SEMINARS IN ARTHROPLASTY 33 (2023) 584–590

Available online at www.sciencedirect.com

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The impact of coracoid morphometry on internal rotation outcome in patients with cuff tear arthropathy treated with reverse shoulder arthroplasty

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ARTICLE INFO

Keywords:
Shoulder internal rotation
Internal rotation after RSA
Activity of daily living
Reverse shoulder arthroplasty clinical results
Range of motion after shoulder arthroplasty
Glenoid lateralization in reverse shoulder arthroplasty

ABSTRACT

Background: Functional internal rotation (fIR) motion remains a concern after reverse shoulder arthroplasty (RSA). The extreme variability of the coracoid morphometry together with the gain in tension of the conjoint tendon could impact internal rotation (IR) after RSA. Our aim was to evaluate the relationship between postoperative IR outcome and coracoid morphometry, evaluated as anteroposterior (AP) and mediolateral (ML) glenocoracoid distances in a 3-dimensional preoperative computed tomography scans, in a consecutive series of patients undergoing the same RSA implant.

Materials and methods: A retrospective analysis of a prospectively collected series of 40 patients (18 male, 22 female; mean age (standard deviation [SD]), 73.4 years [4.1]) submitted to RSA for cuff tear arthropathy was performed. fIR function was measured as the highest midline segment of the back that can be reached and converted into 5 range segments of motion. Participants were divided into 2 groups according to the fIR (group A, ≤ 6; group B, >6). Passive IR was also measured. The AP and ML glenocoracoid distances were measured, in millimeters, on the preoperative 3-dimensional computed tomography scans. Statistics were performed.

Results: The mean follow-up was 29 months (range, 24-39). The mean score for fIR was 6.45 (SD: 1.81) while the mean score for passive IR was 6.84 (SD: 1.75). No difference was found between fIR and passive IR ($P = .328$). No statistical difference was found between fIR and glenosphere size ($P = .562$) and fIR and size of the liner ($P = .429$). Significant statistical correlations have been found between AP and ML coracoid distances and the two groups (AP in group A: 28.50 and B: 31.265, $P = .034$; ML in group A: 23.053 and B: 14.27, $P < .001$).

Sapienza University of Rome institutional review board approved this study (no. 111/2020).

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https://doi.org/10.1053/j.sart.2023.05.003

Conclusions: Our study demonstrated that coracoid morphometry, evaluated as glenocoracoid distance, significantly impact IR outcomes in a 145° neck shaft angle RSA; in particular, a high ML glenocoracoid distance (>23 mm) was found to be determinant. This anatomical parameter should be considered in the preoperative planning of RSA and additional surgical strategies addressed in order to gain satisfactory fIR.

Level of evidence: Level IV; Case Series

Functional internal rotation (fIR) motion remains a concern after reverse shoulder arthroplasty (RSA). Many studies[4,22] have documented the persistence of a deficit or even a loss of internal rotation (IR) after surgery. Kim and colleagues[12] recently evaluated the consequences of this deficit in the ability to perform activities of daily living (ADLs) after RSA; no significant gain between preoperative and postoperative for 5 ADLs that require IR was found. In particular, only 36% of patients were able to wash their back or close their bra in the back at the final follow-up. In that series, the mean IR at the final follow-up was found to be only at L3. Furthermore, poor shoulder IR negatively impacts life quality of elderly patients and discourage some patients to undergo a contralateral RSA for fear of losing their independence, especially in personal hygiene practices.[9,29]

For this reason, numerous biomechanical and modeling studies[6,10,11,13-15,17,19,21,23,27,30] evaluated the implant and surgical-related factors associated with an ideal gain of IR motion; in particular, overhanging baseplate positioning, lateralization of the center of rotation, decreased glenosphere size and humeral insert thickness, a smaller neck shaft angle, a humeral retroversion <20° and an healthy subscapularis were found to be ideally correlated to a greater IR motion after surgery.

Ladermann et al[16] evaluated the effects of bony anatomy on RSA range of motion (ROM) with a specific focus on humeral, scapular neck, and glenoid morphometry and their relationship with scapular notching. Surprisingly, the coracoid morphometry has never aroused interest despite the extreme variability of the coracoid process has been demonstrated.[7] All RSA implants produce a distalization of the center of rotation[34] and, consequently, a gain in tension of the conjoined tendon leading to a possible anterior impingement depending on the morphometry of the coracoid process.

