Reverse shoulder arthroplasty for acute proximal humerus fractures: a systematic review

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Background: Proximal humerus fractures are one of the most common fractures among elderly patients. We performed a systematic review to detail the demographics, outcomes, and complications of patients who undergo reverse shoulder arthroplasty for complex proximal humerus fractures.

Methods: A systematic review of the literature was performed. Two reviewers assessed and confirmed the methodical quality of each study. Studies that met our criteria were assessed for pertinent data, and when available, similar outcomes were combined to generate frequency-weighted means.

Results: Nine studies met the inclusion and exclusion criteria for this review. The frequency weighted mean age was 77.5 years and the mean follow up was 43.2 months. Females comprised 90.4% of the patient population. Four-part fractures were most commonly encountered. The frequency weighted mean Constant's score was 55.9. Frequency weighted mean active forward flexion, abduction, and external rotation at neutral were 122°, 97°, and 18°, respectively. Tuberosity repair was associated with significantly higher external rotation compared to no repair (24° vs 15°; P = .0003). The most common complication was scapular notching (32%) while the impact of this finding remains unknown.

Conclusion: Pooled data and frequency weighted mean outcomes showed that RSA patients tend to be elderly women and still have postoperative dysfunction despite well-controlled pain. Repair of the greater tuberosity allows greater range of motion in patients.

Level of evidence: Level IV, Systematic Review.

Keywords: Reverse shoulder arthroplasty; proximal humerus fractures; systematic review; outcomes; complications; meta-analysis

Proximal humerus fractures are the third most commonly encountered fracture following hip and distal radius fractures.1 The type of treatment used is dependent on variables such as patient age, functional status and co-morbidities, fracture pattern, and classification.29 Complex fracture patterns, those that fail nonoperative modalities or occur in polytrauma patients, may require operative management.

Reverse shoulder arthroplasty (RSA) has gained acceptance for the management of elderly patients with rotator cuff pathology with shoulder pain and dysfunction.16,21,26,32 In addition, RSA is increasingly being used for the management of complex proximal humerus fractures traditionally treated with humeral head replacement and...
tuberosity repair. The outcomes and efficacy of RSA for fracture remains to be fully elucidated with a paucity of adequate literature.

The purpose of this study was to critically evaluate the outcomes of RSA for acute treatment of proximal humerus fractures reported in the current literature and present a synthesized systematic review.

Specifically, we attempted to determine:

1. The demographics and fracture patterns of patients who undergo RSA for treatment of proximal humerus fractures;
2. The outcomes including formal functional scores and range of motion (ROM) following RSA for proximal humerus fractures;
3. The effect of tuberosity repair on range of motion following RSA for proximal humerus fractures;
4. The rate and type of complications after RSA for proximal humerus fractures.

**Materials and methods**

We used PubMed, SCOPUS, and EMBASE computerized literature database to search all years from the beginning of the databases through March 2013. Articles were retrieved by an electronic search of keyword terms and their respective combinations (Table I). Inclusion criteria for studies in this systematic review were studies that: (1) were written in the English language; (2) followed patients for a minimum of 12 months; and (3) reported explicit outcome data. Exclusion criteria for this systematic review were: (1) any study that was a review article, case report, conference paper, or technique article without reported patient data; (2) studies without explicit inclusion criteria; or (3) studies that included fracture etiologies among other etiologies but did not have explicit data reported for the fracture group.

The electronic search was performed by 2 authors, who then independently reviewed the references of the qualifying papers and selected the appropriate studies on the basis of the inclusion and exclusion criteria. Papers were first excluded if their titles were clearly unrelated to the study question. Papers that included one or more relevant keywords in their title moved to the abstract phase, and again papers were selected based on the inclusion criteria. Once a paper was selected by either author from this phase, it moved to the full text review phase. During this final phase, one author reviewed the full text of all remaining qualifying articles for articles that did not fit the above criteria. A second author confirmed the first author’s exclusions with no disagreements.

