	**Post-operative**
ER in Abduction	10°	45°
ER in Adduction	5°	20°

Table 3 – Pre- and post-operative SMCSA/SFCSA ratio groupings for patients undergoing medialized RTSA with subscapularis repair ($P < .01$).

Subscapularis (SMCSA)/ Supraspinatus Fossa Area (SFCSA)	Pre-op (% of patients)	Post-op (% of patients)
< 1.5	4 (12.5)	21 (65.6)
1.5–2.0	13 (40.6)	9 (28.1)
> 2.0	15 (46.9)	2 (6.3)

reduction ($P < .001$). Functional outcomes were not influenced by postoperative SMCSA reduction. No statistically significant correlation was found between gender and pre- or postoperative clinical and radiological results, but the postoperative SMCSA in men was statistically higher ($P < .001$).

Discussion

The principle findings of this study were that postoperative subscapularis size was significantly reduced in the majority of patients at the final follow-up. Nevertheless, a non-lateralized design RTSA with subscapularis tendon repair provides a high degree of patient satisfaction, as well as statistically significant improvements in patient reported outcomes and internal rotation ROM. Our hypothesis that the condition of the subscapularis muscle would correlate with clinical outcomes, was rejected. In fact, similar clinical results were reported regardless the postoperative SMCSA reduction and SMCSA/SFCSA ratio.

The dislocation rate following RTSA has been reported to be between 0% and 9% [29] and is more common with a non-lateralized RTSA design [9]. In our case series of patients treated with a non-lateralized design RTSA and subscapularis repair with transosseous suture to its original insertion, no dislocations (0%) were reported. This result substantiates the findings of previous investigations which have studied dislocation rates after subscapularis repair in the context of RTSA. In a consecutive series of 138 patients, Edwards et al [9] demonstrated that subscapularis integrity increased stability and reduced the dislocation rate in patients undergoing non-lateralized RTSA. Furthermore, these authors reported no dislocations amongst the 62 patients who underwent RTSA with subscapularis repair, but seven dislocations among those 76 patients who underwent when RTSA without subscapular repair. Taken together, these findings support the claim that subscapularis repair in the setting of non-lateralized RTSA may provide additional stability to the prosthesis and result in reduced dislocation events [5,9,24].

In addition to decreased dislocation rates, increased IR ROM is another reported advantage of the subscapularis tendon repair [23]. RTSA has traditionally been associated with significant residual deficits in ROM, particularly of IR and ER. Boileau et al [4] reported improvements of only 2 vertebral levels for IR and of only 4° for ER after RTSA. However, with the exception of subscapularis repair, few patient or surgical factors have been shown to demonstrate improved outcomes in IR/ER postoperatively [23]. The results of the present investigation confirm this finding, as patients who underwent subscapularis repair experienced a statistically significant improvement in the 6-point vertebral-segments related scale. This finding is intuitive, as the subscapularis represents the main internal rotator of the shoulder but also has broad clinical significance, as IR is a fundamental movement required to perform key portions of many ADLs, including dressing or bathing. For this reason, maintaining the integrity and therefore the functionality of the subscapularis may be advisable.

While subscapularis repair may improve IR in patients undergoing non-lateralized RTSA, doing so, especially if repaired with high degrees of tension and if a lateralized design is employed, may limit ER. This may be especially undesirable in patients with existing posterior cuff deficiencies who already struggle with ER. Furthermore, Valenti et al

Table 4 – Radiographic evaluation expressed as number of patients, percent of all patients, percent of patients with the same pre-operative SMCSA/SFCSA ratio.

