

# Outcomes of Oncologic Total Humeral Reconstruction

LEILANI GARAYUA-CRUZ<sup>1</sup>, SAMUEL E. BROIDA<sup>2</sup>, MIKAELA H. SULLIVAN<sup>2</sup>, MARK E. MORREY<sup>2</sup>, JONATHAN D. BARLOW<sup>2</sup>, JOAQUIN SANCHEZ-SOTELO<sup>2</sup> and MATTHEW T. HOUDEK<sup>2</sup>

<sup>1</sup>University of Puerto Rico School of Medicine, San Juan, Puerto Rico;

<sup>2</sup>Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, U.S.A.

## Abstract

**Background/Aim:** The humerus is the most common site for malignant tumors in the upper extremity. Rarely, a total humeral resection with combined replacements of both the shoulder and the elbow are necessary. The aim of this study was to evaluate outcomes after total humeral reconstruction at our institution.

**Patients and Methods:** Nine patients (5 females, 4 males, mean age 48±26 years) with a malignant tumor of the humerus were included in this study. This included five endoprostheses and four allograft prosthetic composites.

**Results:** Postoperative complications occurred in eight patients, most commonly deep vein thrombosis (DVT, n=3) and elbow contractures (n=3). Complications led to a revision procedure in one patient, with a cumulative incidence of failure of 25% at 5-years and a 5-year overall patient survival rate of 13%. At the most recent follow-up, the median Musculoskeletal Tumor Society Score was 50%.

**Conclusion:** Total humerus reconstruction is a rare surgical procedure that is associated with a high rate of complications with relatively poor functional outcomes. However, this option does offer a means of limb salvage for patients with limited options.

**Keywords:** Total humerus, upper extremity, endoprosthesis, allograft prosthetic composite.

## Introduction

In the upper extremity, the humerus is the most common site for developing primary and secondary malignant tumors (1). Rarely, in the setting of extensive tumors, pathologic fractures, or failed reconstructions, a total humeral resection and reconstruction is necessary. In this

situation, total humeral reconstruction allows the patient to avoid amputation and hopefully maintain function of the shoulder and elbow, but more importantly preserve a functional hand (2-4). Current options for reconstruction often include a whole humerus metallic endoprosthesis or allograft prosthetic composite (APC) with a shoulder arthroplasty on the upper end and an elbow arthroplasty



Matthew Houdek, MD, Department of Orthopedic Surgery, Mayo Clinic, 200 First St SW, Rochester MN 55905, U.S.A. Tel: +1 5072848431, Fax: +1 5072664234, e-mail: houdek.matthew@mayo.edu

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Table I. Patients undergoing total humerus reconstruction.

Patient	Sex	Age	Pathology	Implant	Status	Survival	Complication
1	Female	74	Recurrent dedifferentiated liposarcoma	Endoprosthesis	DOD	19 Mo.	Flexion contracture Tumor recurrence
2	Male	13	Ewing sarcoma	APC	DOD	21 Mo.	Allograft fracture
3	Male	45	Metastatic colorectal carcinoma	Endoprosthesis	DOD	2 Mo.	DVT/PE
4	Male	63	Metastatic epithelioid hemangioendothelioma	APC	DOD	3 Weeks	DVT/PE
5	Male	21	Osteosarcoma	APC	DOD	46 Mo.	Elbow contracture
6	Female	16	Recurrent Ewing sarcoma	Endoprosthesis	DOD	11 Mo.	Elbow contracture
7	Female	54	Multiple myeloma	Endoprosthesis	DOD	1 Mo.	-
8	Female	65	Metastatic breast carcinoma	APC	AWED	110 Mo	Dislocation Polyethylene wear Hematoma
9	Female	83	Metastatic endometrial carcinoma	Endoprosthesis	AWED	10 Mo	Wound dehiscence

DOD: Dead of disease; Mo: months; APC: allograft prosthetic composite; DVT/PE: deep venous thrombosis/pulmonary emboli; AWED: alive with evidence of disease.

on the lower end, both of which can be associated with a high rate of complications. Due to the rare nature of these procedures, studies examining outcomes in patients with an underlying oncologic diagnosis are limited. The purpose of this study was to evaluate outcomes for these procedures at our institution.