We initially obtained 833 unique articles using the criteria presented in the Figure 1. Four hundred seventy-seven titles were excluded because of irrelevance to the study question, or were indicated as being a review, editorial, conference paper, or case report. Next, 308 articles were excluded based on review of the associated abstract. These articles were eliminated if they failed the above study criteria. Any abstract that had any potential to address the study question moved to the full text stage. Full text review of the remaining 48 articles excluded 39 because of failure to meet our inclusion and exclusion criteria. One additional paper was identified during this stage that was not among the 48 full text articles. Its full text was also reviewed, but was excluded because it did not meet the inclusion criteria. Of note, 4 of the 48 full text review articles were from the same author and reported data on the same patient cohort at progressively later follow-up points. Only the most recent paper was included, which provided the longest follow-up data.

This systematic review ultimately obtained 9 articles for analysis. References were manually searched for additional titles that fit the inclusion criteria, which were screened in the same systematic manner. No additional articles were identified in this process that fit the inclusion and exclusion criteria.

No study included a nonoperative control group. Two studies compared reverse shoulder arthroplasty to an alternate surgical treatment. One study compared alternate surgical approaches, with one group undergoing tuberosity repair and the other group having tuberosities that were discarded. Only one study included patients with several different etiologies for RSA, including fracture, the etiology of interest. Data were reported by subgroup for outcomes and ROM, but not for complications or radiologic abnormalities; therefore, these patients were not included in our summative results on complication incidence. Only one author included preoperative data along with postoperative outcomes scores.

All papers used statistical analyses to present their data, but only 4 authors used multivariable or stratified statistical analyses to control for confounding factors. Every study contributed patient demographic data. In situations where more than one study contributed data for an identical outcome measure, data were pooled in order to generate frequency-weighted values and summary outcomes. These values represent the mean value for a study weighted by the included number of patients from that study. Student t-test was used to compare frequency weighted means between different subgroups. Besides length of follow-up, there were no instances where standard deviations or ranges were reported uniformly across an outcome, so standard deviations are unable to be reported in this analysis.

**Results**

Nine studies fulfilled all inclusion and exclusion criteria and were included in this systematic review. Three studies were published as level-IV evidence and 6 as level-III evidence. No studies were level II or higher. Six of the 9 studies evaluated a uniform cohort of patients treated with reverse arthroplasty for acute proximal humerus fracture, and 1 study evaluated fracture patients as an individual subgroup along with other
etiologies of cuff tear arthropathy and revision of a failed conventional arthroplasty. Two studies evaluated an additional comparison group of patients treated with hemiarthroplasty for acute proximal humerus fracture. Six studies were retrospective and 3 were prospective. Seven studies evaluated patients treated at one institution. One study evaluated patients at 3 institutions and another study was a retrospective review of the New Zealand Joint Registry. All 9 studies were published between the years 2008 and 2013. All studies recorded the years in which operations were performed, which were between 1993 and 2010. Indications for RSA were always an acute proximal humerus fracture. Only 2 studies explicitly stated exclusion criteria: one stated presence of infection, glenoid deformity, muscular disease, neurovascular disease, dementia, or American Society of Anesthesiologists score $>$3; and one stated age less than 65 years old and history of previous fracture treatment.44

Demographics

There were a total of 265-274 patients (range, 7-55 per study) at baseline in the 9 studies, with 1 shoulder replaced per patient. Demographic data are presented in Table II. One study included 2 other indications for RSA and reported demographic data means for the entire patient dataset only, but did report specific fracture group data for postoperative outcomes. As a result, demographic data from this study was not included in the demographic analysis. The frequency-weighted mean age was 77.5 years (range, 57-94). All studies except for one reported demographic data on sex, with 208 (90.4%) females and 22 (9.6%) males. Two studies reported whether the dominant shoulder was operated on, with 30 (50%) operations on the dominant side and 30 (50%) operations on the nondominant side. One study included 2 patients who had undergone prior rotator cuff surgery on their affected shoulder 6 months and 3 years, respectively, before their injury.