Subscapularis Area (SMCSA)/Supraspinatus Fossa (SFCSA) Pre op	Subscapularis Area (SMCSA)/ Supraspinatus Fossa (SFCSA) Post op			
	≤1.5	1.5–2.0	>2.0	Total
≤1.5	4	0	0	4
	12.5	0.00	0.00	12.5
	100.00	0.00	0.00	
1.5-2.0	12	1	0	13
	37.5	3.1	0.00	40.7
	92.3	7.7	0.00	
>2.0	5	8	2	15
	15.6	25.0	6.3	46.9
	33.3	53.3	13.3	
Total	21	9	2	32
	65.6	28.1	6.2	100,0

NOTE. Overall, a statistically significant difference in pre and post-operative SMCSA/SFCSA ratios was found ($P < .001$). All patients with a pre-operative ratio ≤ 1.5 remained all at the same ratio post - operatively. 92.3% of those with a pre-operative ratio between 1.50 and 2 became <1.5 post – operatively. Only 13.3% of those with a preoperative ratio> 2 remained in the post-operative >2, 53.3% switched to a post-operative relationship between 1.5 and 2 and 33% to a ratio ≤ 1.5.

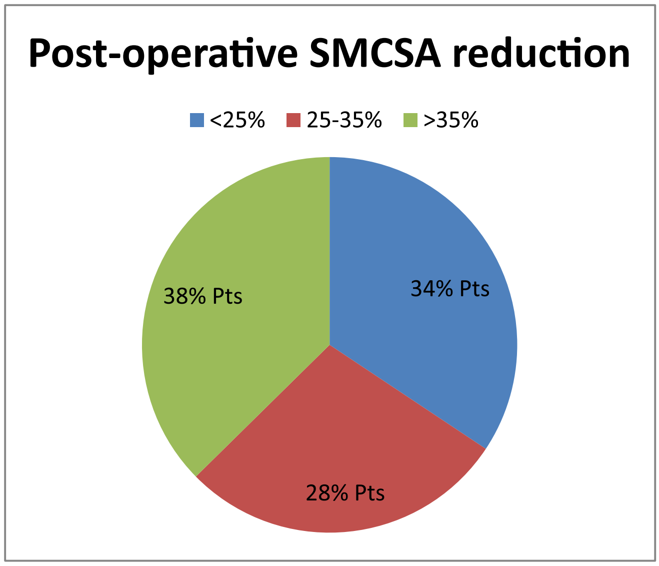

Figure 2 – All patients presented a post-operative subscapularis muscle cross-sectional area (SMCSA) reduction. A post-operative SMCSA reduction of $<$25%, 25−35%, $>$35% was respectively found in 34%, 28% and 38% of patients.

[28] reported that lateralized design implants offer significant gains in ER, suggesting that subscapularis repair may be unnecessary with this type of implant. However, these findings have been largely derived from cadaveric studies or computer-based modeling. Interestingly, in an investigation of lateralized RTSA, Friedman et al [11], in a large series of patients (340 treated with subscapularis repair and 251 without) demonstrated superior clinical outcomes and ROM results in patients treated with subscapularis repair compared to those without repair, in contrast with findings of other computer modeling studies [15]. With the exception of postoperative dislocations, which were more common in patients who did not undergo subscapularis repair, no differences in overall complications were reported between the two groups. In our study there was a significant postoperative improvement in ER ROM either with the arm in abduction or in adduction. Although a significant reduction in postoperative ER ROM was found compared to the non-operative side, this reduction did not seem to affect patients' functional outcomes and satisfaction.

Previous investigations have demonstrated that following RTSA, the subscapularis functions as an adductor for the first 70° of arm abduction [22]. As a result of these biomechanical alterations, a demand is placed on the deltoid to generate a greater force in low and mid-levels of abduction [14]. In an effort to address this biomechanical shortcoming, King et al [18] recently proposed an “over-the-top” repair technique. This technique, according to the authors, repairs the upper third subscapularis above the new center of rotation following RTSA, which may result in improved ROM, strength and clinical results, as the subscapularis acts as an abductor in lower degrees of shoulder elevation. We believe that subscapularis plays a different role in lateral versus medial RTSA designs. If true, this would help explain the different results reported in the literature. As such, in a lateralized-design RTSA, subscapularis repair may be unnecessary since this design affords a greater degree of deltoid wrapping and resulting stability. In summary, subscapularis repair in the lateralized-RTSA design may result in excessive limitations in ER and abduction ROM without clinically important improvements in IR and stability. On the other hand, the non-lateralized design may benefit from subscapularis repair, which is less technically challenging and does not require high degrees of tension needed in lateralized RTSA [29]. Furthermore, because inferior scapular notching is more common and deltoid wrapping less significant than in lateralized designs, subscapularis repair contributes significantly to anterior stability in non-lateralized RTSA.

