

FACTORS AFFECTING OUTCOMES IN PATIENTS TREATED SURGICALLY FOR UPPER EXTREMITY TUMORS AND TUMOR-LIKE LESIONS

Jesse E. Otero, MD, PhD, Christopher M. Graves, MD, Ashley TeKippe, BS,
Joseph A. Buckwalter, MD, MS, Benjamin J. Miller, MD

ABSTRACT

There is little data available regarding outcomes of patients who have undergone surgery for tumors of the upper extremity. Functional data after surgery for upper extremity tumors would aid in guiding patient expectations in the peri-operative period. The purpose of this study was to identify patient, tumor, and surgery-related characteristics associated with patient-reported physical and emotional function before and after surgery for tumors of the upper extremity.

Pre- and post-operative mental and physical Medical Outcomes Study Short Form 36 (SF-36) scores were collected from 79 patients with benign and malignant neoplasms of the upper extremity. A retrospective chart review was performed to ascertain whether tumor behavior, type, location, patient sex, age, surgical specimen size, or type of surgery were correlated with differing outcomes. Our outcome measure was patient-reported physical and mental score (SF-36) at less than one year, one to two years, and greater than two years post-operatively.

We found that patients with tumors proximal to the elbow and patients with right-sided tumors had statistically significantly lower post-operative physical scores at minimum two-year follow-up ($p=0.02$). Additionally, lower physical scores were associated with age greater than 50 ($p=0.03$) and tumor resection rather than curettage ($p=0.01$). The subset of patients with hereditary multiple exostoses had significantly lower post-operative physical scores than other patient sub-populations. There was no difference in physical function after

surgery between patients with benign and malignant tumors, patients with tumors larger than 5 cm and less than 5 cm in greatest dimension, and patients with bone versus soft tissue tumors. Interestingly, we found that there was no difference in mental function scores between any comparisons.

Our results suggest that patient age, tumor location, and type of surgery are correlated with patient-reported physical function following surgery. These findings could be helpful in counseling patients undergoing surgery for tumors of the upper extremity.

INTRODUCTION

Surgical and medical care for patients with bone and soft tissue tumors of the extremities continues to improve with advancement of chemotherapeutic strategies, surgical techniques, and understanding of pathogenesis^{1,4}. The long-term functional and psychosocial disability reported by survivors of bone cancer is among the highest of all cancer survivors, comparable to that reported by survivors of brain cancer^{5,6}. Clearly, more research is needed to understand the factors which contribute to patient outcomes after treatment of cancer of the extremities. This information could guide physician and patient discussions in the perioperative period.

Goals in treatment differ depending on whether a patient's tumor is benign or malignant. For malignant tumors of the extremities, treatment goals focus on both local oncologic control and optimizing function of the affected limb. Surgery, often aided by adjuvant therapy, is the cornerstone in treatment for these patients. Limb-salvage (LS) surgery for malignant extremity tumors⁷ show rates of local disease control and disease-free survival which are comparable to those observed after limb amputation (LA)⁸⁻¹¹. Limb-salvage surgery has a potential advantage over amputation in allowing the patient to retain a functional native limb.

Treatment goals for benign extremity tumors are to reduce pain, optimize function, and prevent local recurrence^{12,13}. Since benign bone and soft-tissue tumors are relatively rare, research involving surgery for benign extremity neoplasms is largely limited to case series on focused patient populations^{14,15}.

University of Iowa Department of Orthopaedic Surgery,
Iowa City, IA 52242

Corresponding Author:

Jesse E. Otero, MD, PhD

Address: 200 Hawkins Drive, Iowa City, IA, 52242

Phone: (319)353-7554.

E-mail: jesse-otero@uiowa.edu

Disclosures: The authors have no financial conflicts relevant to the submitted work. Dr. Miller is supported by grant T32 CA 148062-01 through the National Cancer Institute at the NIH.

Table 1: Diagnoses in Patients Treated Surgically for Upper Extremity Lesions			
Benign		Malignant	
Lipoma	12	Liposarcoma	5
Osteochondroma	6	Osteosarcoma	4
Unicameral Bone Cyst	6	Undifferentiated Sarcoma	4
Aneurysmal Bone Cyst	4	Chondrosarcoma	3
Hemangioma	4	Malignant Peripheral Nerve Sheath Tumor	2
Enchondroma	4	Myxofibrosarcoma	3
Chondromyxoid Fibroma	2	Ewing's Sarcoma	2
Desmoid Tumor	1	Leiomyosarcoma	2
Giant Cell Tumor	2	Metastatic Clear Cell Carcinoma	2
Chondroblastoma	1	Synovial Sarcoma	1
Lymphangioma	1	Extraskeletal Myxoid Chondrosarcoma	1
Osteoblastoma	1	Malignant Neurocristic Hamartoma	1
Schwannoma	1	Metastatic Esophageal Adenocarcinoma	1
Synovial Chondromatosis	1	Multiple Myeloma	1
Total	46	Spindle Cell Sarcoma	1
*one pt with both lipo and lymphangioma		Dermatofibrosarcoma Protuberans	1
		Total	34

Table 1: Tumor diagnosis
Tumor types were ascertained after surgery through surgical pathological analysis. There were 46 benign tumors and 34 malignant tumors. One patient had co-existing primary lipoma and lymphangioma resected during a single procedure.