Surgical technique

Five studies used the standard deltopectoral approach. 2 used the supero-lateral approach (with 1 patient receiving deltopectoral approach), 1 study used the juxta-acromial approach, and 1 did not report their approach.44

Outcomes

A total of 247 patients (range, 7-55) were reported in the final postoperative analyses among all 9 studies. Because one study did not explicitly report lost to follow-up data for their fracture...
we report between 18 (6.5%) and 27 (9.8%) patients lost to follow-up among the 9 studies. Frequency-weighted mean follow-up was 43.2 ± 12.7 months (range, 12-204).

Functional and pain outcomes are summarized in Table III. Functional outcomes measured were American Shoulder and Elbow Surgeons (ASES), Simple Shoulder Test (SST), Disabilities of Arm, Shoulder, and Hand (DASH), Oxford Shoulder Score (OSS), SF-36 functional outcome, Constant score (CS), and CS modified by the authors for age and gender (mCS). One study reported outcomes for 2 separate surgical methods (tuberosity repair versus no repair), so values reported in Table III for that study represent frequency weighted means of the 2 groups. Outcomes with more than one study reporting an identical measure are reported here. Four studies (n = 67) reported ASES scores, with a frequency-weighted mean of 73.9. Five studies (n = 145) reported the CS, with a frequency-weighted mean of 55.9. Pain scores were reported as CS pain component, Visual Analog Scale (VAS), ASES, and SF-36. Four studies (n = 125) reported CS pain component on a scale of 0-15, where 15 is no pain, with a frequency weighted mean of 12.7. Two studies (n = 37) reported a VAS pain score on a scale of 0-5, where 0 is no pain, with a frequency weighted mean of 0.9. Two studies (n = 17) reported an ASES pain score on a scale of 0-50, where 50 is no pain, with a frequency weighted mean of 42.9.

Range of motion (ROM)

ROM outcomes reported were active forward elevation, abduction, external rotation at neutral (0° of abduction), active external rotation at 90° abduction and hand-in-back internal rotation. Seven studies (n = 155) reported forward elevation outcomes with a frequency weighted mean of 122°. Five studies (n = 115) reported active abduction outcomes with a frequency weighted mean of 97°. Six studies (n = 135) reported active external rotation at neutral with a frequency weighted mean of 18°. Four studies (n = 108) reported active external rotation at 90° abduction with a frequency weighted mean of 32°. Five studies (n = 117) reported values for maximum hand-in-back internal rotation, with a range from side to T12.

Tuberosity repair and ROM

ROM outcomes from studies which repaired the greater tuberosity intra-operatively were compared with studies that did not. For the tuberosity repair subset, one paper reported results for one group of patients that received greater tuberosity repair as well as for one group that did not, and each group was added to their respective subset for our data analysis. Two studies reported outcomes for patients who received repair of both tuberosities.
study reported results for a subset of patients receiving greater tuberosity repair for external rotation at neutral. One study reported results for forward elevation and external rotation at neutral for 10 patients who were analyzed, and then included data for the one patient who did not receive tuberosity repair; from this dataset, we calculated the mean outcome values for the remaining 9 patients who received tuberosity repair. For the tuberosity nonrepair subset, 2 studies were included that reported ROM outcomes, one of which was the aforementioned study with 2 comparison groups, as well as a study in which no patients received tuberosity repair. Studies that did not report their operative technique or report ROM outcomes were excluded from this analysis.

Frequency weighted means of ROM with and without greater tuberosity repair were compared (Table IV). Active forward elevation was greater in patients with greater tuberosity repair than in those without repair (126° vs 112°, \( P < .0001 \)). Active external rotation at neutral was greater in patients with greater tuberosity repair than in those without (24° vs. 15°, \( P = .0003 \)). Similarly, external rotation at 90° abduction was greater in patients with greater tuberosity repair than in patients without (38° vs 4°, \( P < .0001 \)).