**Patients and Methods**

Following Institutional Review Board approval, we retrospectively reviewed nine patients (5 females, 4 males, mean age 48±26 years) who underwent reconstruction with total humeral endoprosthesis or allograft prosthetic composite between 1987 and 2024 after oncologic resection of the humerus (Table I). The oncologic diagnosis included metastatic disease (n=4), sarcoma (n=4) and myeloma (n=1). Reconstruction included five endoprostheses and four APCs.

Following resection, patients were followed at regular intervals for disease recurrence or implant related complications. Follow-up included clinical examinations along with plain radiographs. If patients were unable to attend a visit in person, follow-up data was obtained through our institutional Total Joint Registry Database. At most recent follow-up, only two patients were alive, with a median time to death for the remaining patients of 15 months [interquartile ranges (IQR)=26 months].

Postoperative active shoulder and elbow range of motion was evaluated including active shoulder forward elevation and external rotation, and active elbow flexion, extension, pronation, and supination in the plane of the body. Functional outcomes were measured using the Musculoskeletal Tumor Society (MSTS) (5), the Mayo Elbow Performance score (6), and the Simple Shoulder Test (7). Failure of the reconstruction was based on the Henderson Classification (8).

Data is reported as medians with IQRs, with whole numbers with percentages where appropriate. Survival estimates were calculated using the Kaplan–Meier survival method with competing risk analysis for death where appropriate.

**Results**

*Functional outcomes.* Following surgery, the median forward elevation and external rotation at the shoulder at the most recent follow-up were 48° (IQR=31°) and 10° (IQR=20°), respectively. The median elbow flexion and extension arc of motion was 80° (IQR=80°), with a median pronation and supination of 50° (IQR=40°) and 45° (IQR=48°). The median MSTS, SST and Mayo Elbow score were 50% (IQR=20%), 2 (IQR=0) and 65 (IQR=23), respectively.

*Postoperative complications.* Following surgery, the 1-, 2- and 5-year overall survival rates were 53%, 26% and 13%. Complications occurred in eight (89%) patients, with two patients having several complications. Complications led to a repeat surgical procedure in two patients. The most common postoperative medical complication was deep vein thrombosis (DVT, n=3), with two of these patients also suffering a pulmonary embolus. Complications related to reconstruction included elbow contracture (n=3), wound dehiscence (n=1), hematoma (n=1), allograft fracture (n=1), and polyethylene wear of the humeral component with dislocation (n=1).

Failure of the reconstruction occurred in three patients including Type 1 (n=1), Type 3 (n=1) and Type 5 (n=1). With death as a competing risk, the cumulative 1-, 2- and 5- year risk of implant failure based on the Henderson classification was 11%, 25% and 25%, respectively. This led to revision of the implant due to dislocation in one patient who underwent a polyethylene and glenosphere exchange at 69 months. An additional patient with an allograft fracture (Type III) was not revised since the patient had diffuse metastatic disease. One patient developed regional metastatic disease (Type V) involving the axilla leading to a forequarter amputation 15 months postoperative. The overall limb salvage rate at 5-years postoperative was 75%.

## Discussion

Limb salvage surgery has replaced amputation as a means of treatment for most patients with primary and secondary malignancies of the extremities. Although the humerus is the most common area for these malignancies in the upper extremity, rarely is a total humeral resection necessary for local control. The results of the current study show that complications associated with the procedure are high, survival is poor, and function can be limited; however, this procedure offers an alternative to amputation and has the potential to preserve a functional hand.

