


Reverse Total Shoulder Arthroplasty for Treatment of 3- and 4-Part Proximal Humeral Fractures: Clinical and Radiological Analysis With Minimum Follow-Up of 2 Years

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Abstract

Background: Hemiarthroplasty has been associated with inferior and unpredictable outcomes when used in the treatment of complex proximal humeral fractures in elderly patients. In this age-group, reverse shoulder arthroplasty is gaining popularity due to the promising results presented in recent evidence. Our aim is to analyze the cases of complex proximal humeral fractures treated by reverse shoulder arthroplasty, regarding functional results and complications. **Materials and Methods:** Thirty-five fractures from 33 patients with the mean age of 73.5 (65-81) years were treated with reverse shoulder arthroplasty for complex fractures of the proximal humerus. These patients were followed for a mean of 38.3 months (24-68) and analyzed regarding clinical outcomes and complications. **Results:** The average Quick-Disabilities of the Arm, Shoulder and Hand and American Shoulder and Elbow Surgeons scores were 6.8 points and 78.3%, respectively. The mean Constant score on the affected side was 64.4 points, 19.5% less than the nonoperated side. The mean active elevation was 123°, abduction 109°, external rotation 38°, and internal rotation 41°. The radiographic tuberosity healing rate was 85.7%. There were no significant differences in outcomes, between patient with healed and reabsorbed tuberosities. Inferior scapular notching was seen in 8 patients. The global complication rate was 12.8%. **Conclusion:** Reverse shoulder arthroplasty yields good and reproductive results with acceptable complication rates in selected elderly patients with complex proximal humeral fractures.

Keywords

proximal humeral fracture, reverse shoulder arthroplasty, tuberosity, shoulder, outcome

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Introduction

Proximal humeral fractures are increasing in frequency due to the aging of the population observed in the last decades. Approximately 80% of all proximal humeral fractures are minimally displaced and can be treated conservatively, with the remaining requiring surgery to achieve an acceptable functional outcome.¹⁻³ If fracture reconstruction is possible, there is a trend for open reduction and internal fixation (ORIF); however, literature is not consensual if it leads to improved outcomes compared with conservative treatment.⁴⁻⁷

Hemiarthroplasty is used in the cases not amenable to ORIF, leading to an effective pain relief but unpredictable functional outcomes.⁸⁻¹⁴ The success of this procedure relies, among other aspects, in proper tuberosity position and consolidation.^{9,15} To minimize the risk of postoperative tuberosity displacement, a

strict and long rehabilitation protocol must be implemented, posing a challenge when it comes to elderly patients with osteoporotic bone, severe comorbidities, cognitive deficits, and limited access to therapy.

Reverse shoulder arthroplasty (RSA) has been used for quite some time in the treatment of rotator cuff arthropathy since it optimizes the lever arm of the deltoid, decreasing the importance of rotator cuff, mainly in forward elevation.¹⁶ Recently,

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RSA has been used in the management of proximal humeral fractures in an attempt to overcome some of the limitations of hemiarthroplasty. So far, consistently satisfactory outcomes have been published in a few short-term follow-up series, with roughly the same complication rates as hemiarthroplasty.¹⁷⁻²⁴ Despite RSA outcomes improve with tuberosity union, an acceptable range of motion (ROM) can be still be achieved even without tuberosity healing.^{17,25} Nonetheless, to present day, there are limited data regarding long-term outcomes of RSA in these context.²⁶

The purpose of this study is to retrospectively analyze the functional and radiographic outcomes of complex proximal humeral fractures treated with RSA and to understand what variables may influence them.

Materials and Methods

From 2013 to 2017, we operated on 39 shoulders of 37 patients with complex proximal humeral fracture. In all patients, an RSA was performed by 2 surgeons from our institution. Three patients were lost to follow-up before 24 months. One died a few days postoperatively for reasons unrelated to surgery and was also excluded. Another patient died 2 years after surgery and will be included in this series.

Hence, 33 patients (35 fractures), 2 men and 31 women, with the mean age of 73.5 (65-81) years, were included in this study. All patient had computed tomography scan preoperatively that showed severe comminution of the tuberosities and poor bone stock, predicting poor results with osteosynthesis. The fracture pattern, as described by Neer,^{2,3} was a 3-part fracture in 10 cases and a 4-part in 25. Two patients had an associated dislocation.