Because of the diversity of conditions treated by the musculoskeletal oncologist, treatment is individualized in every case. Therefore, little information is available in the literature to aid in appropriately counseling individual patients regarding expected functional outcomes after surgery. The current study was undertaken to analyze patient-reported mental and physical function before and after surgery for benign and malignant tumors of the upper extremity. Specifically, we sought to identify particular patient, tumor, and surgery-related characteristics that are significantly associated with differences in patient-reported mental and physical function post-operatively.

METHODS

All patients in the study underwent surgery for a benign or malignant tumor of bone or soft tissue of the upper extremity between January, 2000 and December, 2010. For the purposes of the study, upper extremity was defined as the shoulder girdle (scapula, clavicle, and axilla) distally to the phalanges, and the overlying soft tissue. The surgical procedure was performed by an orthopaedic musculoskeletal tumor specialist. Anatomic pathology reports confirming the diagnosis of tumor was confirmed for all included cases. Patients were only

included in the study if they filled out a Short Form-36 (SF-36) survey post-operatively. Patients were excluded from the study if they had surgery performed for a reason other than a tumor or if pathology reports did not confirm the diagnosis of tumor. This study was approved by The University of Iowa Institutional Review Board.

Seventy-nine patients met inclusion criteria. Thirty-seven patients (47%) were male, and 42 (53%) were female. Average age at the time of surgery was 38 years (range 1 to 85 years). There was a bimodal distribution of age at time of surgery with one peak occurring in the second decade and another occurring in the fifth decade of life.

Tumors:

In 79 patients who met inclusion criteria for the study, 80 tumor types were diagnosed. Ninety-four surgeries were performed in the 79 patients. Forty-six (58%) tumor types were benign, while thirty-four (42%) tumor types were malignant (Table 1). The tumors involved the left upper extremity of 37 patients, and the right upper extremity of 42 patients involved the right upper extremity (Table 2). Thirty-eight tumors were of the soft tissue, and 41 tumors were of bone. Fifty-seven patients had tumors proximal to the elbow, and 22 had tumors distal to the elbow (Figure 1).

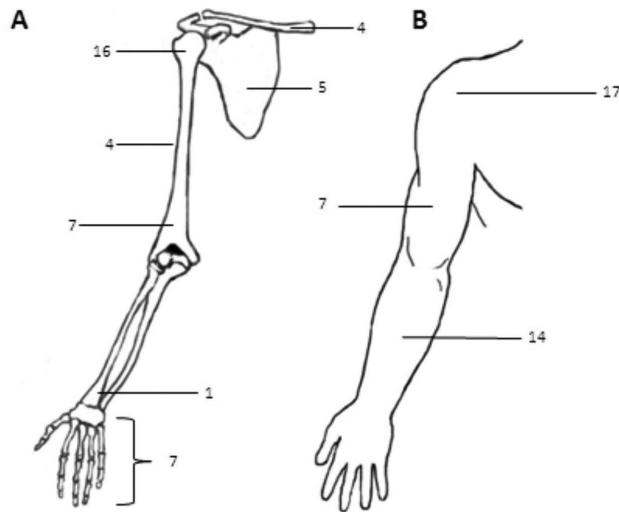


Figure 1: Location of Tumors
 Localization of tumors of the upper extremity in the current study. (A) Tumors of bone with localization in clavicle, scapula, proximal, mid, and distal humerus, forearm bones, and bones of the hand (carpal bones, metacarpals or phalanges). (B) Tumors of soft tissue with localization in the shoulder region, arm, and forearm. Tumor localization was determined based on operative reports and anatomic pathology reports.

Outcomes Measured:

Post-operative Medical Outcomes Study (MOS) Short Form-36 (SF-36) data were collected from all patients in the study, and pre-operative SF-36 scores were available for 50 of the 79 patients in our study¹⁶. Mental component scores (MCS) and physical component scores (PCS) were tabulated¹⁷. Post-operative data were divided into three periods for statistical analysis: less than one year follow-up (31 surveys available in 26 patients), one to 2 year follow-up (35 surveys available in 31 patients), and greater than two year follow-up (76 surveys available in 71 patients). Variables were analyzed in each time period in the study: male versus female patients; patients 50 years of age and younger versus patients older than 50; tumors on the right versus the left upper extremity; patients with tumors proximal versus distal to the elbow joint; bone versus soft tissue tumors; benign versus malignant tumors; surgical specimens whose largest dimension was 5 cm or less versus greater than 5 cm. Resection specimen size was gleaned from pathology reports. Within the group of patients who underwent surgery for a soft tissue tumor, we compared outcomes between those who had resection of mass alone versus those who had resection of mass including muscle and/or nerve tissue. Time periods were separated into less than two years and greater than two years post-operatively. For the subset of patients who underwent surgery for

a primary bone tumor, a comparison was made between those who underwent curettage versus bone resection versus resection involving a joint surface. Post-operative time periods were separated into less than two years and greater than two years post-operatively (Table 2).

Statistical Analysis:

SF-36 MCS and PCS scores were compared pre-operatively and at each post-operative time period between each of the demographic, pathologic, and surgical variables. The differences in scores were analyzed with the Student's t-test in Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA). P values less than 0.05 were considered statistically significant. When patients submitted more than one survey in one of the analyzed time periods, their MCS and PCS scores were averaged and tabulated as one score to avoid inappropriate influence of one patient on the average score for a group.