Our results demonstrate that there is no correlation between the radiographic status of the subscapularis muscle after repair and clinical outcomes. The effects of muscle fatty infiltration and degeneration on clinical outcomes has been matter of great interest, not only for shoulder [13] but also for hip surgery [27]. Recently, innovative CT scan-based methods of evaluation for fatty infiltration and atrophy were proposed [25]. Furthermore, Dedy et al [8] utilized sonography to evaluate the integrity of the subscapularis tendon at a mean follow-up of 19 months following RTSA. The authors found the tendon to be intact in only 13% of patients, absent in 23% patients and with various grades of attenuation in the remaining cases. No differences in patient reported and clinical outcomes were demonstrated between patients with intact and attenuated or absent subscapularis tendons. However, a significantly higher IR ROM was found in patients in whom the tendon was intact or mildly attenuated rather than absent and ER ROM did not differ according to subscapularis tendon quality. Similarly, De Boer et al [7] demonstrated that 40% of repaired subscapularis tendon maintain integrity after 36 months, but that the degree of tendon integrity did not correlate with ROM, strength and functional scales scores.

In our study a CT scan assessment of subscapularis muscle area was performed pre- and postoperatively. The overall reduction in subscapularis size, as expressed by postoperative SMCSA/SFCSA ratio and absolute SMCSA reduction, could be explained as the natural rotator cuff muscles degeneration developing after a mean follow-up of 74.6 ± 15.2 months in an elderly study population or as damage related to the surgical procedure [13,27]. Interestingly, the changes found in subscapularis did not affect clinical results and patients satisfaction reported at the same follow-up. Therefore, despite the reduction of SMCSA found, we support, if technically possible, to repair the subscapularis tendon for the associate advantages (greater implant stability, improved internal rotation, decreased dead space in the joint and reduced related complications).

Based on the results of the present investigation, we recommend subscapularis repair whenever tendon conditions permit, as doing so allows for excellent clinical outcomes, restoration of IR/ER ROM, and maintenance of strength, as well as increases stability of the implant. Further study will be necessary to better elucidate role and contribute of subscapularis in RTSA.

This study has several strengths. Firstly, the length of follow-up, because patients in the study cohort were examined at a mean 74.6 months after their operation. Secondly, all surgeries were performed by the same expert shoulder surgeon. Thirdly, the exclusion of difficult glenoid (A2, B2 and C [30]) allow reproducible surgical technique with 10° of glenoid inclination and 10° of humeral retroversion. Lastly this is the first study, to our knowledge, investigating the possible correlation between subscapularis condition on CT scan and clinical outcomes.

It also has several notable limitations: Firstly, the sample size of 32 is relatively small. However, in order to directly study the effects of subscapularis integrity on clinical and radiographic outcomes, precise inclusion and exclusion criteria were applied. Secondly, the absence of a control group to make comparison with not-repaired subscapularis or lateralized-design RTSA. However, the outcomes in these groups has been studied extensively in the literature. A further potential limitation was that a single examiner performed all CT scan evaluation.