Common complications following a total humeral replacement have previously been reported to be

instability of the shoulder component, ulnar fracture, infection and radial nerve palsy (4, 9-11). The magnitude of the soft-tissue resection, in addition to the need for systemic treatment such as chemotherapy or radiation therapy, likely accounts for the high risk of dislocation and infection. In the series by Bernthal *et al.* (10) the authors noted a high rate of dislocation that they felt could have been potentially reduced by the use of a reverse total shoulder. In the current study, we had no cases of postoperative infection, and our only case of subluxation/dislocation was in a patient with a reverse total shoulder arthroplasty; however, in this particular shoulder, instability was likely secondary to polyethylene wear. It also should be noted that this patient had the longest survival as well, and the high rate of perioperative mortality likely accounts for our low rate of dislocation and infection.

There are various advantages and disadvantages to consider when choosing between an APC and an endoprosthesis. In the shoulder and elbow, the use of both an APC and endoprosthesis have been shown to have acceptable functional outcomes (12, 13). There is limited data on the use of a APC of the entire humerus, and the data on the use of endoprostheses focuses on implants that are no longer commercialized in the United States for off the shelf use (10), or implants which are not available for use in the United States (3, 4, 9). In the United States, currently only the Zimmer/Biomet (Warsaw, IN, USA) Segmental Revision System (SRS) is available for off-the-shelf implantation of a whole humerus metallic replacement. Although the proximal humeral portion of this system has had a reliable track record with good functional outcomes (12, 14), the distal portion of the SRS system, namely the Nexel Total Elbow, one study has reported to be associated with a high rate of early failure secondary to its design (15). Based on this, our institutional preference is to utilize a total humeral APC (when possible) as it allows for the use of different implants for the shoulder and elbow based on surgeon preference and implant track record. Currently we consider the use of an SRS only in patients with limited life

expectancy (<6 months) secondary to the risk of early failure of the elbow component.

One finding in our study was the high rate of mortality observed in our patient population following these procedures, with three patients dying of disease within two months of the procedure. This is likely due to our use of these procedures in patients with metastatic disease compared to other large series (3, 9, 10). In addition to the poor survival, our functional outcome scores are lower than those previously reported. We are unable to directly compare differences between studies, however this could be due to the high rate of elbow contractures possibly due to the effects of adjuvant treatments. Although our complication rate was high, only one patient had a revision surgery. That being said, the rate of implant “failure” was higher than other studies and likely is secondary to the use of a competing risk analysis, versus other series which only use a Kaplan–Meier method, which does not account for death due to disease prior to implant failure (3, 10).

*Study limitations.* This is a small, retrospective study with limited available data, which constrained the analysis. Nevertheless, this is a rare procedure, and the prospective nature of our Total Joint Registry Database helps to limit recall bias. This study spans a long period of time over which surgical, medical imaging and reconstruction techniques have evolved. Multiple surgeons were involved in the tumor resection and reconstruction and due to the heterogenous nature of the tumors, there was no standard approach to each case.

Overall, the results of the current study show that total humeral resection and reconstruction is a demanding procedure with a high rate of complications, and relatively poor functional outcome scores. This procedure does provide an option for extremity reconstruction and a functional hand for a patient population with very limited alternative options. Our current preference is to perform an APC whenever possible, as it allows off-the-shelf customization of the implants and overcomes the current lack of endoprosthetic options.

## Conflicts of Interest

LGC, SEB, MHS, MEM: Declare no conflicts of interest related to this study. JDB, JSS: Consultant and IP from Stryker Orthopedics. MTH: Consultant for Stryker Orthopedics.

## Authors' Contributions

LGC: Drafting of initial and final manuscript, data collection, data analysis; SEB: Review and editing of final manuscript, data collection, data analysis; MHS: Review and editing of final manuscript; MEM: Review and editing of final manuscript; JDB: Review and editing of final manuscript; JSS: Review and editing of final manuscript; MTH: Drafting of initial and final manuscript, data analysis, supervision.

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