RESULTS

The mean post-operative physical component score (PCS) of the SF-36 in all patients was 45.8 (standard deviation 9.9). There was no statistical difference in pre-operative SF-36 PCS scores between any of the groups compared. The PCS was compared between multiple groups at less than one year (early), 1-2 years (intermediate), and greater than two years follow-up (long-term). Statistically significant differences in outcome were detected in the following comparisons: Patients 50 years of age and younger had higher PCS in the long-term follow-up period (47.5 versus 42.8, $p=0.03$). Patients with right upper extremity tumors had a lower PCS than did patients with left-sided tumors in the long-term follow-up period (43.8 versus 49.0, $p=0.02$). Additionally, patients with tumors proximal to the elbow had a lower PCS than did patients with tumors distal to the elbow at long-term follow-up (45.1 versus 49.8, $p=0.02$). We did not detect a significant difference in post-operative PCS between patients undergoing surgery for soft-tissue versus bone tumors (Figure 2, Table S1). Within the group of patients undergoing surgery for bone tumors, those treated with resection of tumor had statistically significantly lower post-operative PCS than those undergoing curettage at long-term follow-up (38.9 versus 49.9, $p=0.01$) (Figure 2, Table S2).

The mean post-operative mental component score (MCS) of the SF-36 in all patients was 53.9 (standard deviation 8.5). The MCS was also compared between multiple groups at less than one year (early), 1-2 years (intermediate), and greater than two years (long-term) follow-up. The MCS was not significantly different between groups in any comparison (Table S1 and S2).

Table 2: Characteristics of patients, their tumors, and their surgeries

Age at Surgery	Sex	Diagnosis	Location	Greatest Demension (cm)	Surgery	Details
20	F	Aneurysmal Bone Cyst	Left Scapula	2.7	Rsx	Two surgeries ending with Resection and Grafting
40	F	Aneurysmal Bone Cyst	Left Olecranon	2.4	Curettage	Curettage with Cancellous Allograft
48	F	Aneurysmal Bone Cyst	Left Proximal Humerus	5.2	Curettage	Curettage with Cancellous Allograft
21	F	Aneurysmal Bone Cyst	Right Distal Humerus	1	Rsx	Curettage with Cancellous Allograft
15	F	Chondroblastoma	Left Proximal Humerus	2	Curettage	Curettage with Cancellous Allograft
47	M	Chondromyxoid Fibroma	Left Distal Humerus	3	Curettage	
38	F	Chondromyxoid Fibroma	Left Distal Humerus	2.5	Curettage	Curettage and Cancellous Allograft
56	F	Chondrosarcoma - Grade I	Right Humerus	2.2	Curettage	Two surgeries ending with Curettage and Cancellous Allograft
59	F	Chondrosarcoma - Grade II	Right Scapula	17	Rsx	Four total surgeries for local recurrence
54	F	Chondrosarcoma - Grade II	Right Proximal Humerus	10	Rsx + Jt	Modular Hemiarthroplasty
19	M	Dermatofibrosarcoma protuberans	Left shoulder	4.1	Exc	
34	F	Desmoid Tumor	Left Anterior Shoulder	7	Exc + Muscle	Two total surgeries for local recurrence
11	F	Enchondroma	Right Index Finger	2.5	Curettage	Curettage and Cancellous Grafting
57	M	Enchondroma	Left Proximal Humerus	2.5	Curettage	
40	F	Enchondroma	Right Second Finger	2	Curettage	
48	F	Enchondroma	Left Second Finger Middle Phalanx	2.5	Curettage	Curettage and Grafting
2	F	Ewing's Sarcoma	Left Ring Finger	5.6	Curettage	
1	M	Ewing's Sarcoma	Left Dorsal Forearm	3.4	Rsx + Jt	
63	M	Extraskeletal Myxoid Chondrosarcoma	Left Forearm	8	Exc + Muscle	
32	M	Giant Cell Tumor	Left Proximal Humerus	4	Curettage	Two separate surgeries
76	M	Giant Cell Tumor	Right Distal Radius	4.5	Rsx + Jt	Proximal Fibular Autograft
10	F	Hemangioma	Right Posterior Elbow	3.6	Exc + Muscle	
34	F	Hemangioma (Intramuscular)	Right Forearm	3.9	Exc + Muscle	
31	M	Hemangioma (Intramuscular)	Left Forearm - FDS	2.5	Exc + Muscle	
17	F	Hemangioma and Lipoma	Left Posterior Axilla	2	Exc + Muscle	
11	M	Hereditary Multiple Exostosis	Shoulder Right	1.7	Rsx	
11	F	Hereditary Multiple Exostosis	Right Scapula	2	Rsx	
19	M	Hereditary Multiple Exostosis	Right Proximal Humerus, Right Distal Clavicle		Rsx	Three surgeries involving shoulder girdle
44	M	Hereditary Multiple Exostosis	Right Proximal Humerus	2.5	Rsx	

Factors Affecting Outcomes in Patients Treated Surgically for Upper Extremity Tumors and Tumor-like Lesions

