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Original Article

The effect of cement augmentation and anteromedial plating on proximal humerus allograft reconstruction

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A B S T R A C T

Background: Limb salvage following the resection of tumor from the proximal part of the humerus, poses many challenges, and there is no consensus regarding the best reconstructive technique after proximal humerus resection. The aim of this study was to evaluate the effect of anteromedial placing of the plate in the absence of deltoid muscle and cement augmentation on the functional outcome, complication rate and survival of proximal humerus allograft reconstruction.

Patients and methods: A number of 36 osteoarticular allograft reconstructions of proximal humerus were included in final study. In 26 cases, medullary canal of the allograft was filled by cement and the complication rate and survival was compared to non-cemented allografts. In addition, anteromedial placement of plate was applied for all resection type IB (18 cases), in which the deltoid muscle was resected. The mean follow-up of patients was 46 months.

Results: In total, 12 complications including 3 fractures, 4 resorptions, 3 infections and 2 nonunions were reported. Complication rates were significantly lower in cemented allografts ($p = 0.001$). Five year survival rates of cemented and non-cemented allografts were found to be 82% and 70%, respectively. The mean MSTS score was 84.9%, ranging 76–90.

Conclusion: According to our results, cement augmentation improves survival and reduces the complication rate of allografts. Moreover, our results showed that anteromedial placing of the plate in resection type IB could improve the functional outcome of allografts. However, the detailed effect of anteromedial plating should be further investigated in future studies.

1. Introduction

Proximal humerus is one of the most common sites of primary bone tumors after distal femur and proximal tibia [1]. Wide resection of tumors without compromise of oncologic margin, results in a considerable amount of osteoarticular defects, loss of periarticular soft-tissue stabilizers of the shoulder, and a significant impairment of rotator cuff and deltoid muscles. Available reconstructive options for these defects include osteoarticular allograft [2–4], oncologic modular endoprosthesis [5,6], and allograft-prosthesis composite (APC) [7,8]. There is no consensus regarding the best reconstructive technique after proximal humerus tumor resection [9]. During osteoarticular allograft reconstruction, attachment of the remaining muscles and rotator cuff tendons to the soft tissue of the allograft, improves healing and function of the soft tissues [7]. However, allograft survival rate is usually lower than other reconstruction procedures, mainly due to the higher fracture rate [4,7,10,11]. Modifying osteoarticular allograft reconstruction technique may improve functional results and reduce complication rates of this procedure. Given that fractures are the main complication of allograft reconstruction, cement augmentation could be considered as a choice to reduce the fracture rate. In addition, we propose that anteromedial plate placement in resection type IB, in which the deltoid muscle is lost, could improve the functional outcome of such procedure by avoiding plate prominence beneath the skin and also preventing probable radial nerve injury.

In this article we retrospectively evaluated the effect of cement augmentation and anteromedial plate placement on the complication rate, survival and functional outcome of allograft

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reconstruction of proximal humerus following wide resection of the tumor.

2. Materials and methods

2.1. Patients

This study was approved by the ethics committee and institutional review board of our university. We retrospectively reviewed the medical records of patients with proximal humerus tumor referred to the musculoskeletal oncology department of our university hospital from 1990 to 2010. All patients with primary malignant or benign aggressive proximal humerus tumor treated with fresh-frozen osteoarticular allograft were evaluated to enter in the study. Patients with metastatic lesions, diffused disease (such as multiple myeloma), recurrent lesions and patients with a history of previous surgery or radiation therapy were excluded from the study. A total of 44 patients, (26 male and 18 female) with over two years of follow-up were included in the study. From those, 6 patients including 4 female and 2 male died at a median of 34 months (4 from metastatic sarcoma and 2 from metastatic carcinoma). Loss of follow-up led to the further exclusion of 2 patients from the study (2 female) and the final evaluation was performed on the remaining 36 cases. The mean age of patients was 27 years, ranging from 6 to 75 years. All benign aggressive tumors included in this study were stage 3, whilst malignant tumors were stage I and II (according to Enneking surgical staging) [12]. Neoadjuvant and adjuvant chemotherapy was administered for all patients with high-grade malignant tumors, excluding chondrosarcoma for which limited efficacy of chemotherapy has been reported [13,14]. Patients' demographic and pathologic characteristics have been summarized in Table 1.

