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Reverse total shoulder arthroplasty provides stability and better function than hemiarthroplasty following resection of proximal humerus tumors

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Background: Tumors may necessitate resection of a substantial portion of the proximal humerus and surrounding soft tissues, making reconstruction challenging. We evaluated outcomes in patients undergoing treatment of tumors of the proximal humerus with reverse total shoulder arthroplasty (rTSA) or shoulder hemiarthroplasty.

Methods: Patients who underwent rTSA (n = 10) or shoulder hemiarthroplasty (n = 37) for tumors of the proximal humerus in 2009 to 2017 were reviewed. Of these patients, 27 had died, leaving 20 for review. The mean follow-up period of the survivors was 27.1 months. They were evaluated clinically and contacted to determine the American Shoulder and Elbow Surgeons score, Simple Shoulder Test score, and visual analog scale score.

Results: Postoperative complications occurred in 13 hemiarthroplasty patients (34%). Tumor recurrence occurred in 3 hemiarthroplasty patients (7.9%), whereas in the rTSA group, 1 patient (10%) had a postoperative complication, with no recurrences. One hemiarthroplasty patient required revision surgery with rTSA to improve shoulder function. Six dislocations and two subluxations occurred in the hemiarthroplasty group, whereas no subluxations occurred in the rTSA group ($P = .14$). Mean range of motion was 85° of forward flexion for rTSA patients (n = 10) compared with 28° for hemiarthroplasty patients ($P < .001$). The mean American Shoulder and Elbow Surgeons score was 63 for hemiarthroplasty patients (n = 5) and 59 for rTSA patients (n = 4). The mean Simple Shoulder Test scores were 3.8 and 2.4, respectively. The mean visual analog scale pain scores were 2.4 and 2.5, respectively.

Conclusion: Reverse total shoulder arthroplasty can reproducibly reconstruct the shoulder in patients requiring oncologic proximal humerus resection. Patients have good outcomes, better range of motion, and no increase in instability rates compared with hemiarthroplasty.

This project was approved by The Ohio State University Biomedical Institutional Review Board (study No. 2017H0042).

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The proximal humerus is a common site for benign and malignant bone tumors, and these tumors pose surgical and reconstructive challenges.[15] Options following resection include allograft reconstruction, arthroplasty, and definitive resection with a flail shoulder (also known as ‘‘resection arthroplasty’’).[3] Hemiarthroplasty and allograft-prosthetic composite with hemiarthroplasty have been the workhorse reconstructions, with low complication rates and typically below–shoulder level function.[15] However, there are frequently substantial functional deficits associated with these reconstructions.[4] Because of the extensive soft-tissue resection often required to achieve adequate surgical margins, many of the static and dynamic soft-tissue restraints that contribute to glenohumeral stability are removed. As a result, anterosuperior escape of the prosthesis is common and can be quite debilitating, owing to both poor function and persistent pain (Fig. 1).[5] Reverse shoulder arthroplasty may provide a more reliable reconstruction, with better functional and pain outcomes.[14] In this semiconstrained implant, the deltoid muscle is used to provide function in the absence of a rotator cuff.[1,2] Reverse shoulder arthroplasty is not commonly performed for tumors of the proximal humerus; there are only a few centers performing this procedure. At our center, a 2-surgeon approach (orthopedic oncologist and shoulder surgeon) has been used with encouraging early outcomes.

The current orthopedic oncology literature reports promising outcomes with the reverse total shoulder arthroplasty (rTSA) procedure, but data for only about 79 total patients have been reported.[1,2,8-12] Furthermore, to our knowledge, no study has directly compared hemiarthroplasty with reverse arthroplasty. Therefore, the purpose of this study was to evaluate functional outcomes, complication rates, and tumor recurrence rates in patients undergoing treatment of tumors of the proximal humerus with either rTSA or shoulder hemiarthroplasty.