68	M	High Grade Sarcoma	Right Posterior Arm	13	Exc	
68	M	High Grade Sarcoma	Left Dorsal Forearm	7.6	Exc + Muscle	Involved Brachioradialis
11	F	High Grade Sarcoma	Left Dorsal Forearm	7	Exc + Nerve + Musc	
44	F	High Grade Sarcoma	Left Biceps Brachii	14.5	Exc + Musc + Nerve	
34	M	Leiomyosarcoma	Left Forearm	4	Exc + Muscle	Three total surgeries for local recurrence
38	F	Leiomyosarcoma	Right Medial Forearm	4	Exc + Muscle	
45	F	Lipoma	Right Lateral Deltoid	2.9	Exc + Muscle	
57	F	Lipoma	Right Shoulder Subdeltoid	14	Exc	
49	M	Lipoma	Left Forearm	11	Exc + Muscle	
67	M	Lipoma	Right Antecubital Region	11.5	Exc	
39	F	Lipoma	Right Antecubital Region	3	Exc	
40	F	Lipoma	Right Shoulder	14	Exc	
60	F	Lipoma	Left Proximal Arm and Shoulder	15	Exc	
17	F	Lipoma	Right Arm	6.7	Exc	
43	F	Lipoma	Right Shoulder	6.8	Exc	
49	F	Lipoma	Left Shoulder	9.5	Exc	
67	F	Lipoma	Right Shoulder	5	Exc	
61	M	Liposarcoma (High-grade)	Right Forearm	5	Exc + Muscle	
65	F	Liposarcoma	Right Deltoid	5.5	Exc + Muscle	
29	M	Liposarcoma	Right Shoulder	12	Exc	
57	F	Liposarcoma (Well-differentiated)	Right Shoulder	14	Exc	
47	M	Liposarcoma (Well-differentiated)	Right Shoulder	14.5	Exc	
37	F	Lymphangioma	Right Dorsal Wrist, Right Lateral Forearm	4.5	Exc	
66	M	Metastatic clear cell carcinoma (renal primary)	Left Humerus Diaphysis	2.6	Rsx	Resection with Interclary Graft
67	M	Metastatic clear cell carcinoma (renal primary)	Left Glenoid	2	Curettage	Curettage and Cancellous Autograft
46	M	Metastatic Esophageal Adenocarcinoma	Left Proximal Humerus	6.3	Rsx + Jt	Modular Hemiarthroplasty
55	M	Multiple Myeloma	Right Distal Humerus	2.5	Curettage	Curettage and Cancellous Allograft
77	F	Myxofibrosarcoma - High Grade	Right Posterior Arm - Triceps	7.2	Exc + Muscle	Involved Treceps
51	F	Myxofibrosarcoma	Right Shoulder	10.5	Rsx	
43	M	Myxofibrosarcoma Intermediate Grade	Right Shoulder Rotator Mass	6.2	Exc + Muscle	
0	M	Neurocristic Hamartoma	Left Shoulder	5.5	Exc	
21	M	Osteoblastoma	Left Proximal Humerus	1.1	Curettage	Curettage and Graft
25	M	Osteochondroma	Right Scapula	7.1	Rsx	
11	M	Osteochondroma	Left Ring Finger	0.9	Rsx	
23	M	Osteosarcoma	Proximal Left humerus	18	Rsx + Jt	Modular Hemiarthroplasty
24	M	Osteosarcoma	Left Proximal Humerus	11.8	Rsx + Jt	Modular Hemiarthroplasty

28	F	Parosteal Osteosarcoma	Left Proximal Humerus	12.5	Rsx + Jt	Hemiarthroplasty
60	M	Parosteal Osteosarcoma	Right First Metacarpal	6	Rsx + Jt	Fibular Autograft
54	M	Recurrent Malignant Peripheral Nerve Sheath Tumor	Right Humerus Diaphysis	3.5	Exc + Nerve	Two surgeries for local recurrence. Radial Nerve sacrificed
85	M	Recurrent Malignant Peripheral Nerve Sheath Tumor	Left Proximal Humerus	11.6	Rsx + Jt	Two surgeries because of Metastasis to proximal humerus treated with Modular Hemiarthroplasty
37	F	Schwannoma	Right 2nd Metacarpal Head	2	Curettage	
43	M	Spindle Cell Sarcoma - Low Grade	Right Medial Arm	1.2	Exc	Two total surgeries for local recurrence
52	F	Synovial Chondromatosis	Left Elbow	5.1	Exc	
11	F	Synovial Sarcoma	Left Forearm	3.1	Exc	
8	F	Unicameral Bone Cyst	Right Proximal Humerus	1	Curettage	Curettage and Graft
12	M	Unicameral Bone Cyst	Right Proximal Humerus	5.5	Curettage	Curettage and Graft
15	F	Unicameral Bone Cyst	Right Midshaft Humerus	1	Curettage	Curettage and Graft
4	M	Unicameral Bone Cyst	Right Clavicle	3.5	Curettage	
18	F	Unicameral Bone Cyst	Left Distal Humerus	2	Curettage	Curettage and Graft
7	M	Unicameral Bone Cyst	Left Midshaft Humerus	Not given	Curettage	Curettage and Graft

Table 2: Patient, Tumor, and Surgical Characteristics
 Retrospective chart review was used to determine patient age and sex, tumor pathologic diagnosis, location, size, and method of surgical treatment.