Conclusion

Postoperative subscapularis size, expressed as SMCSA and SMCSA/SFCSA ratio, was significantly reduced in the majority of patients treated with non-lateralized RTSA design and concurrent subscapularis tendon repair at final follow-up. Higher preoperative SMCSA were correlated with greater reductions in postoperative SMCSA. Despite these subscapularis deteriorations, RTSA with subscapularis tendon repair is associated with a high degree of patient satisfaction, as well as statistically significant improvements in clinical outcomes and internal rotation ROM. A correlation between radiological findings and clinical outcomes was not found. Further studies would be necessary comparing RTSA with and without a concurrent subscapularis repair. Subscapularis repair may not be necessary to achieve good clinical results with a non-lateralized RTSA for rotator cuff arthropathy, although several advantages of the subscapularis repair can support its routinely use

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REFERENCES

[1] Armstrong A, Lashgari C, Teefey S, Menendez J, Yamaguchi K, Galatz LM. Ultrasound evaluation and clinical correlation of subscapularis repair after total shoulder arthroplasty. J Shoulder Elbow Surg 2006;15(5):541–8 https://doi.org/10.1016/j.jse.2005.09.013.

[2] Berhouet J, Garaud P, Favard L. Influence of glenoid component design and humeral component retroversion on internal and external rotation in reverse shoulder arthroplasty: a cadaver study. Orthop Traumatol Surg Res 2013;99(8):887–94. https://doi.org/10.1016/j.otsr.2013.08.008.

[3] Berliner JL, Regalado-Magdos A, Ma CB, Feeley BT. Biomechanics of reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2015;24(1):150–60. https://doi.org/10.1016/j.jse.2014.08.003.

[4] Boileau P, Watkinson DJ, Hatzidakis AM, Balg F. Grammont reverse prosthesis: design, rationale, and biomechanics. J Shoulder Elbow Surg 2005;14(1 Suppl S):147S–61S.

[5] Chalmers PN, Rahman Z, Romeo AA, Nicholson GP. Early dislocation after reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2014;23(5):737–44. https://doi.org/10.1016/j.jse.2013.08.015.

[6] Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 1987:(214):160–4.

[7] De Boer FA, van Kampen PM, Huijsmans PE. The influence of subscapularis tendon reattachment on range of motion in reversed shoulder arthroplasty: a clinical study. Musculoskelet Surg 2016;100(2):121–6. https://doi.org/10.1007/s12306-016-0401-8.

[8] Dedy NJ, Gouk CJ, Taylor FJ, Thomas M, Tan SLE. Sonographic assessment of the subscapularis after reverse shoulder arthroplasty: impact of tendon integrity on shoulder function. J Shoulder Elbow Surg 2018;27(6):1051–6. https://doi.org/10.1016/j.jse.2017.12.008.

[9] Edwards TB, Williams MD, Labriola JE, Elkousy HA, Gartsman GM, O'Connor DP. Subscapularis insufficiency and the risk of shoulder dislocation after reverse shoulder arthroplasty. J Shoulder Elbow Surg 2009;18(6):892–6. https://doi.org/10.1016/j.jse.2008.12.013.

[10] Flatow EL, Harrison AK. A history of reverse total shoulder arthroplasty. Clin Orthop Relat Res 2011;469(9):2432–9. https://doi.org/10.1007/s11999-010-1733-6.

[11] Friedman RJ, Hawthorne KB, Genez BM. The use of computerized tomography in the measurement of glenoid version. J Bone Jt Surg Am 1992;74(7):1032–7.

[12] Giles JW, Langohr GD, Johnson JA, Athwal GS. The rotator cuff muscles are antagonists after reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2016;25(10):1592–600. https://doi.org/10.1016/j.jse.2016.02.028.

[13] Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. Clin Orthop Relat Res 1994:(304):78–83.

[14] Hamilton MA, Diep P, Roche C, Flurin PH, Wright TW, Zuckerman JD, et al. Effect of reverse shoulder design philosophy on muscle moment arms. J Orthop Res 2015;33(4):605–13. https://doi.org/10.1002/jor.22803.