Materials and methods

Patient charts from January 1, 2009, to June 1, 2017, were reviewed. All patients who underwent upper-extremity surgery for tumors of the proximal humerus at our institution were identified. Charts were reviewed to include any patient aged between 18 and 89 years who underwent proximal humeral reconstruction with shoulder hemiarthroplasty or rTSA for bone or soft-tissue tumors. Prisoners were excluded. We included 48 surgical procedures (47 patients) in this study, comprising 38 hemiarthroplasty procedures for a tumor of the proximal humerus and 10 rTSA procedures. The diagnoses requiring resection included B-cell lymphoma in 1 case, chondrosarcoma in 7, clear-cell sarcoma of bone in 1, enchondroma in 1, Ewing sarcoma in 1, pleomorphic sarcoma in 1, metastatic disease in 30 (renal, prostate, colon, hepatocellular, esophageal, neuroendocrine, or Merkel cell), multiple myeloma in 3, and osteosarcoma in 4.

Surgical methods for rTSA are described in our previous technique report.[7] In brief, an orthopedic oncologist resects the tumor with wide margins. A deltopectoral approach is used for metastatic disease, whereas an anterior trans-deltoid–splitting approach is used for primary bone sarcomas. The anterior deltoid-splitting approach occurs laterally to the deltopectoral interval (but within the anterior head of the deltoid) with the length determined by the size of the primary bone tumor. This approach is used in the event that there are positive tumor margins as the cancer cell–contaminated plane and cuff of surrounding tissue would need to be excised at the time of re-resection. By necessity, there is likely partial denervation of some of the anterior deltoid musculature with this approach. A standard deltopectoral approach is not used for primary tumor resections because this places multiple compartments at risk of cancer cell contamination. A shoulder-trained surgeon implants the reverse shoulder megaprosthesis. We most frequently use the Biomet Segmental Reconstruction System (Zimmer Biomet, Warsaw, IN, USA). We preferentially use a larger glenosphere (41 mm on average) to, in theory, reduce postoperative instability in the setting of substantial loss of surrounding soft tissue. With this system, our standard is to use 4 screws in addition to the central peg for glenoid fixation. Stem length and modular humeral components largely depend on the degree of humeral bone resected as part of the oncologic portion of the procedure. The humeral stem is cemented if there is planned radiation therapy or poor bone stock; otherwise, an uncemented stem is used. Soft-tissue reconstruction depends on the remaining tissue after adequate resection has occurred for the oncologic portion of the procedure. When possible, the deltoid, teres minor, latissimus, infraspinatus, and subscapularis are repaired to the humeral component. We repair the subscapularis as we believe this may potentially contribute to stability when substantial soft-tissue loss is present. The long head of the biceps undergoes tenodesis to the conjoint tendon, and the pectoralis major is repaired to the deltoid. For hemiarthroplasty procedures, a cemented long-stem component is placed, attempting to recreate the anatomic length and offset based on the known resection.

Patients who met the inclusion criteria were reviewed for the type of cancer, surgical margins, surgical time, intraoperative