DISCUSSION

Our study is unique in its attempt to analyze patient-reported functional scores in a diverse patient population with tumors and tumor-like lesions of the upper extremity. We included all patients with tumors and tumor-like lesions of the upper extremity, benign and malignant, treated by an orthopaedic oncologist at our institution. We collected data to determine whether particular patient-, tumor-, or surgery-related factors exist which may affect patient reported outcomes. The theoretical benefit of such research is to offer evidence-based information to guide patient expectations regarding their long-term function after surgery.

The MOS SF-36 is used to ascertain patient-reported outcomes. This simple test was developed to provide a global assessment of patients' perspective on their physical and mental health.¹⁶ We simplified our analysis by using the physical and mental component scores of the SF-36¹⁷. The use of the SF-36 in global health assessment has been validated previously for the assessment of orthopaedic surgery outcomes¹⁸. The SF-36 has been shown to reliably correlate with the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire with Pearson coefficients reaching -0.62. The SF-36 has also been shown to correlate with the Enneking scale, a musculoskeletal tumor-specific outcome measurement tool¹⁹.

This study analyzed patient, tumor, and surgery-related characteristics to determine which factors affect patient-reported physical and mental scores, including patient sex and age, tumor behavior and location, along with type of surgery and resection specimen size. We detected no pre-operative (baseline) difference in PCS between any of the groups defined by the demographic, surgical, or pathological characteristics compared. Furthermore, there were no differences in MCS for any of the comparisons performed pre-operatively or post-operatively. This has clinical importance because a patient's sense of emotional well-being may affect how he or she perceives his or her physical capabilities, which would confound detected differences in patient-reported physical function.

This study found no difference in physical outcomes between patients in our study with benign and malignant tumors. We observed uncharacteristically low post-operative scores for the subset of patients with hereditary multiple exostoses (HME). When the scores of these patients were removed from the analysis, a significantly higher PCS was seen in patients with benign tumors at early followup compared to patients with malignant tumors (Benign, 49.1 versus Malignant, 42.6; $p=0.04$). This effect was not seen at intermediate or long-term follow-up. We did not perform a survival analysis in our study. The low post-operative PCS scores in patients with HME may be related to the effect of their multiple

