Reverse total shoulder arthroplasty for the management of failed shoulder arthroplasty with proximal humeral bone loss: is allograft augmentation necessary?

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**Background:** Patients undergoing revision shoulder arthroplasty frequently have deficient proximal humeral bone stock. Proximal humeral allograft has been recommended to augment reverse total shoulder arthroplasty (RTSA) to improve stability and function. This study reports the results of RTSA without proximal humeral allograft in patients with proximal humeral bone loss secondary to failed shoulder arthroplasty.

**Materials and methods:** From 2005 to 2008, 251 patients were enrolled in a prospective RTSA cohort study. Significant humeral bone loss was demonstrated in 15 of 56 undergoing revision for failed arthroplasty. Average age was 67 years. Average bone loss measured 38.4 mm (range, 26-72 mm). Patients were followed up for a minimum of 2 years with American Shoulder and Elbow Surgeons (ASES), Subjective Shoulder Value (SSV), Constant Score (CS), and visual analog scale (VAS) pain scores, as well as self-reported satisfaction and radiographs.

**Results:** Patients demonstrated significant improvement in mean CS (23.0 to 44.2), ASES (38.2 to 68.3), ASES activities of daily living (7.0 to 15.9), SSV (19.2 to 75.8), and VAS pain (4.6 to 1.6) scores. Thirteen of 15 patients reported satisfaction (87%). Range of motion improved in forward flexion (38.3° to 103.2°) and external rotation (−0.5° to 11.9°). Radiographs demonstrated noching in 3 patients (20%), no humeral subsidence or loosening, and prosthetic fracture of 1 modular humeral stem.

**Conclusions:** Use of RTSA for failed shoulder arthroplasty and deficient humeral bone stock provides a significant clinical benefit without the need for allograft augmentation. Monoblock humeral component use may diminish risk for prosthetic fracture.

**Level of evidence:** Level IV, Case Series, Treatment Study.

Approval for this study was granted by the Beaumont Hospitals Human Investigation Committee (HIC 2006-088) on March 23, 2011.

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Revision anatomic shoulder arthroplasty is a difficult problem that traditionally has had few satisfactory solutions. Recently, reverse total shoulder arthroplasty (RTSA) has been used as a viable solution for the revision of failed shoulder arthroplasty in cases of...
infection, malunion, nonunion, and cuff deficiency, with varying results.\textsuperscript{4,12,15,20} In a small percentage of these complicated cases, the bone stock of the proximal humerus is deficient, providing an additional challenge in the fixation and stability of the prosthesis. To address the problem of proximal humeral bone deficiency, recent studies have proposed the use of an allograft-prosthesis composite to enhance prosthesis stability, minimize forces acting on the prosthesis, reconstitute bone stock, and allow reattachment of the subscapularis tendon.\textsuperscript{4,12} This technique raises significant concerns, however, including cost of the allograft, increased risk of de novo infection, donor-to-host infection, increased operative time and complexity, graft resorption, and failure of allograft incorporation.

Given these concerns, we have frequently performed RTSA in the setting of proximal humeral bone loss, without the use of a bulk proximal humeral allograft. Since 2005, we have prospectively collected our results on all patients undergoing RTSA as a revision of previous shoulder arthroplasty. This study focused on a subset of these patients who had significant proximal humeral bone loss for the purpose of reporting the results of patients undergoing RTSA in the setting of proximal humeral bone loss, without the use of proximal humeral allograft.

**Materials and methods**

From 2005 to 2008, 251 patients treated with RTSA were enrolled in a prospective outcomes study at our institution, of which 56 (23%) were revision arthroplasty cases. Postoperative radiographs showed that 15 of the 56 (26%) had significant proximal humeral bone loss and were included in the present study. Our inclusion criteria were a painful shoulder arthroplasty refractory to nonoperative treatment, a functioning deltoid muscle, follow-up exceeding 24 months, and significant proximal humeral bone loss, including absence of the greater and lesser tuberosities as measured on postoperative radiographs. Exclusion criteria were active infection, follow-up of less than 24 months, a nonfunctioning deltoid muscle, and inability to complete follow-up. All patients had undergone a trial of nonoperative management and had been cleared for surgery by their internal medicine physician.