[15] Hansen ML, Nayak A, Narayanan MS, Worhacz K, Stowell R, Jacofsky MC, Roche CP. Role of subscapularis repair on muscle force requirements with reverse shoulder arthroplasty. Bull Hosp Jt Dis 2015;73 Suppl 1(2013):S21–7.
[16] Henninger HB, Barg A, Anderson AE, Bachus KN, Burks RT, Tashjian RZ. Effect of lateral offset center of rotation in reverse total shoulder arthroplasty: a biomechanical study. J Shoulder Elbow Surg 2012;21(9):1128–35. https://doi.org/10.1016/j.jse.2011.07.034.
[17] Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. J Bone Jt Surg Am 2011;93(24):2249–54. https://doi.org/10.2106/JBJS.J.01994.
[18] King JJ, Greene AT, Hamilton MA, Diep PT, Gil J, Wright TW, et al. The over-the-top subscapularis repair in reverse shoulder arthroplasty: biomechanical evaluation of a novel technique. JSES Open Access 2019;3(4):304–10. https://doi.org/10.1016/j.jses.2019.09.005.
[19] Langohr GD, Giles JW, Athwal GS, Johnson JA. The effect of glenosphere diameter in reverse shoulder arthroplasty on muscle force, joint load, and range of motion. J Shoulder Elbow Surg 2015;24(6):972–9. https://doi.org/10.1016/j.jse.2014.10.018.
[20] Miller SL, Hazrati Y, Klepps S, Chiang A, Flatow EL. Loss of subscapularis function after total shoulder replacement: a seldom recognized problem. J Shoulder Elbow Surg 2003;12(1):29–34. https://doi.org/10.1067/mse.2003.128195.
[21] Oh JH, Sharma N, Rhee SM, Park JH. Do individualized humeral retroversion and subscapularis repair affect the clinical outcomes of reverse total shoulder arthroplasty? J Shoulder Elbow Surg 2020;29(4):821–9. https://doi.org/10.1016/j.jse.2019.08.016.
[22] Roche CP, Hamilton MA, Diep P, Wright TW, Flurin PH, Zuckerman JD, et al. Optimizing deltoid efficiency with reverse shoulder arthroplasty using a novel inset center of rotation glenosphere design. Bull Hosp Jt Dis 2015;73(Suppl 1):S37–41.
[23] Rol M, Favard L, Berhouet J, la Société d'orthopédie de l'Ouest (SOO). Factors associated with internal rotation outcomes after reverse shoulder arthroplasty. Orthop Traumatol Surg Res 2019;105(8):1515–9. https://doi.org/10.1016/j.otsr.2019.07.024.
[24] Routman HD. The role of subscapularis repair in reverse total shoulder arthroplasty. Bull Hosp Jt Dis. 2013;71(Suppl 2):108–12.
[25] Terrier A, Ston J, Dewarrat A, Becce F, Farron A. A semi-automated quantitative CT method for measuring rotator cuff muscle degeneration in shoulders with primary osteoarthritis (2017). Orthop Traumatol Surg Res 2017;103(2):151–7. https://doi.org/10.1016/j.otsr.2016.12.006.
[26] Thomazeau H, Rolland Y, Lucas C, Duval JM, Langlais F. Atrophy of the supraspinatus belly. Assessment by MRI in 55 patients with rotator cuff pathology. Acta Orthop Scand 1996;67(3):264–8.
[27] Vadalà AP, Mazza D, Desideri D, Iorio R, Fedeli G, Scrivano M, et al. Could the tendon degeneration and the fatty infiltration of the gluteus medius affect clinical outcome in total hip arthroplasty? Int Orthop 2020;44(2):275–82. https://doi.org/10.1007/s00264-019-04468-x.
[28] Valenti P, Sauzières P, Katz D, Kalouche I, Kilinc AS. Do less medialized reverse shoulder prostheses increase motion and reduce notching? Clin Orthop Relat Res 2011;469(9):2550–7. https://doi.org/10.1007/s11999-011-1844-8.
[29] Vourazeris JD, Wright TW, Struk AM, King JJ, Farmer KW. Primary reverse total shoulder arthroplasty outcomes in patients with subscapularis repair versus tenotomy. J Shoulder Elbow Surg 2017;26(3):450–7. https://doi.org/10.1016/j.jse.2016.09.017. 2017.
[30] Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty 1999;14(6):756–60.