Functional outcomes were measured through the Quick Disabilities of the Arm, Shoulder, and Hand (Q-DASH) and American Shoulder and Elbow Surgeons (ASES) scores.^{27,28} The Constant-Murley score,²⁹ flexion, abduction, internal rotation, external rotation, and abduction strength were obtained in both arms, using the contralateral shoulder as an estimative of pre-injury function.

Strength of abduction was measured with the arm abducted at 90° pulling upward (isometric contraction) against the resistance of a spring balance.³⁰ External and internal rotation were measured with a goniometer with the patient supine and the arm at 90° of abduction, the elbow was stabilized by the observer, and the patient was asked to rotate the arm inward and outward.

A radiographic analysis was performed by 2 senior orthopedic surgeons independently based on an anteroposterior view in neutral rotation and an axillary view. If they disagree, the X-rays were reviewed between them to reach an agreement. Greater tuberosity was classified as consolidated if it was in anatomical position in both views and nonconsolidated if it was displaced or reabsorbed. Inferior scapular notching (according to Sirveaux classification) and evidence of loosening were also analyzed.³¹

Surgical Technique

The patients were placed in a beach chair position and operated under a combination of general anesthesia and brachial plexus block. A deltopectoral approach was used in all cases. The tuberosities were identified and retracted for better exposure (Figure 1). If the long portion of the biceps was present, it was detached and a tenodesis to pectoralis major tendon was performed in the end. If the lesser tuberosity (LT) was attached to humeral head, an osteotomy of the LT was done. The glenoid baseplate was fixed in the center of the glenoid using 2 locked screw and 2 lag screws. For optimal glenosphere position, an eccentric or a standard glenosphere diameter was chosen for best fit. The same principle was applied when choosing the diameter size. The length of the humeral component was measured with a trial and the definitive cemented Monobloc Implant was fixed at the appropriate height at 30° of retroversion. The polyethylene insert height was also tested for optimal tension and stability. Lastly, the tuberosities were reattached around the prosthesis using high-resistance sutures (Figure 2). In the cases with severe metaphyseal destruction, bone graft or bone substitute was used to fill in the space between the metaphysis and the tuberosities. The wound was closed in a standard fashion, and before skin closure, the articular space was infiltrated with gentamycin. A drain was left in place, opened after 2 hours, and maintained for 24 hours.

Postoperative Care

After surgery, the patients was placed in a sling for 2 weeks for pain management. They started physiotherapy the day after surgery with passive ROM of the shoulder. Hospital discharge occurred about the third day after surgery and physiotherapy was encouraged to be maintained. Patients were allowed to start active ROM at 6 weeks postoperatively and heavy lifting at 12 weeks.

Statistical Analysis

Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences) version 23. Nominal data were evaluated using χ^2 test. Pearson correlation test was also used to correlate mobility with outcome scores.

Spearman analyses were applied to correlate outcome scores with tuberosity healing and notching. A *P* value inferior to .05 were considered statistically significant.

Results

The patients were followed for a mean of 38.3 months (24-68). The majority were pain-free during their daily activities. Seven patients referred minor pain in their usual activities.

The mean ASES and Quick-DASH scores were 78.3% (range: 30%-98%) and 6.8 points (range: 0-49.9), respectively. The mean Constant score (CS) was 64.4 points (38-85 points), 15.6 points (19.5%) less than the nonoperated side. The