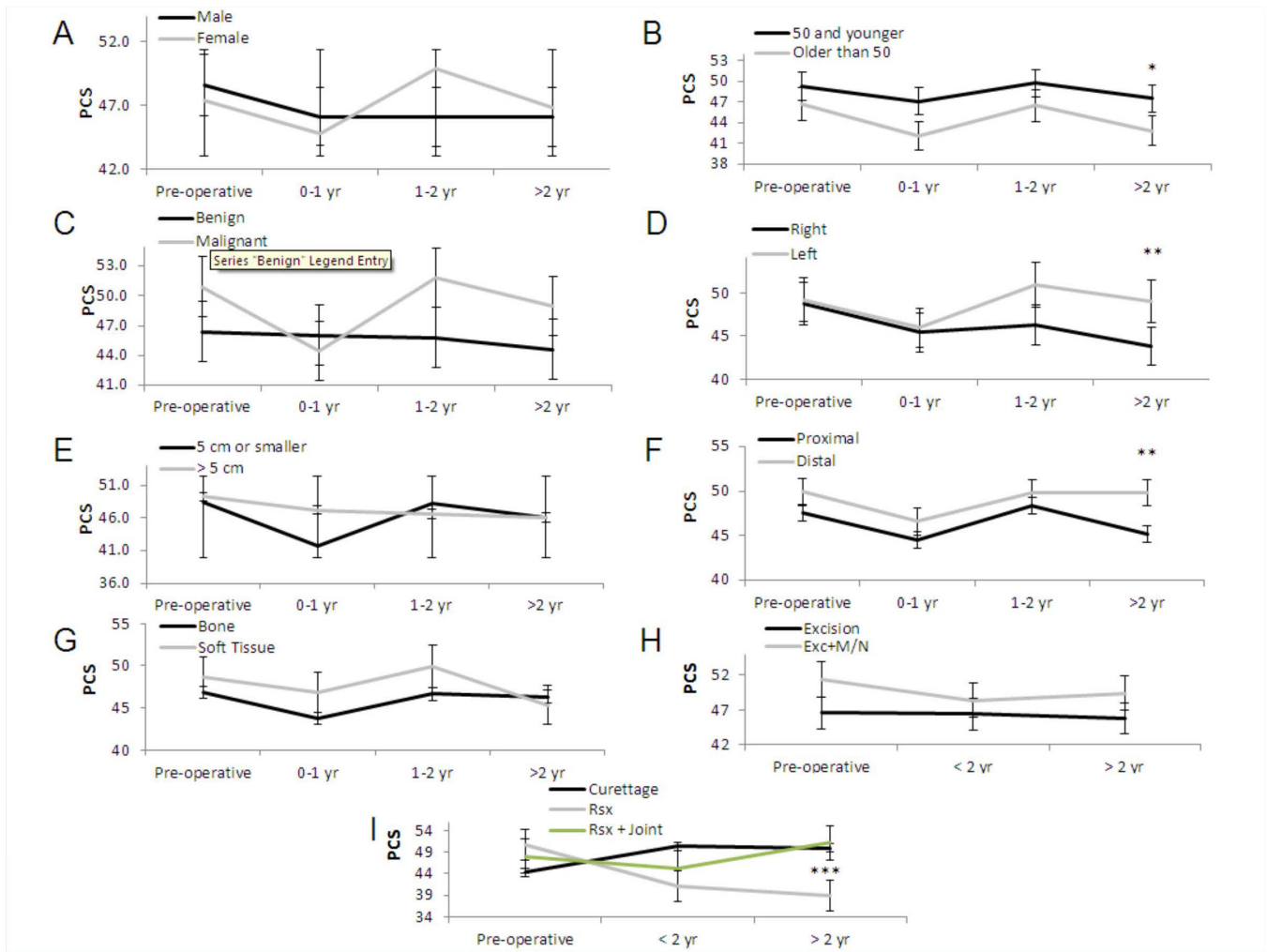


Figure 2: SF-36 Physical Component Scores comparing patient, tumor, and surgical parameters
 Average MOS SF-36 physical component scores (PCS) in patients treated by an orthopaedic surgeon for upper extremity malignancy at baseline (Pre-operative) and at early (0-1 yr) follow-up, intermediate (1-2yr) follow-up, and long-term (> 2 yr) follow-up. Patients were divided into separate groups for comparing the effect of (A) sex, (B) age, (C) malignancy, (D) laterality, (E) size, (F) location in relation to the elbow, and (G) Tissue-type involved. (H) A separate analysis compared outcomes within soft tissue tumors comparing those excised alone, or those whose excision involved muscle or nerve. Followup was divided into less than two years and greater than two years. (I) Likewise, bone tumors were divided into those treated with curettage, Resection (Rsx), and Resection involving joint (Rsx + Joint). Statistically significant results denoted by asterisks: *, $p=0.03$; **, $p=0.02$; ***, $p=0.01$.

physical deformities which make it difficult to adapt to life post-surgically²⁰. We did not have pre-operative SF-36 scores for these patients.

We were unable to detect a difference in post-operative PCS between patients with tumors 5 cm or less and patients with tumors larger than 5 cm. We performed a separate analysis comparing outcomes based on size of tumor with 3 cm as the cutoff. No significant difference in PCS was seen post-operatively at early follow-up. In a similar study assessing functional outcome after limb-salvage surgery for malignant bone and soft-tissue tumors, Johansen and colleagues found that tumor size did not significantly affect Musculoskeletal Tumor Society score²¹ in patients post-surgically²².

We found significantly lower post-operative PCS scores for patients older than 50. Pre-operative scores in older patients did not differ significantly, arguing that the difference in post-operative scores is not a result of co-morbidities in elderly patients, but rather, the effect of recovery from surgery in older individuals. In this regard, a study that analyzed factors affecting function after limb-salvage surgery for tumors of the lower extremity found age to be an independent predictor of pre-operative SF-36 score²³. The reason pre-operative SF-36 score was not different between age groups in our study most likely relates to specific characteristics of the populations which we did not analyze.

In comparing patients with right upper extremity tumors to those with left-sided tumors, we found no difference in pre-operative SF-36 score. Interestingly, those with right-sided tumors had lower PCS scores in all follow-up periods. These scores were significantly lower than patients with left-sided tumors at long-term follow-up. We assume that the majority of patients in our study were right-hand dominant, although we were unable to confirm this in our retrospective chart review. This data suggests that recovery from surgery involving the dominant limb poses greater physical difficulty, given post-operative limitations in function.

In comparison of outcomes between patients with tumors located proximal and distal to the elbow, we found a significantly lower post-operative PCS at long-term follow-up in patients with tumors proximal to the elbow than distal to the elbow. Pre-operative scores were not different. In a recent analysis of patients with aggressive tumors of the upper extremity reconstructed with vascularized fibular grafts, Rashid and colleagues also found that patients with tumors proximal to the elbow had lower functional scores. The authors postulated that this discrepancy was related to compromised function of the elbow or shoulder after surgery²⁴. Motion at these joints is essential for activities such as eating and personal hygiene, which are accounted for by the SF-36 PCS. We also sought to determine whether there was an effect of tissue origin (bone versus soft tissue) of tumor on PCS and MCS post-operatively. We did not detect a difference in post-operative scores at early, intermediate, or long-term follow-up. The heterogeneity of surgical treatments within the groups may have affected our results. We attempted to address this concern by subdividing patients as follows: We separated patients with soft tissue tumors into those whose tumors were excised

alone versus those whose tumor excisions involved nerve or muscle tissue. For bone tumors, we subdivided into those treated with curettage, resection, or resection involving a joint surface. Among the different subgroups, we detected significantly lower post-operative scores at long-term follow-up in those with bone tumors treated with surgical resection compared with curettage.

Our study was limited by several important factors. First, the retrospective nature of the study limited our data to that available on chart review. All data were gathered in the context of patient care, and therefore, scheduled follow-ups for uniform data collection were not available. Additionally, the number of patients who filled out the survey was low compared to the total number of patients with upper extremity tumors treated between 2000-2010, so a significant amount of data were missing in our study. Related to low patient numbers, the study may have been inadequately powered to detect differences in some comparisons. Furthermore, the population analyzed was heterogeneous with regard to age, diagnosis, and type of surgery, so fine differences in outcomes may have been missed. Finally, our data were incomplete in that many of our patients did not submit surveys during all of the time periods analyzed, so each individual in the study did not necessarily contribute to every statistical comparison made.