The average follow-up was 34.5 months (range, 25-49 months). Average age was 67 years (range 53-89 years). There were 3 men and 12 women. Patients had an average of 1.7 prior surgeries on the affected shoulder: 8 (57%) had 1 prior surgery, 1 (7%) had 2 prior surgeries, 3 (21%) had 3 prior surgeries, and 2 (14%) had 4 prior surgeries. Average bone loss measured 38.4 mm (range, 26-72 mm).

Indications for RTSA were failed hemiarthroplasty for fracture in 12 and previously infected hemiarthroplasty in 3. Uncemented stems were used in 4 and cemented stems in 11. Three patients (20%) had a history of infection. At the time of revision surgery, all patients were noted to have an absent or irreparable rotator cuff.

**Surgical technique**

All patients were treated with a RTSA using a standard deltopectoral approach. After exposure of the proximal humerus, the rotator cuff was examined for the possibility of repair, and in all patients it was irreparable or absent. Extraction of the humeral prosthesis was undertaken using osteotomes, a high-speed burr, and a slap hammer. An extended humeral osteotomy was necessary in 3 patients. After removal of the prosthesis, multiple specimens from the humeral canal and glenohumeral joint capsule were sent to pathology for frozen sections and culture. Cement was removed using curettes and osteotomes as necessary.

If the frozen sections confirmed the absence of acute inflammation, implantation of a reverse prosthesis was undertaken. After implantation and screw fixation of the glenosphere and base plate, the height of the humeral component was judged by soft tissue tensioning and stability of the prosthesis. No specific measurements of humeral length were used as a template. After final implantation of the prosthesis, the deltopectoral interval was closed with nonabsorbable suture over a large drain to prevent hematoma formation, and the soft tissue and skin were closed in layers.

In the postoperative period, patients received 24 hours of parenteral antibiotics and were placed in an abduction sling for 4 weeks. Physical therapy of the elbow, wrist, and hand was initiated on postoperative day 1, with formal physical therapy for the shoulder restricted until 2 weeks after surgery. All patients were kept in the sling, non-weight bearing on the operative extremity, for a minimum of 4 weeks.

Several prosthesis designs and fixation techniques were used during the study period. The prosthesis included 2 Delta III (DePuy, Warsaw, IN, USA), 9 Aequalis (Tornier, Edina, MN, USA), and 4 Trabecular Metal reverse (Zimmer, Warsaw, IN, USA). Two humeral prosthesis were inserted using a press-fit technique and 13 were inserted using a cemented technique. All humeral prostheses were modular, except for the 4 Trabecular Metal stems, which were monoblock.

**Preoperative and postoperative clinical assessment**

Patients were assessed preoperatively and at 2 weeks, at 3, 6, and 12 months, and at 2 years postoperatively. All patients were evaluated using the American Shoulder and Elbow Surgeons (ASES) assessment of pain and function and activities of daily living (ADL), Subjective Shoulder Value (SSV), pain on a Visual Analog Scale (VAS), Constant Score (CS), overall self-reported satisfaction, and active range of motion for forward flexion (aFF) and external rotation (aER). Evaluations were conducted by a research nurse not involved with the care of the patient. Range of motion in aFF and aER was measured by hand-held 60-cm metallic goniometer.

**Radiographic assessment**

All patients were evaluated with anteroposterior, Y-lateral, and axillary views of the shoulder at each visit. The radiographs at the 2-year postoperative visit were evaluated for baseplate radiolucency, humeral radiolucency, prosthesis migration, periprosthetic fracture or dislocation, inferior glenoid notching, and hardware failure. Glenoid notching was evaluated using the classification of Sirveaux et al\textsuperscript{18} and humeral loosening by the method of Sanchez-Sotelo et al.\textsuperscript{17} Humeral bone loss was measured by calculating the distance from the lateral aspect of the upper end of the prosthesis to the most proximal aspect of the remaining humeral bone (Fig. 1). Given that the native humerus can extend proximal to the
prosthesis, we estimate that the actual magnitude of bone loss was 10 to 15 mm greater than our measurements, although this was not included in our calculations.