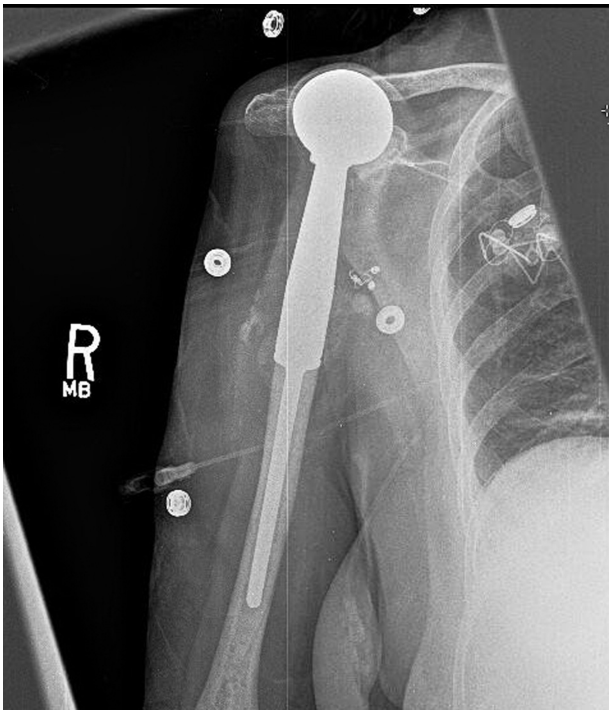

Figure 1 Radiographic example of anterior-superior escape in a patient with metastatic cancer treated with resection and proximal humeral hemiarthroplasty. In this example, a pseudocapsule has developed around the prosthetic humeral head. The prosthesis is easily palpable with a thin tissue layer between the skin and the implant. The patient has 30° of external rotation and 20° of internal rotation with the elbow by her side; forward elevation is severely limited at 20°.

complications, and body mass index, among other characteristics. Subsequent follow-up visits were reviewed to determine postoperative complications, including infection, nerve damage, or instability. To determine the functional status of the patients postoperatively, we reviewed their active and passive range of motion (abduction, flexion, internal rotation, and external rotation). We also recorded their functional status and pain at each follow-up visit. Follow-up visits typically occurred at 2 weeks, 6 weeks, 3 months, 6 months, 1 year, and 2 years after surgery.

For a subset of patients available for follow-up (27 patients had died, leaving 20 patients potentially available for follow-up), the visual analog scale (VAS) pain score,[10] American Shoulder and Elbow Surgeons (ASES) score,[13] and Simple Shoulder Test (SST) score[6] were obtained. Patients lacking complete follow-up were contacted by phone or E-mail to complete surveys for the VAS, ASES, and SST scores.

Statistical analysis was performed using a standard software package (Stata, version 13.1; StataCorp, College Station, TX, USA). An a priori power analysis was performed, and the sample was determined to be adequate to detect a mean 25° difference in postoperative range of motion at 80% power and $\alpha = .05$. Differences in continuous variables between groups were determined by the 2-tailed Student *t* test for normally distributed data and Wilcoxon rank sum test for non–normally distributed data. Differences in categorical variables were determined by the Fisher exact test.

Table I Patient demographic characteristics

	Hemiarthroplasty (n = 38)	rTSA (n = 10)	*P* value
Follow-up, average (SD), mo*	32.7 (16.3)	20.9 (12.0)	.20
Age at surgery, average (SD), yr	61.8 (15.5)	64.2 (11.2)	.65
Sex (M/F), n	20/18	5/5	>.99
BMI, average (SD)	29.4 (7.4)	32.5 (6.4)	.23

rTSA, reverse total shoulder arthroplasty; *SD*, standard deviation; *M*, male; *F*, female; *BMI*, body mass index.
* Excluding patients who died prior to final follow-up.