The research presented provides an analysis of mental and physical function in patients after surgery for upper extremity tumors and tumor-like lesions. We found that patient age, tumor relation to the elbow joint, and tumor laterality were significantly associated with physical function after surgery. The data, although limited by study population size, may be helpful in counseling patients regarding functional outcomes after surgery for upper extremity tumors.

Table S1: Numerical PCS and MCS Data

Physical Component Score (PCS)

Mental Component Score (MCS)

Benign v Malignant	Benign	Malignant	p		Benign	Malignant	p
Pre-operative	46.42	50.94	0.07		53.01	53.06	0.98
0-1 yr	46.05	44.48	0.34		53.91	49.90	0.23
1-2 yr	45.81	51.87	0.09		50.53	49.90	0.05
>2 yr	44.61	49.01	0.05		52.61	55.23	0.25
Age	<=50	> 50	p		<= 50	> 50	p
Pre-operative	49.30	46.70	0.16		52.40	53.70	0.26
0-1 yr	47.11	42.11	0.11		52.70	50.79	0.59
1-2 yr	49.76	46.48	0.20		52.79	51.96	0.74
>2 yr	47.49	42.85	0.03		53.13	54.92	0.47
Right v Left	Right	Left	p		Right	Left	p
Pre-operative	48.70	49.20	0.43		54.40	52.50	0.19
0-1 yr	45.40	45.93	0.89		50.70	54.97	0.14
1-2 yr	46.23	50.91	0.20		52.14	52.84	0.79
>2 yr	43.81	49.00	0.02		52.27	55.53	0.11
Male v Female	Male	Female	p		Male	Female	p
Pre-operative	48.60	47.35	0.64		53.40	52.10	0.57
0-1 yr	46.12	44.80	0.74		52.80	49.95	0.44
1-2 yr	46.09	49.88	0.42		53.48	51.82	0.51
>2 yr	46.09	46.79	0.77		53.09	53.68	0.80
Size of Specimen	<=5 cm	> 5 cm	p		<=5 cm	> 5 cm	p
Pre-operative	48.40	49.24	0.75		53.94	52.10	0.38
0-1 yr	41.72	47.24	0.17		49.88	51.86	0.60
1-2 yr	48.29	46.60	0.65		53.64	50.78	0.40
>2 yr	46.14	46.01	0.95		53.97	52.92	0.65
Proximal v Distal	Prox	Dist	p		Prox	Dist	p
Pre-operative	47.50	49.90	0.36		52.40	54.00	0.38
0-1 yr	44.45	46.60	0.57		50.25	53.03	0.36
1-2 yr	48.30	49.79	0.70		54.09	50.90	0.28
>2 yr	45.12	49.83	0.02		52.90	54.37	0.44
Bone v Soft Tissue	Bone	ST	p		Bone	ST	p
Pre-operative	46.86	48.58	0.27		51.59	53.87	0.36
0-1 yr	43.78	46.82	0.49		50.40	53.92	0.40
1-2 yr	46.60	49.87	0.37		55.12	50.79	0.11
>2 yr	46.32	45.32	0.66		53.20	53.67	0.83

Table S1: Numerical PCS and MCS Data

Average PCS and MCS score at early (0-1 yr), intermediate (1-2 yr) and long-term (>2 yr) followup are listed for all comparisons. Student's t-test with two tailed null-hypothesis for non-paired means was used to compare average scores between groups. Italics denote statistically significant p-values. Prox, Proximal to elbow joint; Dist, Distal to elbow joint; ST, Soft Tissue Tumor.

Table S2: Numerical PCS and MCS Data Comparing Method of Surgical Treatment

Physical Component Score (PCS)												
Soft Tissue				Bone								
	Excision	Exc+M/N	p		Curettage	Resection	Resx + Joint	p (C v R)	p (R v Rjt)	p (C v Rjt)	p(R v E)	p(R v E+M/N)
Pre-operative	46.53	51.43	0.17	Pre-operative	44.28	50.70	48.01	0.32	0.70	0.50	0.46	0.89
< 2 yr	46.38	48.38	0.66	< 2 yr	50.33	41.10	45.21	0.08	0.58	0.17	0.51	0.18
> 2 yr	45.73	49.37	0.32	> 2 yr	49.95	38.89	51.23	0.01	0.07	0.72	0.12	0.06

Mental Component Score (MCS)												
Soft Tissue				Bone								
	Excision	Exc+M/N	p		Curettage	Resection	Resx + Joint	p (C v R)	p (R v Rjt)	p (C v Rjt)		
Pre-operative	52.45	53.43	0.68	Pre-operative	52.88	55.77	51.30	0.45	0.63	0.77		
< 2 yr	51.54	50.18	0.71	< 2 yr	54.94	51.76	51.35	0.37	0.95	0.44		
> 2 yr	54.18	56.12	0.90	> 2 yr	56.12	50.91	55.31	0.20	0.54	0.54		

Table S2: Numerical PCS and MCS Data Comparing Method of Surgical Treatment

We compared method of surgical treatment of soft tissue tumors, separating treatment into surgeries which required excision alone versus excision in which muscle and or nerve was sacrificed (Exc+M/N). We also compared method of surgical treatment of bone tumors, separating treatment into curettage, resection, or resection involving a joint surface (Resx + Joint). Upper table lists PCS with p-values for multiple comparisons: C, Curettage; R, Resection; Rjt, Resection involving a joint surface; E, Excision; E+M/N, Excision in which muscle and or nerve was sacrificed. Statistically significant p-values are italicized.