Statistical methods

Preoperative and postoperative pain, functional scores, and range of motion values were evaluated by an independent statistician. For continuous outcomes, the distribution of differences (postoperative minus preoperative) was examined to decide on appropriate techniques. Paired t test, Wilcoxon signed rank test, or sign test analyses were used, along with 95% confidence intervals for the mean/median difference. For binary outcomes, the McNemar test was used to evaluate changes between postoperative and preoperative. All values of P are 2-sided. Results with a P < .05 are considered statistically significant. Analyses were performed using SAS 9.2 (SAS Institute Inc., Cary, NC, USA), Minitab Release 14 (Minitab Inc, State College, PA, USA), and StatXact 9 (Cytel Inc, Cambridge, MA, USA) software programs.

Results

Clinical outcomes

Range of motion improved in FF from mean 38.3° to 103.2° (change, 64.9°; P = .001). ER improved from an average of –0.5° to 11.9° postoperatively (change, 12.4°, P = .1), which was not statistically significant. Complete data for drop arm sign and ER lag sign were available for 14 patients. Drop arm sign decreased from 13 patients preoperatively to 3 patients postoperatively (P = .002) and ER lag sign decreased from 10 patients preoperatively to 6 patients postoperatively (P = .22), which was not statistically significant.

Mean total ASES score increased from 38.2 to 68.3 (change, 30.1; P = .0001). Mean ASES ADL score increased from 7.0 to 15.9 (change, 8.9; P = .0007). Two patients did not have a preoperative CS; thus, they were not included in the CS analysis. Mean CS of the other 13 patients improved from 23.0 to 44.2 (change, 21.2; P = .002). Mean SSV improved from 19.2 to 75.8 (change, 56.7; P = .0001), mean VAS pain decreased from 4.6 to 1.6 (change, –3.0; P = .0007), and 13 of 15 patients (87%) reported satisfaction with their procedure. Clinical results are summarized in Table I.

Radiographic outcomes

Radiographs in 10 of 15 patients showed no evidence of notching, 3 (20%) had evidence of grade 1 notching, 1 had evidence of grade 2 notching, and 1 had evidence of grade 3 notching. There was no evidence of humeral radiolucent lines in any zone, and no lucency was noted behind any base plate. A fracture of the prosthesis at the modular metaphyseal connection was noted in 1 patient at the 2-year follow-up (Fig. 2). Average bone loss measured 38.4 mm (range, 26-72 mm).

Complications

Overall, 7 of 15 patients (47%) experienced complications related to the surgery. Complications in 2 of the 15 patients (13%) required operative intervention. An intraoperative periprosthetic fracture of the humerus occurred in 1 patient, and he was treated with cable cerclage fixation during surgery. The postoperative rehabilitation protocol was not modified for this patient, and he had an uneventful postoperative course and a good clinical outcome (ASES, 78; aFF, 96°).

Another patient experienced 3 episodes of dislocation and underwent revision surgery with the addition of dual stacked metallic spacers to increase soft tissue tension. The patient did well after this first revision surgery, without any further episodes of dislocation. However, as a result of complications from a total knee arthroplasty, the patient was subsequently weight-bearing on the extremity with crutches and sustained a fracture of his humeral stem at the modular metaphyseal connection 2.5 years after the index arthroplasty (Fig. 2). The patient underwent repeat revision of the prosthesis and eventually obtained an excellent outcome (ASES, 87; aFF, 150°). Minor complications occurred in 5 of 15 patients (33%), including 1 deep venous thrombosis, 3 transient nerve palsies, which resolved with observation, and 1 patient experienced painful cerclage cables that required hardware removal. There were no infections.
Discussion