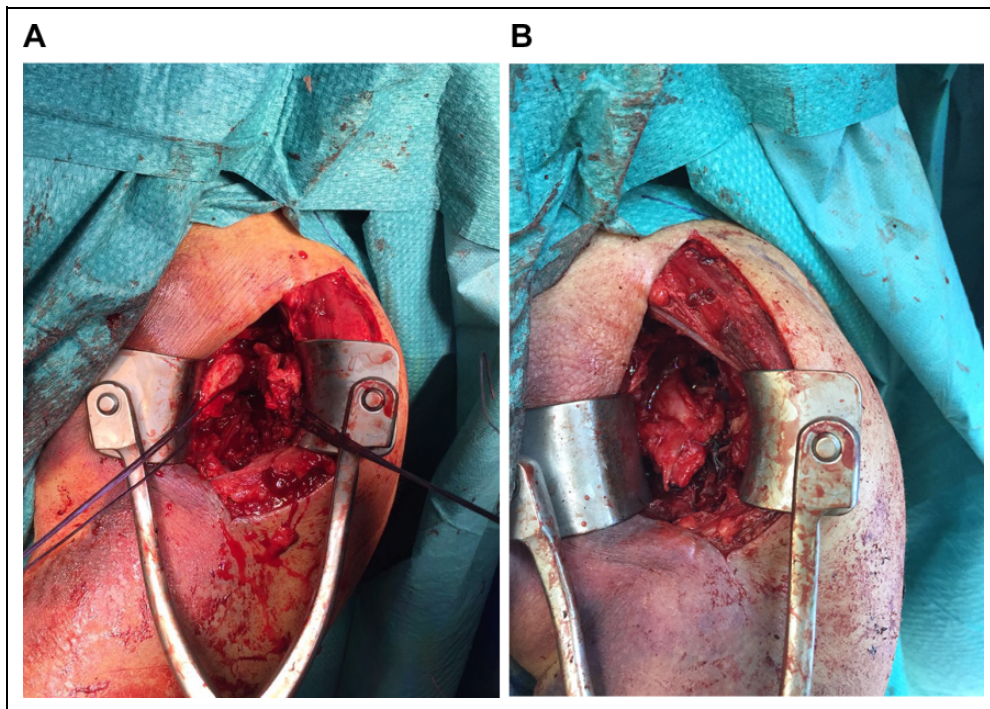


Figure 1. Tuberosities were identified and retracted with sutures (A) and, in the end of the procedure, were reattached around the metaphyseal section of prosthesis (B).



Figure 2. Postoperative imaging shows grade 3 notching in a 77-year-old woman.

average active elevation was 123° (range: 70° - 160°), abduction 109° (range: 70° - 140°), external rotation 38° (range: 0° - 70°), and internal rotation 41° (range: 5° - 70°). The differences between the operated and the contralateral side are summarized in Table 1. We found no correlation between the age of the patient and ASES score ($P = .23$) or Q-DASH score ($P = .77$). We found a negative correlation between the difference in external rotation and the ASES score ($P = .037$). There was

no correlation between any of the other parameters measured with the outcome scores.

The overall radiographic tuberosity healing rate was 85.7% (30/35). We found no correlation between tuberosity healing and internal ($P = .39$) or external rotation ($P = 0.26$). There were no significant differences in outcomes, between patient with healed and reabsorbed tuberosities ($P = .21$). Inferior scapular notching was seen in 8 patients: 5 patients with notching grade 1, 2 with grade 2, and 1 grade 3 (Figure 2). Patients with radiological notching had similar outcomes and complication rates compared with those without evidence of notching.

Complications

From the total of 39 shoulders operated (37 patients), we had 2 infections. One case 2 months after surgery and had the implants removed. This patient was followed until 4 months after revision but since then he missed all the next appointments. We know that he died 2 years later of medical reasons. The other 18 months postoperatively and was revised for a cement spacer. Despite the functional outcomes were poor, this patient was pain-free and refused a later revision for RSA.

We report one case of dislocation with great tuberosity displacement occurred at the second week postoperatively. This patient was reoperated with reduction in the prosthesis and refixation of the great tuberosity (Figure 3). Despite the tuberosity never consolidated, no more dislocations occurred. Her Q-DASH and ASES scores were 18.2 and 68.3, respectively.

Two patients had periprosthetic fractures of the humerus. One case had a well-aligned fracture just under the tip of the

Table I. Difference Between Sides of Constant Score and Shoulder Mobility.

| Measurement | Operated Shoulder ^a | Contralateral Shoulder ^a | Difference | Difference (%) |
|-------------------------------|--------------------------------|-------------------------------------|------------|----------------|
| Constant score (points) | 64.4 (38-85) | 80 (61-98) | 15.6 | 19.5% |
| Active anterior elevation (°) | 123 (70-160) | 148 (95-180) | 25 | 16.9% |
| Active abduction (°) | 109 (70-140) | 131 (100-170) | 22 | 16.8% |
| External rotation (°) | 38 (0-70) | 68 (35-90) | 30 | 44.1% |
| Internal rotation (°) | 41 (5-70) | 63 (5-90) | 22 | 34.9% |
| Abduction strength (kg) | 5.1 (0.11-9) | 6 (0.2-10.5) | 0.9 | 15% |

^aThe values are given as the mean and the range.