**Radiographs/complications**

All studies commented on radiographic outcomes and complications of RSA. One study did not report complications, so their patients were excluded from the total dataset. Another study reported complications only for their entire dataset, which included other indications for RSA besides fracture, and their patients were thus excluded from this analysis, leaving a total of 172 patients. Finally, for scapular notching, only studies that reported on or stated that they evaluated scapular notching were included in this dataset. There were 55 (32.0%) instances of scapular notching, 15 (8.7%) instances of ectopic ossification, 14 (8.1%) instances of inferior spurs, 4 (2.3%) instances where humeral bone loss was noted, and 4 (2.3%)
instances of baseplate loosening/progressing radiolucent lines at the glenoid border. Complex sympathetic dystrophy was reported in 3 (1.7%) patients. Dislocations occurred in 6 (3.5%) patients, infection occurred in 5 (2.9%), revisions were outright reported twice (1.2%) while 1 study noted 1.7 revisions per component year, and there was 1 (0.6%) instance each of deltoid paresis, acromion fracture, lower extremity deep vein thrombosis, and lymphedema. No hematomas or peri-prosthetic fractures were reported.

Discussion

RSA has proven to be a reliable treatment option for patients with rotator cuff arthropathy and pseudoparalysis. Its utility for treatment of complex proximal humerus fractures is a relatively new concept. Following the pioneering work of Neer on treatment of 3- and 4-part proximal humerus fractures, hemiarthroplasty was considered the surgical treatment of choice for these fractures. However, subsequent analysis of outcomes has revealed that hemiarthroplasty when used to treat complex fractures is too often associated with unstable results due to dependence on anatomic tuberosity healing. As a result, and in conjunction with improved proximal humeral locking plate technology, open reduction and internal fixation (ORIF) have gained in popularity compared to hemiarthroplasty. However, proximal humerus ORIF presents a unique set of complications such as screw cut out, risk of avascular necrosis, fracture collapse, tuberosity resorption and loss of fixation. RSA works only with a functional deltoid, axillary nerve and adequate bone stock to achieve satisfactory results, thereby forgoing some of the variables necessary for success with other treatment options. Therefore, in a subset of patients with complex proximal humerus fractures, RSA may represent a predictable means of achieving clinical success when treating complex proximal humerus fractures.

In this systematic review, we observed that RSA is used more commonly in the elderly population as the average age in the aggregated cohort was 77.5 years. Most of the patients are female in keeping with the higher incidence of proximal humerus fractures in women. While not uniformly reported, patients who underwent RSA tended to have more significant fracture patterns as a relatively high incidence of 4-part fractures were noted. This is likely reflective of the concerns when using other treatment options for these more complex fractures. Solberg et al compared their results after ORIF of 3- and 4-part fractures; the 4-part fractures were noted to have lower postoperative Constant scores than the 3-part fractures. Another study showed comparable results following hemiarthroplasty or nonoperative treatment for the treatment of 4-part fractures.

In terms of outcomes we noted average ASES and Constant score of 73.9 and 55.9, respectively. Most patients had minimal pain at final follow-up (weighted VAS and Constant pain score mean of 0.9 and 12.7, respectively). In a systematic review by Kontakis et al on hemiarthroplasty for proximal humerus fractures, they noted an average Constant score of 56.6. However, one must note that a minimum follow-up requirement was not used in that study. In addition, potential selection bias exists when comparing hemiarthroplasty to RSA as the treating surgeon is more likely to attempt RSA for the most complex fractures. In a comparative study of 19 and 21 patients with proximal humerus fractures who underwent either RSA or hemiarthroplasty respectively, 79% of the patients that underwent RSA had 4-part fractures compared to 62% in the hemiarthroplasty group. The authors noted that the RSA group had better constant scores at final relatively short follow-up. Plate fixation of proximal humerus fractures may result in outcomes that are comparable or better. A prospective multicenter study followed 187 patients who underwent ORIF for proximal humerus fractures for 1 year. These patients, in comparison to those noted in the current study, were much younger (average mean age of 62.9) and presented with mostly nonarticular bifocal fractures (AO type B1); at 1 year, the average Constant score in this group of patients was 70.6. However, 19% of these patients underwent a subsequent unplanned surgery due to complications. It is therefore difficult to compare the efficacy of these surgical modalities as the patient groups and fracture patterns may differ significantly. However, one may assume that elderly patients that have RSA for fracture management have satisfactory pain relief but may note moderate functional limitation.