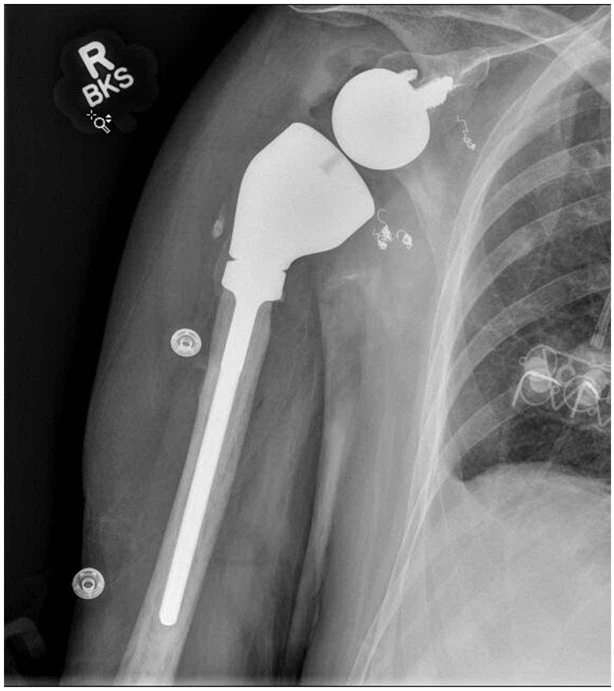

Figure 2 Radiograph after conversion from a hemiarthroplasty for metastatic cancer to an oncologic reverse total shoulder arthroplasty. Conversion to reverse total shoulder arthroplasty was performed in this patient because of anterior-superior escape of the humeral prosthesis and poor function.

Results

There were no differences between groups in patient age, sex, body mass index, or length of follow-up (Table I). One patient who originally underwent hemiarthroplasty required revision surgery with rTSA (Fig. 2). The average follow-up period was 32.7 months (standard deviation, 16.3 months) for hemiarthroplasty procedures and 20.9 months (standard deviation, 12.0 months) for rTSA ($P = .20$).

Table II Outcomes

	Hemiarthroplasty (n = 38)	rTSA (n = 10)	*P* value
Revision surgery, n (%)	1 (2.6)	0 (0)	>.99
Death, n (%)	27 (71.1)	0 (0)	<.001
Local recurrence, n (%)	3 (7.9)	0 (0)	>.99
Infection, n (%)	3 (7.9)	0 (0)	>.99
Dislocation and subluxation events, n (%)	6 (4 dislocations and 2 subluxations) (27) (n = 22)	0 (0) (n = 10)	.14
ROM: forward flexion, mean (SD), °	28 (31) (n = 22)	85 (16) (n = 10)	<.001
ASES score, mean (SD)	63 (23) (n = 5)	59 (10) (n = 4)	.75
SST score, mean (SD)	3.8 (3.7) (n = 5)	2.4 (2.6) (n = 5)	.51
VAS score, mean (SD)	2.4 (2.3) (n = 5)	2.5 (2.4) (n = 4)	.95

rTSA, reverse total shoulder arthroplasty; *ROM*, range of motion; *SD*, standard deviation; *ASES*, American Shoulder and Elbow Surgeons; *SST*, Simple Shoulder Test; *VAS*, visual analog scale.

Complications

No hemiarthroplasty or rTSA patients had any intraoperative complications. A total of 6 dislocations or subluxations occurred in the hemiarthroplasty group (4 dislocations and 2 subluxations), whereas no instability events occurred in the rTSA group.

For a total of 16 hemiarthroplasty procedures (42%), a postoperative complication or failure of surgery occurred. One patient had a failure that required revision rTSA to improve shoulder function. Three patients reported numbness in the median nerve distribution after surgery that improved with time. Three patients had recurrence of their tumor; 2 required revision to amputation. Three patients had an infection after surgery. One patient required intravenous antibiotics and, later, open reduction–internal fixation of a periprosthetic humeral fracture. Another improved after a course of intravenous antibiotics. The final patient had poor wound healing because of smoking and radiation changes, requiring multiple irrigation and débridement procedures and, ultimately, removal of hardware. Six patients had shoulder instability. Two patients had medical issues in the week after surgery; one had blood loss after surgery that required a 4-day intensive care unit stay, and another was admitted for dehydration 7 days after surgery. Of the patients who underwent rTSA, 1 (10%) had postoperative complications or failure of surgery. This patient had ulnar nerve paresthesia that improved with time.

