

Free Fibula Reconstruction for Bone Tumors Involving Humerus: Our Experience

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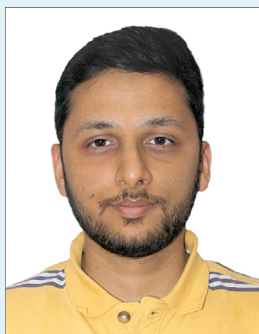
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Abstract



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Background Malignant primary bone tumors constitute only 0.2% of all malignancies in adults and approximately 5% of childhood malignancies. The humerus is a common site for malignancies like chondrosarcoma, osteosarcoma, Ewing sarcoma, and metastatic carcinomas. Management consists of multimodality treatment including chemotherapy, radiotherapy, and surgery depending on histology of the tumor and response to therapy. Reconstruction of humerus following oncological resection is a challenging procedure and the surgical options include endoprosthesis, plates, avascular bone grafts, and vascularized autologous bone using microvascular surgery.

Materials and Methods This was a single institutional, retrospective observational study conducted at a tertiary cancer center in Northeast India from June 2018 to March 2020. All the reconstructions were done with free fibular osseous flap. Postoperative outcome was measured with Musculoskeletal Tumor Society (MSTS) scoring. Data was collected from patient records and hospital online reporting system. All data were analyzed using Statistical Package for Social Sciences, version 21. Histograms were used for descriptive statistics; Spearman's correlation was run to determine the relationship between MSTS score and age. Rest of the data was checked with Mann–Whitney and Kruskal–Wallis test. A *p*-value less than 0.05 was considered as statistically significant at 5% level of significance.

Results Six patients were included in our study (*n* = 6), three of Ewing sarcoma and one each of osteosarcoma, angiosarcoma, and chondrosarcoma. Mean age was 21.7 ± 18.6 years; there was no flap necrosis in the series. One old lady developed nonunion and fracture at the native humerus in follow-up. At the end of 1 year the mean MSTS score of the series was 24.7/30. From data analysis a significant decrease in mean MSTS score was by 0.134 times (*p* = 0.035), been observed with increasing age. The correlation between gender and MSTS score (*p* = 0.325), type of tumor and MSTS score (*p* = 0.490), and location of the tumor and MSTS score (*p* = 0.351) was statistically not significant.

Conclusion Free vascularized fibular graft is an important option for bony reconstruction following tumor resection. In our small series we find it very effective for

Keywords

- sarcoma
- microvascular surgery
- vascularized fibular flap

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reconstruction of proximal humerus, particularly in younger patients, when microvascular expertise is present. Following a positive initial experience in humerus reconstruction with free fibular osseus flap a large study population will be considered in near future.

Introduction

Malignant primary bone tumors constitute 0.2% of all malignancies in adults and approximately 5% of childhood malignancies.¹ Osteosarcoma is one of the most common malignant bone tumors in the humerus which usually occurs between 10 and 30 years of age, but about 10% develop in patients between 60 and 70 years with a slight male preponderance.² Chondrosarcoma arises from cartilage cells and is common at upper end of the humerus. Chondrosarcoma is rare before 20 and after 75 years.² Ewing's sarcoma often arises in diaphysis of the humerus in children and adolescents but is uncommon after 30 years of age.² Angiosarcoma of bone is a rare but very aggressive primary bone neoplasm which is composed of tumor cells showing endothelial differentiation characterized by frequent local recurrence and distant metastases. Most patients die within a year of diagnosis.³

Earlier, extremity sarcomas frequently ended up with amputation or disarticulation, but after the 1970s, there is paradigm shift toward limb salvage. This has happened from the changeover of management of bone tumors from purely surgical to multimodality treatment encompassing chemotherapy, radiotherapy, and limb salvage surgery.⁴ Treatment of malignant tumors of proximal humerus frequently requires excision of the deltoid, rotator cuff tendons, and/or glenohumeral joint. The options for limb salvage in such patients are endoprosthesis, simple customized reconstruction with plate/nail spacer, vascularized fibular graft, combination of the allograft prosthesis, and avascular bone graft.

Materials and Methods

This was an observational retrospective study carried out in a tertiary cancer center from June 2018 to March 2020. Data was collected from electronic medical records and paper-based documentations of the hospital. Preoperative evaluation included detailed history, physical examination, and imaging studies. Computed tomography (CT) scan and magnetic resonance imaging (MRI) were used to determine the extent of disease. Histopathology, anticipated size of the defect, patient's preferences, and design of the free fibular osseous flap were recorded preoperatively.