External rotation is not predictably restored following RSA. Repair of the greater tuberosity is gaining momentum as a potential solution to incompetent external rotation following RSA for fracture. We therefore aimed to see if we could determine from this study the effect of tuberosity repair on outcomes. We noted that in this cohort of patients, those patients who had tuberosity repair had significantly higher forward flexion (126° vs 112°) and external rotation (24° vs 15°) compared to the group with no repair. One must note that the amount of external rotation gained/retained is dependent on the tuberosity healing adequately after an anatomic repair. While variable, displacement of the tuberosity may occur in up to 50% of cases. Only 1 study specifically denoted and analyzed those patients whose tuberosities healed and those that did not. Therefore, the difference in external rotation between the repair and non-repair groups may be higher if the tuberosities that heal are isolated.

The rate and types of complications after RSA in the fracture population is not fully understood. Scapula notching after RSA for cuff arthropathy is common and has been reported to have an incidence of 19-96%. The effect of scapula notching remains controversial but there is concern about the long-term outcome of patients with these scapula defects. In this analysis, we noted scapula...
notching to occur in 32% of the patients. This represents the most common complication in the group. It is possible that more cases of notching will be found with longer follow-up; however, evidence of inferior scapula impingement is usually noted within 14 months of surgery. In addition, this adduction impingement may be associated with varying severity of humeral bone loss; one of the studies noted progressive humeral bone loss in 10 of 21 patients with scapular notching. In the absence of the fractured humeral head, adequate exposure of the glenoid is more easily achieved. It is possible that with this increased visualization, the treating surgeons can more reliably place the baseplate and glenosphere along the inferior border of the glenoid which has been noted to lower the incidence of scapula notching. Postoperative instability is a concern following RSA and is one of the more commonly occurring complications. We noted postoperative instability in 3.5% of the patients. This is important as the ability to assess and restore soft tissue tension in fracture cases may be more challenging than in cases of rotator cuff arthropathy. However, we did not note a higher incidence of instability compared to RSA for rotator cuff arthropathy.

In our practice, assessing and ensuring adequate soft tissue tensioning begins with careful preoperative planning. Bone loss about the humerus should be noted with plans to reconstitute this with the implant or graft material and ensure that the prosthesis and deltoid are properly tensioned. If the proximal bone loss if severe, the contralateral humerus may be imaged and measured so as to replicate the measurements on the operative shoulder. Some lengthening (up to 1.5 cm) assists with tensioning the deltoid and conjoint tendon. Ultimately, intraoperative assessment is our most important tool in assessing stability; we aim to provide sufficient soft tissue tensioning without excessively constraining the prosthesis; full passive ROM without impingement should be attainable.

There are limitations inherent to a systematic review; therefore, it is subject to cumulative weaknesses of the studies chosen (6 retrospective and 3 prospective studies). Therefore, limitations in our conclusions are defined by the limitations in these respective studies. Preoperative data are not available as is the case for most fracture studies therefore we present only postoperative outcomes. As we do not have individual patient information, we cannot ensure that the patients are standardized and matched properly. In addition, different outcome measures were used amongst the studies. Despite these limitations, we believe that this current systematic review of the literature does provide insight into the use and outcomes of RSA for proximal humerus fractures. The standard minimum follow-up for arthroplasty research is 24 months. However, arthroplasty for fracture is a much different entity and therefore important observations can be noted at 12 months in this elderly population. The frequency weighted mean follow-up was 38.4 months for the minimum 12 month follow-up studies. While different results could possibly be noted with longer follow-up, we do not believe that the results of this study with a mean follow-up of 43.2 months are significantly limited by short follow-up.

**Conclusion**

We present a systematic review of the current literature of RSA for management of complex proximal humerus fractures. While providing predictable results, these elderly patients still do note some dysfunction postoperatively, even though pain is usually well controlled. Further research is needed to expand our understanding of the complications following fracture management. In addition, higher level research is necessary for more definitive conclusions about the efficacy of the reverse shoulder arthroplasty to treat fracture patients.

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