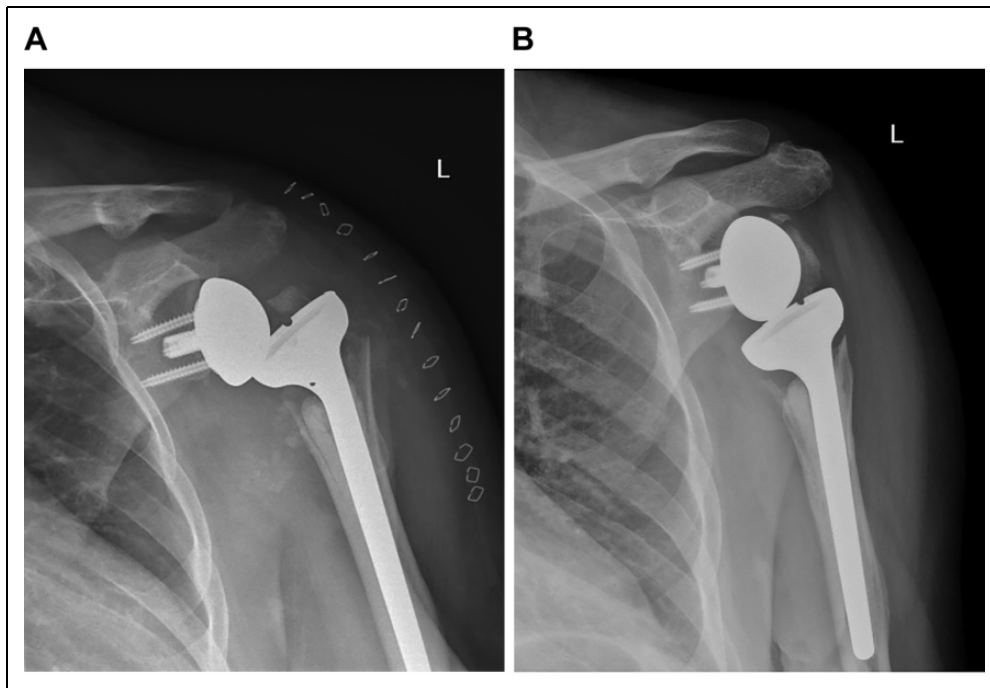


Figure 3. Postoperative radiographs of a 65-year-old woman who sustained a dislocation of the prosthesis with great tuberosity displacement (A). The patient was treated with surgical reduction and fixation of the great tuberosity (B).

stem and was treated conservatively with a sling and later a Sarmiento brace and it healed uneventfully after about 4 months. The other had a more displaced pattern and was treated surgically. The prosthesis was well attached to the proximal humerus and an open reduction with internal fixation was performed. The patient was last evaluated at 1 year after osteosynthesis and regained most of her former shoulder function and was satisfied with the outcome (ASES: 78; Q-DASH: 0). Hence, the global complication rate was 12.8% (5 cases), and 4 shoulders needed a revision surgery (10.3% reoperation rate).

Discussion

Three-part and 4-part proximal humerus fractures are a challenge, mainly because it occurs in elderly patients with bad bone stock, thus creating a problem for osteosynthesis. In fact, this solution leads to an unacceptable rate of complications, and so the arthroplasty is probably the best option. Latest evidence supports that RSA yields better outcomes than hemiarthroplasty

in these patients.³² Complication rates are reported heterogeneously, possibly because some are specific to one procedure. A recent meta-analysis by Lädermann et al found that only 3 studies directly compared these 2 techniques, reporting a total complication rate of 6% to 35% for RSA and of 20% to 30% for hemiarthroplasty and a revision rate of 0% to 3% for RSA and of 3% to 20% for hemiarthroplasty.^{21,24,33,34}

Based on this evidence, RSA is our treatment of choice in this cases. Another reason we also favor RSA over hemiarthroplasty is the limited access to physiotherapy in our population.²⁵ Table 2 summarizes some of the recent papers on the use of RSA for acute fractures.

Although in recent years a tendency toward RSA in complex fracture patterns is evidenced in the literature, its indication are not clear nor consensual. In our series, the indication for RSA was based on several factors, such as the biological age of the patient, the comminution of the tuberosities, severe osteopenia, size of calcar attached to articular segment, and disruption of the medial hinge.