The planning of surgery and the surgery itself were performed as per the location of the tumor. The length of hospitalization and presence of postoperative local and systemic complications were assessed. A total of six ($n=6$) patients were operated, out of which four patients ($n=4$) were male and two ($n=2$) were female. All six patients completed a minimum follow-up period of 1 year.

Results and Observations

1. Age Distribution:

The mean age of the series was 21.7 ± 18.6 years. The youngest patient was 8 years old and the oldest was 56 years old ([Table 1](#)).

2. Type of the Primary Tumor:

Fifty percent of patients ($n=3$) presented with Ewing's sarcoma, while 16.7% each ($n=1$ each) with osteosarcoma, angiosarcoma, and chondrosarcoma. Postoperative resection margins were free in all the patients.

3. Location of the Tumor:

Note that 83.3% ($n=5$) patients had tumor in epiphysis and metaphysis, and 16.7% ($n=1$) tumor in diaphysis and metaphysis of the humerus.

4. Procedures Performed:

Histopathological diagnosis was made from multiple core biopsies with relevant immunohistochemistry. Patients received neoadjuvant therapy (Methotrexate, Doxorubicin, Cisplatin [MAP] protocol for osteosarcoma, VAC/IE [Vincristine, Doxorubicin (Adriamycin) and Cyclophosphamide followed by Ifosfamide and Etoposide] protocol for Ewing's sarcoma) as per standard protocols of treatment.

According to the location of the tumor, two different types of procedures were performed in the series. Five patients had type 1 shoulder resection with excision of the abductors, and one had a large intercalary resection. If preoperative MRI suggested any skip lesion it was included in the resection. The tumor was resected with adequate margins. Vessels suitable for anastomosis were carefully preserved. All six patients were operated with a "two-team" approach.

The exact length of bone required for reconstruction was calculated preoperatively. The left leg was chosen for harvesting, since most of the lesions were right sided, and all patients were right dominant. We initially believed that preserving the right leg in a right dominant patient would be beneficial in limiting postoperative movement disabilities. In the first two patients we harvested the flap with skin paddle, but realized that incorporation of the paddle into the reconstructed area was cumbersome. Subsequently, the flaps were harvested without paddle. When harvested with paddle, anterior incision was made, superficial peroneal nerve and skin perforator were identified, attachment of peroneus longus muscle detached from the fibula, anterolateral septum incised, and anterior compartment muscles and anterior tibial vessels were separated from the fibula. The interosseous membrane was incised and osteotomy made at proximal and distal end of fibula to retain the previously calculated length of bone in the

Table 1 Data chart

Serial no.	Name	Age	Sex	Tumor	Preop treatment	Site of tumor	MSTS	Defect size (cm)	Intraop blood loss (mL)	Follow up (mo)	Operative time (min)	Recurrence	Donor site complications	Recipient site complications
1	AH	10	M	Ewing sarcoma	Induction chemo	Dia-/metaphysis	24	8	150	14	350	Lung metastasis	No	No
2	SA	8	M	Ewing sarcoma	Induction chemo	Epi-/diaphysis	27	11	200	18	410	No	No	No
3	RD	14	M	Osteosarcoma	Yes	Do	26	12	200	15	450	No	No	No
4	RK	12	F	Ewing sarcoma	Induction chemo and radiotherapy	Do	26	21	450	12	380	No	No	No
5	IA	30	M	Angiosarcoma	Nil	Do	26	18	300	12	420	No	No	No
6	RP	56	F	Chondrosarcoma	Nil	Do	19	16	500	12	400	No	No	Nonunion and fracture

Abbreviations: F, female; M, male; MSTS, Musculoskeletal Tumor Society.

middle. Posterior compartment muscles were separated from the fibula and peroneal pedicle was identified between tibialis posterior and flexor hallucis longus muscle. The posterior skin cut was now made and the flap dissected out from the gastrosoleus. When harvested without skin paddle, a single incision was made over the fibula. The peroneal pedicle was dissected till bifurcation of posterior tibial and peroneal vessels. Posterior tibial nerve was identified traversing between the posterior tibial and peroneal vessels, and protected. Prior to division of the pedicle the humeral vessels were prepared for anastomosis. The pedicle was then detached and the graft taken to the bony defect. Subsequently, the bone was fixed, followed by vascular anastomosis.