The purpose of our study was to evaluate the correlation between postoperative IR and coracoid process morphometry, evaluated as glenocoracoid distance in the preoperative 3-dimensional (3D) computed tomography (CT), in a consecutive series of patients undergoing the same RSA implant.

Materials and methods

A retrospective analysis of a consecutive series of 44 patients submitted to RSA (Medacta Reverse Shoulder System) with a minimum follow-up of 24 months was performed.

The initial diagnosis was cuff tear arthropathy for all participants. Exclusion criteria were applied: body mass index (BMI) >35; subscapularis irreparable tear, previous shoulder surgery, history of shoulder fracture; >10° of glenoid retroversion requiring correction.

Patients were placed in beach chair position under general anesthesia and interscalene nerve block. A deltopectoral approach was performed. A subscapularis tenotomy 1 cm medial to long head biceps tendon was done. A Medacta Reverse Shoulder Arthroplasty was implanted with a 145° neck shaft angle, 0° of humeral retroversion,[13] a 39 mm glenosphere size in males and 36 mm in females. In 13 and 15 cases, a +0 mm and a +3 mm liner was used, respectively. A short humeral stem was implanted in all participants. At the end of surgery, subscapularis tendon was reattached with 4 non-reabsorbable #2 sutures.

All patients were submitted to the same postoperative protocol which consists of 25 days of immobilization in an IR sling in order to protect subscapularis repair. Passive- and active-assisted shoulder ROM were allowed starting the day of sling removal with a daily session with experienced physiotherapist together with a self-managed rehabilitation program (10 minutes of exercise for ROM recovery repeated for six times per day).

At the last follow-up, fIR function was measured as the highest midline segment of the back that can be reached[5] by a single-blinded observer. As a means of controlling for measurement bias, the measurement was converted into 5 range segments of motion: 1: buttock/greater trochanter; 2: sacrum-L4; 3: L3-L1; 4: T12-T8; 5: >T7 and converted into a 10-point scale, as previously reported.[20] A subjective assessment was also performed allowing all participants to select the picture best representing their IR motion. The analysis was repeated for three times and the mean of the measurements was recorded. Participants were divided into 2 groups according to the fIR: group A: ≤6; group B: >6. Passive IR was also measured. The same measurements were recorded in the preoperative period.

The coracoid morphometry was assessed in the 3D bone models created on the CT scans by using the Medacta MyShoulder (https://www.medacta.com/EN/myshoulder), a software for both preoperative planning and measurements. The glenocoracoid distances in the anteroposterior (AP) and mediolateral (ML) planes were measured as described by Dugarte et al[3] and adapted to 3D models.[24]

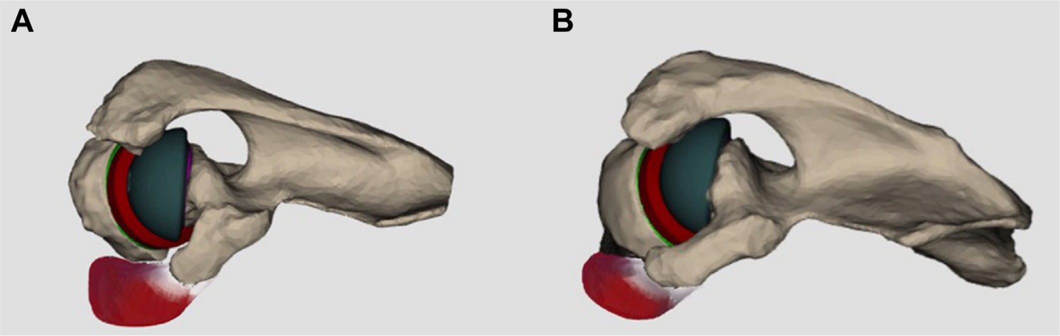

Figure 1 – 3D axial view: low (A) and high (B) ML glenocoracoid distance. *ML*, mediolateral; *3D*, 3-dimensional.