REFERENCES

- Hameed M, Dorfman H.** Primary malignant bone tumors—recent developments. *Semin Diagn Pathol* 28:86-101, 2011
- Hegy M, Semsei AF, Jakab Z, et al.** Good prognosis of localized osteosarcoma in young patients treated with limb-salvage surgery and chemotherapy. *Pediatr Blood Cancer* 57:415-22, 2011
- Hong S, Shin SJ, Jung M, et al.** Comparison of long-term outcome between doublet and triplet neoadjuvant chemotherapy in non-metastatic osteosarcoma of the extremity. *Oncology* 80:107-17, 2011
- Subbiah V, Anderson P, Lazar AJ, et al.** Ewing's sarcoma: standard and experimental treatment options. *Curr Treat Options Oncol* 10:126-40, 2009
- Ness KK, Mertens AC, Hudson MM, et al.** Limitations on physical performance and daily activities among long-term survivors of childhood cancer. *Ann Intern Med* 143:639-47, 2005
- Zeltzer LK, Lu Q, Leisenring W, et al.** Psychosocial outcomes and health-related quality of life in adult childhood cancer survivors: a report from the childhood cancer survivor study. *Cancer Epidemiol Biomarkers Prev* 17:435-46, 2008
- Yaw KM.** Pediatric bone tumors. *Semin Surg Oncol* 16:173-83, 1999
- Bacci G, Ferrari S, Bertoni F, et al.** Prognostic factors in nonmetastatic Ewing's sarcoma of bone treated with adjuvant chemotherapy: analysis of 359 patients at the Istituto Ortopedico Rizzoli. *J Clin Oncol* 18:4-11, 2000
- Bielack SS, Kempf-Bielack B, Delling G, et al.** Prognostic factors in high-grade osteosarcoma of the extremities or trunk: an analysis of 1,702 patients treated on neoadjuvant cooperative osteosarcoma study group protocols. *J Clin Oncol* 20:776-90, 2002
- Simon MA, Aschliman MA, Thomas N, et al.** Limb-salvage treatment versus amputation for osteosarcoma of the distal end of the femur. *J Bone Joint Surg Am* 68:1331-7, 1986
- Sluga M, Windhager R, Lang S, et al.** Local and systemic control after ablative and limb sparing surgery in patients with osteosarcoma. *Clin Orthop Relat Res*:120-7, 1999
- Payne WT, Merrell G.** Benign Bony and Soft Tissue Tumors of the Hand. *Journal of Hand Surgery-American Volume* 35A:1901-1910, 2010
- Plate AM, Lee SJ, Steiner G, et al.** Tumorlike lesions and benign tumors of the hand and wrist. *J Am Acad Orthop Surg* 11:129-41, 2003
- Kaila R, Ropars M, Briggs TW, et al.** Aneurysmal bone cyst of the paediatric shoulder girdle: a case series and literature review. *J Pediatr Orthop B* 16:429-36, 2007
- Clement ND, Ng CE, Porter DE.** Shoulder exostoses in hereditary multiple exostoses: probability of surgery and malignant change. *J Shoulder Elbow Surg* 20:290-4, 2011
- Ware JE, Jr., Sherbourne CD.** The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care* 30:473-83, 1992

17. **Ware JE, Kosinski M.** Interpreting SF-36 summary health measures: a response. *Qual Life Res* 10:405-13; discussion 415-20, 2001
18. **Martin DP, Engelberg R, Agel J, et al.** Comparison of the Musculoskeletal Function Assessment questionnaire with the Short Form-36, the Western Ontario and McMaster Universities Osteoarthritis Index, and the Sickness Impact Profile health-status measures. *J Bone Joint Surg Am* 79:1323-35, 1997
19. **Wada T, Kawai A, Ihara K, et al.** Construct validity of the Enneking score for measuring function in patients with malignant or aggressive benign tumours of the upper limb. *J Bone Joint Surg Br* 89:659-63, 2007
20. **Stieber JR, Dormans JP:** Manifestations of hereditary multiple exostoses. *J Am Acad Orthop Surg* 13:110-20, 2005
21. **Enneking WF, Dunham W, Gebhardt MC, et al.** A system for the functional evaluation of reconstructive procedures after surgical treatment of tumors of the musculoskeletal system. *Clin Orthop Relat Res*:241-6, 1993
22. **Johansen R, Nielsen OS, Keller J.** Functional outcome in sarcomas treated with limb-salvage surgery or amputation. *Sarcoma* 2:19-23, 1998
23. **Davis AM, Sennik S, Griffin AM, et al.** Predictors of functional outcomes following limb salvage surgery for lower-extremity soft tissue sarcoma. *J Surg Oncol* 73:206-11, 2000
24. **Rashid M, Hafeez S, Zia ul Islam M, et al.** Limb salvage in malignant tumours of the upper limb using vascularised fibula. *J Plast Reconstr Aesthet Surg* 61:648-61, 2008