Revision shoulder surgery in the setting of severe proximal humeral bone loss creates a complicated situation for the surgeon not only in bony stabilization of the humeral prosthetic component but also in soft tissue balance of the shoulder due to the absence of the rotator cuff attachment sites. The advent of RTSA has provided a possible solution to this problem because it substitutes the deltoid for the rotator cuff and has intrinsic stability due to its semi-constrained design. However, bony stability of the humeral prosthetic component remains a concern. Recent clinical reports of acceptable outcomes using RTSA in the setting of severe humeral bone loss have indicated that RTSA could provide a solution to this difficult problem.

In an attempt to further improve the outcomes of patients with proximal humeral bone loss undergoing revision shoulder surgery, some investigators have advocated the use of allograft-prosthetic composites as a method to reconstruct the bony defect in the humerus. This method has been used in tumor reconstruction to provide a functional upper extremity to patients undergoing wide excision of the shoulder girdle, although most of this literature focuses on the use of an anatomic humeral prosthesis. Proponents of allograft-prosthetic composites in RTSA purport its benefits to be reconstitution of bone stock, reattachment of the subscapularis tendon, lateralization of the pull of the deltoid, and improved contour of the shoulder. Several downsides of using allograft remain, however, including the risk of infection from the donor graft to the host, graft resorption, increased nidus for de novo infection, increased operative complexity and time, cost of the graft, and the risk of nonunion or malunion at the graft–host junction.

The purpose of our study was to determine the necessity of using a proximal humeral allograft during RTSA in the setting of proximal humeral bone loss. The results of our study indicate good radiographic and clinical outcome scores at the 2-year follow-up without the use of a proximal humeral allograft. There are several reasons for these favorable results:

First, rotational and length stability of the prosthesis can often be achieved with the use of long-stem components, negating the need for allograft support.

Second, none of our patients had rotator cuff tissue present, including the subscapularis, negating the need for reattachment of the rotator cuff.

Third, the semi-constrained nature of the reverse prosthesis and the ability to adjust the soft tissue tension with spacers resulted in a low rate of instability (1 of 15), while

Table I Summary measures of changes in function from reverse shoulder arthroplasty in the setting of proximal humeral bone loss without allograft composite augmentation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preoperative Mean (range)</th>
<th>Postoperative Mean (range)</th>
<th>Improvement Mean</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active range of motion, °</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward flexion</td>
<td>38.3 (10-74)</td>
<td>103.2 (54-140)</td>
<td>64.9</td>
<td>.001</td>
</tr>
<tr>
<td>External rotation</td>
<td>−0.5 (−20 to 60)</td>
<td>11.9 (−14 to 50)</td>
<td>12.4</td>
<td>.1</td>
</tr>
<tr>
<td>ASES score, points</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>38.2 (17-63)</td>
<td>68.3 (42-87)</td>
<td>30.1</td>
<td>.0001</td>
</tr>
<tr>
<td>ADL</td>
<td>7.0 (0-14)</td>
<td>15.9 (4-26)</td>
<td>8.9</td>
<td>.0007</td>
</tr>
<tr>
<td>Constant Score, points</td>
<td>23.0 (12-39)</td>
<td>44.2 (7-75)</td>
<td>21.2</td>
<td>.002</td>
</tr>
<tr>
<td>SSV, points</td>
<td>19.2 (0-50)</td>
<td>75.8 (45-100)</td>
<td>56.7</td>
<td>.0001</td>
</tr>
<tr>
<td>Pain VAS, score</td>
<td>4.6 (1-10)</td>
<td>1.6 (0-7)</td>
<td>−3.0</td>
<td>.0007</td>
</tr>
</tbody>
</table>

ADL, activities of daily living; ASES, American Shoulder and Elbow Surgeons; SSV, Subjective Shoulder Value; VAS, Visual Analog Scale.

* Indicates statistically significant difference.
at the same time maintaining an acceptable range of motion without the addition of an allograft to lateralize the pull of the deltoid.