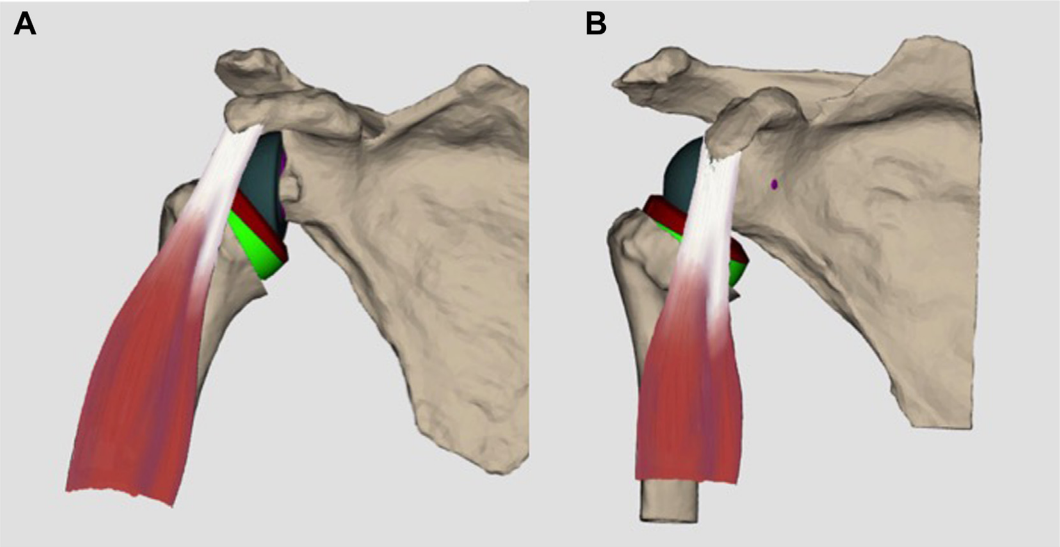

Figure 2 – 3D coronal view: high (A) and low (B) ML glenocoracoid distance. *ML*, mediolateral; *3D*, 3-dimensional.

Statistical analysis

The Shapiro-Wilk test was used to assess the normal data distribution. Categorical variables were ordinated using frequencies and proportions while continuous data have been estimated by means, standard deviations (SDs), and ranges.

An independent *t*-test was used to analyze differences between the 2 groups. One-way analysis of variance test or Kruskal-Wallis has been used to analyze differences between three or more groups. In addition, the Spearman's R correlation has been used for testing linear correlation between numerical data. Significant levels for multiple comparisons were adjusted using the Bonferroni procedure. Calculated *P* values were 2-tailed, a *P* value of < .05 was considered as significant and the range of confidence interval was 95%, when appropriate.

Statistical analysis was performed using JASP Team (2020; JASP version 0.14.1; https://jasp-stats.org/).

Results

The final study group was composed of 40 patients (18F; 22M; mean age 73.4 +- 4.1 range, 65-78; mean BMI: 29.2+-2.1) with a mean follow-up of 29 months (range: 24-39). No statistical correlations have been found between age and gender (P = .22). The mean preoperative glenoid version was −4.5 (SD 2.8). The glenocoracoid distances (Figs. 1-3), in both AP and ML planes, are reported in Table I. No linear correlation was found between AP and ML glenocoracoid distances (P = .265). No statistical correlation was found between BMI and AP (P = .453) or ML (P = .238) glenocoracoid distances and between BMI and fIR (P = .329). No statistical difference was found between fIR and glenosphere size (P = .562) and between fIR and height of the liner (P = .429).

The mean score for fIR was 6.45 (SD: 1.81) while the mean score for passive IR was 6.84 (SD: 1.75).

No significant difference was found between fIR and passive IR (*P* = .328) and between the measured fIR and the subjective patient assessment (*P* = .421). With respect to the preoperative period, the fIR was 6.55 (SD: 2.34). No differences were found between the preoperative and postoperative periods (*P* = .431).

Groups A and B were composed of 18 and 22 patients, respectively. Based on the postoperative fIR, descriptive results are reported in Table II.

Significant statistical correlations have been found between AP and ML coracoid distances and fIR; in particular: AP

Figure 3 – 3D sagittal view: high AP glenocoracoid distance. *AP*, anteroposterior; *3D*, 3-dimensional.

Table I – Anthropometric characteristics of the studied group.