Table 2. Summary of Literature Reporting Proximal Humerus Fractures Treated With RSA.

| Study | n | Mean Follow-Up | ASES | Constant Score | Forward Elevation | Abduction | External Rotation | Complication Rate |
|-------------------------------------|----|----------------|------|----------------|-------------------|-----------|-------------------|-------------------|
| Valenti et al ⁴⁰ | 27 | 22.5 | – | 54.9 | 112 | 97 | 55 | 7% |
| Klein et al ²³ | 20 | 33.3 | 68 | 53 | 122 | 112 | 25 | 15% |
| Buquin et al ³⁶ | 43 | 22 | – | 44 | 97 | 86 | 30 | 28% |
| Cazeneuve, Cristofari ¹⁷ | 36 | 6 years | – | 53 | 7.5 on CS | 6.5 on CS | 1 on CS | 19% |
| Lenarz et al ¹⁸ | 30 | 23 | 78 | – | 139 | – | 27 | 10% |
| Garofalo et al ³⁵ | 87 | 27 | – | – | 137.7 | – | 29.1 | 6% |
| Grubhofer et al ³⁸ | 51 | 35 | – | 62 | 118 | 111 | 18 | 5% (revision) |

Abbreviations: ASES, American Shoulder and Elbow Surgeons Shoulder; CS, Constant score; RSA, reverse shoulder arthroplasty.

The CS of 64.4 achieved in our study is comparable to other reported series. The proximity of the scores from different studies is indicative of the reliability of this procedure in the matter of functional outcome. Regarding forward flexion, the 123° achieved was average compared to other studies. Two series reported more than 130° of forward flexion, and only one reported less than 100°. ^{18,35,36} Inferior scapular notching is a frequent finding in RSA, although its true impact in patient outcome is still not well established. In this series, we did not find any correlation between this finding with functional outcomes and complications.

Recent literature support that shoulder rotational ability is improved by anatomically fixing the tuberosities around the implant. A study by Gallinet et al³⁷ compared patients who undergo tuberosity excision or fixation during RSA. They found that 66% of the fixated tuberosities healed in anatomic position, resulting in an improved external rotation and outcome scores. Another study by Garofalo et al³⁵ found a positive correlation between improved active elevation, internal and external rotation, and radiographic healing of the great tuberosity. A retrospective study by Grubhofer et al³⁸ with 51 patients found that those with a resected or displaced greater tuberosity had an inferior outcome. Although we found differences, both in external rotation and outcome scores, between patients with healed and nonhealed tuberosities, they did not reach statistical significance. This is probably due to the small number of patients with nonhealed tuberosities (5 cases) and also to the overall small sample size of this series.

The negative correlation found between the deficit of external rotation and the ASES score supports the notion that this movement of major importance in the daily life activities of these patients. It is also an argument in favor of the careful and anatomic reconstruction of the great tuberosity. A recent study by Formaini et al³⁹ utilizing the “black and tan” method (hybrid cementation-impaction grafting technique) reported a tuberosity healing rate of 88%,³⁹ close to the 85.7% achieved in our study. This high rate of consolidation may be due to the medialization of the center of rotation causing lesser tension on the tuberosities.

We notice that both the patients with infection had heavy medical comorbidities, which may not have been the best

candidates for surgery. In this regard, the authors recommend caution in patient selection, especially with obese diabetic patients.

Limitations

This study has several limitations. Both time of initiation and duration of physiotherapy may influence functional outcomes. In this study, due to local logistic restraints, patients may had different physiotherapy protocols and some did not even do any physiotherapy after hospital discharge. The surgeries were performed by 2 surgeons, that despite following the same technique, some details may vary.

Conclusion

According to latest evidence, we can state RSA is a valid and reliable option in selected elderly patients with complex proximal humeral fractures. It enables patients to do their daily living tasks more consistently than with hemiarthroplasty, with similar complication rates.

We believe that the correct tuberosity fixation and subsequent healing were a major contributor to the results achieved in this series and also a good predictor of outcome.

Despite the high healing rates, internal and external rotation are always inevitably reduced. This should be the focus of future research, in an attempt to overcome this limitation.

Authors' Note

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The manuscript has been read and approved by all authors. Each author believes that the manuscript represents honest work.


Declaration of Conflicting Interests

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