The structural allograft does, however, have some specific benefits, including a potentially improved cosmetic appearance of the shoulder and possible reconstitution of bone stock. Similarly, the addition of proximal humeral allograft can provide increased support and stability for stems that contain a modular neck–stem junction by minimizing the bending and torsional forces acting on the prosthesis. The only component fracture in this series occurred in a patient with a modular prosthesis that was unsupported by bone proximally. This observation is further supported by recent a biomechanical study showing improved torsional stability in RTSA when allografts are added to humeri with modular components. Concerns about the risk of prosthetic fracture can be eliminated by choosing a nonmodular monoblock humeral prosthetic design. In fact, no prosthesis-related complications occurred in any the monoblock stems in this series. On the basis of our findings, we recommend the use of a monoblock humeral stem in patients with severe proximal humeral bone loss.

Compared with other published series using allograft-prosthetic composites for failed shoulder arthroplasty with bone loss, our clinical outcomes show comparable if not superior results, including improved scores for both ASES (68 vs 69) and aFF (103° vs 82.4°). Our radiographic results were also comparable, with no evidence of humeral or glenoid implant lucency. However, a 25% rate of inferior scapular notching was noted in this series and is likely related to the medialized glenosphere design and valgus neck-shaft angle of these specific Grammont-style implants. This was not noted to affect clinical outcomes. Our overall complication rate of 47% was also higher than reported in other series; however, most of our complications were minor and did not change the patient’s course of treatment. A direct comparison of complication rates between series is difficult because failure of allograft incorporation is not routinely reported as a complication. Similarly, minor complications, such as deep venous thrombosis and transient nerve palsy, are infrequently reported in the literature.

Strengths of our study include its prospective nature, the use of a variety of RTSA systems, a low reoperation rate (13%), and comparable amounts of humeral bone loss in relation to other studies. The use of multiple prosthetic systems allows some generalizability of our results among manufacturers with similar designs. Our relatively low reoperation rate may be at least partly due to the absence of allograft. Previous reports of shoulder reconstruction using allograft-prosthetic composites describe an allograft fragmentation/resorption rate of 21%, an allograft nonunion rate of 11% to 18%, and an allograft failure rate of 50%. Because we did not use allograft, the possibility of these particular complications was eliminated.

In terms of the amount of humeral bone loss, we note that in the only other published report on the use of RTSA allograft-prosthetic composites for the treatment of failed shoulder arthroplasty, Chacon et al presented a series of patients with an average of 53.6 mm of proximal humeral bone loss compared with 38.4 mm in our series. We expected our numbers would be smaller compared with this result because their measurement included the proximal portion of the allograft bone that extended above the visible metal cup on radiographs. We estimate this distance is 10 to 15 mm, and with the addition of this height to our measurement, our results are comparable.

Weaknesses of our study include the lack of a comparative group using an allograft-prosthetic composite, a small number of patients, and short-term follow-up. Given the relative infrequency of revision shoulder arthroplasty and the limited time that RTSA has been available in the United States, we were unable to compile a larger cohort of patients. Similarly, we believe that the results of 2-year follow-up would be of interest to surgeons who encounter this difficult surgical problem.

Conclusion

RTSA without structural proximal humeral allograft in the setting of severe humeral bone loss provides outcomes equivalent to previous studies using allograft-prosthesis composites and avoids numerous disadvantages associated with bulk structural bone allografts. Thus, our results suggest that the addition of allograft offers no significant advantages and does not appear to improve clinical or radiographic outcomes. However, when a modular humeral stem is used in patients with bone deficiency, the addition of proximal humeral allograft may increase the stability of the construct and prevent fracture at the modular stem–cup junction. As mentioned, the risk of prosthetic fracture in this situation can be reduced or possibly eliminated entirely by using a monoblock humeral prosthesis. Further studies to define the patients who would benefit from an allograft-prosthesis composite are certainly warranted.

Disclaimer

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