	BMI	Glenocoracoid distance AP (mm)	Glenocoracoid distance ML (mm)
Mean	27.855	30.438	16.905
Standard deviation	1.88	1.81	5.7
Minimum	23	22.53	4.76
Maximum	33	32.76	29.02

AP, anteroposterior; *BMI*, body mass index; *ML*, mediolateral.

Table II – Glenocoracoid distances in group A and B.

	Glenocoracoid distance AP		Glenocoracoid distance ML	
	Group A	Group B	Group A	Group B
Mean	28.508	31.265	23.053	14.27
Standard deviation	1.969	0.887	5.463	3.284
Minimum	22.53	29.31	7.46	4.76
Maximum	30.41	32.76	29.02	19.8

AP, anteroposterior; *ML*, mediolateral.

distance was significantly lower in group A with respect to group B, $P = .034$; ML distance was significantly higher in group A with respect to group B, $P < .001$ (Fig. 4).

Discussion

The success of RSA in the treatment of shoulder pain and loss of function due to rotator cuff arthropathy is well-known.[1,2,26,31,32,33] However, the minimun or absent gain of IR after surgery is motive of discussion. In Latif et al,[18] Puskas et al,[25] Young et al,[34] and Kim et al[13] series, comparing ROM after RSA to both healthy and operated shoulders (with total shoulder arthroplasty), IR was found to be the worst clinical outcome. Recently, Hochreiter et al[8] performed a clinical study analyzing factors influencing IR after RSA. The authors concluded that poor postoperative fIR was associated to poor preoperative fIR, smoking, male gender, less preoperative to postoperative distalization of the greater tuberosity, a thin humeral insert height, and a high American Society of Anesthesiologists score.[8] In the last years, many authors attempted to modify the implant design, including those focusing on the lateralized humeral stem or lateralized glenoid baseplate, or change the surgical method, as in humeral component retroversion, to resolve these known issues of limited external and IR. However, no consensus regarding an effective approach has been reached.

This is the first study that analyzes the relationship between postoperative fIR and the anatomy of the coracoid/conjoint tendon complex. The glenocoracoid distance, in both AP and ML planes, of patients submitted to the same 145° RSA implant (Medacta Shoulder System) was correlated with both functional and passive IR. Patients in which the same surgical procedure was always performed were enrolled. Patients with glenoid erosion resulting in >10° of retroversion requiring correction and excessive medialization of the joint line were excluded. Only patients with functional and reparable subscapularis after tenotomy were enrolled in order to obtain reliable data regarding fIR; the same glenosphere size (39 mm for males and 36 mm for females) was implanted. As previously demonstrated, our study confirmed that IR is a real concern after RSA; in fact, only 58% of patients obtained a score >6, which is the score of IR needed to perform the ADLs and no differences were found comparing with the preoperative IR. In our series, the glenocoracoid distance was found to significantly correlate with fIR after RSA: a lesser AP and a greater ML glenocoracoid distances were correlated to the worst functional IR. In particular, the ML glenocoracoid distance seemed to have the major influence; in fact, in patients in group A

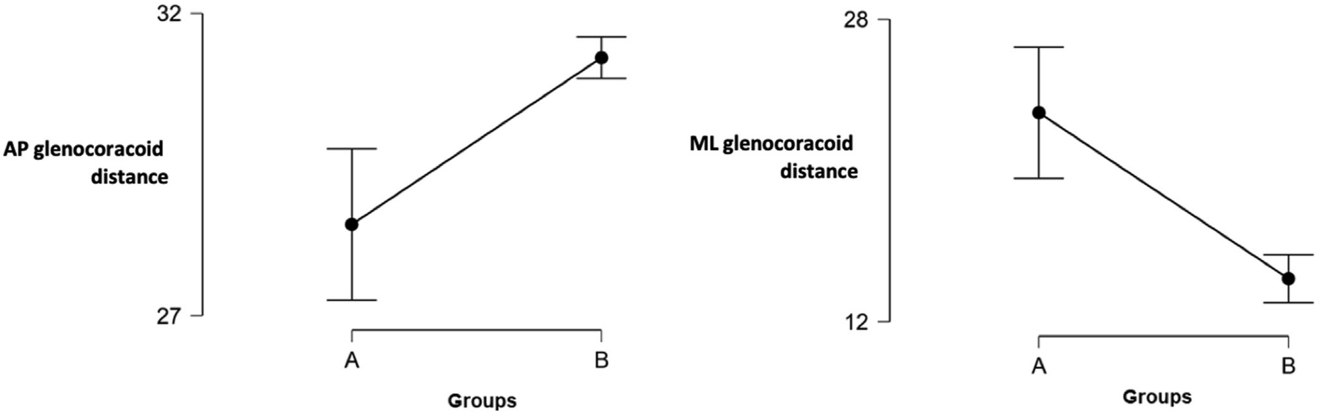

Figure 4 – **AP and ML glenocoracoid distances in groups A and B. (group A: ≤6; B: >6).** ***AP*****, anteroposterior;** ***ML*****, mediolateral.**