Functional outcomes

The mean range of motion for rTSA patients (n = 10) was 85° of forward flexion (range, 65°-110°) compared with 28° of forward flexion (range, 0°-100°) for hemiarthroplasty patients (n = 22), with $P < .001$ (Table II). The mean ASES score was 63 (range, 28-93) for hemiarthroplasty patients (n = 5) and 59 (range, 42-70) for rTSA (n = 4). The mean SST scores were 3.8 (range, 0-9) and 2.4 (range, 1-7), respectively. The mean VAS pain scores were 2.4 (range, 0-6) and 2.5 (range, 1-6), respectively. Among the patients who were alive and available for follow-up (20 total; the remaining 27 had died), 5 of 10 hemiarthroplasty patients (50%) responded to our survey whereas 5 of 10 rTSA patients (50%) responded to our survey.

Discussion

Shoulder reconstruction following proximal humerus tumor resection is challenging. Hemiarthroplasty has left patients with an unstable shoulder with poor function. Initial reports of rTSA have been encouraging, but comparative studies of hemiarthroplasty vs. rTSA are lacking. In this study, we demonstrate superior shoulder function compared with hemiarthroplasty without an increase in instability or complication rates. Our study results are consistent with what has been reported previously in case series of rTSA oncologic reconstructions. Bonnevialle et al[1] reported an instability rate of 50%, which is higher than our instability rate although their average follow-up time was greater (42 months). De Wilde et al[2] reviewed 9 rTSA procedures at their institution and reported a complication rate of 22% (2 of 9). Guven et al[8] reported no complications in their case series of 10 rTSA patients, whereas Kaa et al[9] reported a complication rate of 50% in their case series of 10 rTSA patients.

Our study found mean forward flexion to be 85° for rTSA patients and 28° for hemiarthroplasty patients. Lazerges et al[11] reported similar functional results in a series of 6 rTSA patients, with mean shoulder range of motion of 95° of forward flexion. In a case series of 8 patients, Maclean et al[12] found mean forward flexion of 71°. Our functional results for rTSA are similar to what has been reported, but none of these studies have compared the results with hemiarthroplasty.

A few conclusions can be drawn when comparing rTSA and hemiarthroplasty in this study. Most important, it appears that rTSA allows for a better functional outcome with increased range of motion and no increase in complication rates compared with hemiarthroplasty. Although the shoulder scores are not as robust, the range-of-motion difference is significant. The rate of complications or failure of surgery was higher in hemiarthroplasty patients than in rTSA patients, although follow-up for rTSA was shorter. There is no evidence to suggest that tumor recurrences are greater with rTSA than with hemiarthroplasty. It is reasonable to believe that performing rTSA with the goal of preserving shoulder function postoperatively would subconsciously cause the surgeon to perform a less-aggressive resection. The lack of recurrences in our rTSA group refutes this hypothesis.

Limitations

Our study has both strengths and limitations. Although it was adequately powered to determine clinically meaningful differences in range of motion and patient-reported symptoms between the hemiarthroplasty and rTSA groups, it was underpowered to reliably compare postoperative instability and complication rates. This is a common limitation in the orthopedic oncology literature in general, and few oncologic shoulder reconstructions are performed even at highly specialized centers. We report a favorable complication rate for rTSA (20%) compared with other reports in the literature,[1,2,8-12] although the rates reported in our study as well as other oncologic rTSA studies all have limited reliability because of small sample sizes. Furthermore, this is the only study, to our knowledge, that directly compares hemiarthroplasty and rTSA. Limitations with the current study design are present as well. The follow-up time for our study is shorter than that for some of the other reported series on oncologic applications of rTSA,[1,2,8-12] although maximal return to function following shoulder arthroplasty typically occurs within a year of surgery. Prospective studies and/or randomized controlled trials are warranted to further investigate the best surgical treatment of these tumors.

Conclusion

Surgical management of tumors of the proximal humerus can prolong patients' lives.[3] However, patient quality of life after these lifesaving procedures is important. Our data show that rTSA can reproducibly reconstruct the shoulder in patients requiring oncologic resections of the proximal humerus. These patients have good outcomes with better range of motion and no increase in instability rates or complication rates compared with shoulder hemiarthroplasty.

Disclaimer

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