2.2. Surgical technique

The aforementioned osteoarticular allograft procedure method was performed with some modifications [15,16]. To this aim, after considering oncologic principles of negative surgical margin, the resection of the tumor was performed through deltopectoral approach. Appropriate length of the humerus containing the tumor, involved surrounding soft tissues, and the biopsy tracts were excised by intra-articular resection. Intra-operative frozen section analysis was performed for all patients, in order to ensure no residual disease was present at surgical margins.

Matched size, fresh-frozen osteoarticular proximal humerus allografts were obtained from our university bone bank, which harvests and stores allografts according to standard tissue banking protocol of allograft preparation and processing [17]. For matching sizes, we used anteroposterior and lateral radiographs of the allograft, and uninvolved proximal humerus of the patients. In the operating room, allografts were thawed by immersion in the sterile saline (0.9%), for 30–60 min. Allograft was fixed to the host bone in close opposition by a broad 4.5 dynamic compression plate (DCP). The correspondent DCP was selected as to cover the entire length of the allograft, with at least 4 extra holes in order to be fixed to the host bone. Following the resection, the osteoarticular allograft was applied in appropriate rotation. Subsequently, patients' rotator cuff was sutured to the cuff remnants on the head of the allograft with non-absorbable sutures.

In 26 cases, the medullary canal of the allograft was reamed and filled using low viscosity cement.

Cement augmentation was applied after the year 1995, following the Wunder et al. report on the significantly smaller fracture rate of cemented allografts compared to those not cemented [18]. The clinico-demographic characteristics of cemented and non-cemented allografts have been demonstrated in Table 2. After full hardening of the cement, screws were inserted into the firm cement through drilling and tapping the cortical bone and cement.

According to Malawer classification of shoulder girdle resection [19], patients were classified as type IA (where deltoid muscle could be saved) and as type IB (where deltoid muscle was sacrificed). Altogether, 18 patients with resection type IA, and 18 patients with resection type IB were included in this study. In resection type IA, the deltoid muscle and axillary nerve was saved and the plate was placed on the anterolateral surface of the humerus shaft. Anteromedial plate placement (Fig. 1) was applied for resection type IB, in order to avoid plate prominence beneath the skin and prevent probable radial nerve damage (Fig. 2). The shoulder was immobilized in Sling and Swathe, and motion exercises were administered four weeks after surgery.

Table 1
Patients' demographic and pathologic characteristics.

Parameter	Groups	Number	Percent
Gender	Female	12	33.3
	Male	24	66.6
Tumor type	Malignant	31	86
	Benign	5	14
Diagnosis	Osteosarcoma	18	50
	Chondrosarcoma	7	19.4
	Ewing sarcoma	5	13.8
	Giant cell tumor	4	11.1
	Lymphoma	1	2.7
	chondroblastoma	1	2.7
Stage of malignant tumors	IB	5	16.1
	IIA	1	3.2
	IIB	25	80.7

Table 2
Demographic and pathologic characteristics of cemented versus non-cemented allografts.

Grouping variable	Cement status	
	Cemented number (%)	Uncemented number (%)
Number	26 (72.2)	10 (27.8)
Age		
<20 years	9 (34.6)	4 (40)
>20 years	17 (65.4)	6 (60)
Gender		
Female	9 (34.6)	3 (30)
Male	17 (65.4)	7 (70)
Resection length		
<154.5	12 (46.1)	5 (50)
>154.5	14 (53.9)	5 (50)
Tumor type		
Malignant	23 (88.4)	8 (80)
Benign	3 (11.6)	2 (20)
Resection type		
IA	13 (50)	5 (50)
IB	13 (50)	5 (50)
Diagnosis		
Osteosarcoma	13 (50)	5 (50)
Chondrosarcoma	5 (19.3)	2 (20)
Ewing sarcoma	3 (11.5)	2 (20)
Giant cell tumor	3 (11.5)	1 (10)
Lymphoma	1 (3.85)	0 (0)
chondroblastoma	1 (3.85)	0 (0)
Stage of malignant tumors		
IB	3 (14.25)	2 (20)
IIA	1 (4.75)	0 (0)
IIB	17 (81)	8 (80)