(IR < 6) and in group B (IR > 8), the mean ML glenoocoraoid distance was found to be 14 and 23 mm, respectively. Our data regarding coracoid anatomy are not surprisingly; previous anatomical studies on dry scapulae[7] documented the extreme morphological variability of the coracoid.

The low fIR after RSA may be explained by the anterior impingement that occurs between the proximal humerus/prosthesis and the coracoid-conjoint tendon complex. In fact, the vast majority of ADLs that require IR are performed with the adducted and extended shoulder contrary to those requiring external rotation that are performed in abduction.[13] In patients with cuff tear arthropathy, as those in our series, the distalization of the shoulder center of rotation inevitably involves an increase in tension of the conjoint tendons, which is proportional to the preoperative upward migration of the humeral head, miming a real “bony” impingement which justifies the IR deficit found in our series in patients with particular coracoid process morphometries. This hypothesis is also supported by the lack of significant difference between functional and passive IR in our group.

Our findings lead to several considerations:

1) The preoperative planning systems calculate the IR impingement free ROM of RSA considering only the coracoid process; usually, a greater internal ROM is usually furnished by the system, erroneously with respect to those of the postoperative clinical evaluation. It could be useful to add in the preoperative evaluation of the coracoid-conjoined tendon complex in order to furnish realistic data. Furthermore, the gain in tension of the conjoint tendon, due to the distalization of the centre of rotation, should also be furnished with the aim of avoiding excessive gain. Further studies are focusing on this aspect.
2) When treating patients with low AP and, in particular, a high ML glenocoracoid distances (>23 mm), additional surgical strategies should be considered in order to obtain a satisfactory IR; lateralization of the glenoid, with the aim of lateralizing the centre of rotation and detensioning coracoid-conjoined tendon complex, could be the better choice. Future research will analyze the correlation between AP and ML glenocoracoid distances and fIR in patients submitted to 145° neck shaft angle RSA with different degrees of glenoid lateralization. Interestingly, Werner et al[31] recently published their series of patients submitted to RSA concluding that glenoid lateralization influences IR.
3) In case of limited IR during the intraoperative check with the adducted shoulder, a conjoint tendon plasty (conjointplasty), consisting in a partial tendon release from the coracoid tip, in order to decrease tension, may be a savage procedure that surgeons should consider. A complete tendon release has been proposed recently by Tashjian et al[28] in case of persistent anterior shoulder pain in patients submitted to RSA. The authors demonstrated significant pain decrease after this procedure, but also the gain in shoulder ROM that may be related to the decrease of the anterior impingement with the coracoid-conjoined tendon complex.

The study has limitation that need to be assessed: it is a retrospective review and no postoperative CT scans were obtained; preoperative IR and postoperative distalization were not accounted for. However, the same procedure was always performed by the same surgeon in a single center; the same RSA implant was always used and the same postoperative protocol was applied; patients with the same preoperative diagnosis were enrolled in order to reduce bias. Furthermore, patients with BMI>35 were excluded in order to limit bias regarding fIR in these patients; in fact, in the obese, the abdominal engorgement forces the patient to performed IR associated with relative shoulder abduction; it leads to a decrease of the coracoid-conjoined tendon complex tension and therefore to a decrease of the impingement during fIR.

Conclusions

Our study demonstrated that coracoid morphometry, evaluated as glenocoracoid distances, significantly impact IR outcomes in a 145° neck shaft angle RSA; in particular, a high ML glenocoracoid distance (>23 mm) was found to be determinant. This anatomical parameter should be considered in the preoperative planning of RSA and additional surgical strategies addressed in order to gain satisfactory fIR.

Disclaimers:

Funding: No funding was disclosed by the authors.

Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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