Bony Fixation and Reconstruction

Following Long Intercalary Excision (One Case)

The free fibular flap was placed in-between the proximal and distal cut ends of the humerus and fixed with titanium miniplates. Arterial and venous anastomoses were performed with profunda brachii artery and the cephalic vein, respectively. Drains were placed and wound closed in layers. The mechanical stability of the reconstructed humerus was further protected by an external fixator applied between acromioclavicular girdle and proximal ulna. A nuclear scan on the 15th postoperative day showed good perfusion of the grafted bone. External fixator was kept for 3 months.

Following Excision of Proximal Humerus with the Head (Five Cases)

The harvested fibula was fixed to the distal humerus with dynamic compression plate and screws. The upper end of the humerus was stabilized with an innovative technique. When the tumor had spared the humeral head and the glenoid was preserved, a short segment of the tendon of long head of biceps was usually available going over the greater tubercle and entering into the bicipital groove. An eyelet was drilled in the proximal end of fibular graft about 1 cm from its end, and this segment of tendon looped through the eyelet and tenodesed. Remaining long head of biceps was sutured to the short head. When the tendon was not available, braided polyethylene terephthalate (Ethibond, Johnson & Johnson)/Dacron No 5 (Patterson) were used to create a sling from acromion to fibula.

A polyester/polypropylene mesh was next sutured around the glenoid or the acromioclavicular girdle, and brought down on the fibula as far as possible, preferably beyond the fixation plate. It was wrapped around the fibula to cover half of its circumference while carefully avoiding contact of its margins with anastomosed vessels. All muscular stumps were tacked to the mesh.

The arterial and venous anastomoses were performed with anterior circumflex humeral artery and cephalic vein, respectively, in all five cases. We applied external fixator in one patient to immobilize the shoulder and the elbow joint, but in the rest four cases a simple arm pouch was used.

Continuous heparin infusions were used for anticoagulation at 200 to 250 units/kg dose for 24 to 36 hours. Postoperatively, drain outputs ranged from 100 to 180 mL. We did not

find any increase in drain output with use of anticoagulants. Drains were removed when output was less than 20 mL for two consecutive days. Average day of drain removal was 6th day (range: 5–9 days).

Complications

There was no flap necrosis in the series. One middle-aged female developed nonunion at the graft-humerus interface and a fracture in the native humerus through the site of screws. She was later managed with internal fixation with a long plate and cancellous bone grafts. No donor site-related morbidity was seen in any case.

Hospital Stays

The lengths of hospital stay varied from 8 to 15 days with an average of 9.8 days.

Recurrence

One patient with Ewing sarcoma developed pulmonary metastasis after 14 months of surgery and succumbed to it. All other patients were alive and on follow-up till the end of study period.

Functional Outcome

Functional score was assessed with the Musculoskeletal Tumor Society (MSTS) scoring system (→Fig. 1). All patients were included for postoperative rehabilitation schedule in the physiotherapy unit of our hospital. Patients were followed up on 2nd week postsurgery and thereafter at the 3rd, 6th, and 12th month. On follow-up, X-ray of the limb and chest X-ray was done at 3-monthly intervals and CT thorax at 6 months postoperatively. MSTS scores were evaluated at every visit and the score at the end of 1 year were taken for the study. The mean MSTS score was 24.7/30 in the series. Highest score recorded was in an 8-year-old boy who pre-

sented with malignancy at upper and middle third of the humerus. The lowest score was in a 56-year-old lady who presented as swelling at the surgical site after 12 months of surgery. X-rays showed fracture at the native humerus which was osteoporotic and nonunion at the humerus and fibula interface. In spite of surgical management of the fracture and nonunion, her MSTS score remained low (score = 19). A Spearman's correlation was run to determine the relationship between MSTS score and age in the study. There was a moderate, negative correlation between age and MSTS score ($r = -0.577$, $n = 6$, $p = 0.231$). From the analysis it was observed that as age increases, there was a significant decrease in mean MSTS score by 0.134 times ($p = 0.035$) (→Fig. 2). In male patients, the mean MSTS score was 25.57 ± 1.258 (standard deviation [SD]) while in female it was 22.5 ± 4.95 (SD) but there was no significant difference between the two ($p = 0.325$) (Mann–Whitney test). Mean MSTS score was 24.80 ± 3.271 (SD) in tumors involving epiphysis and diaphysis and in tumors affecting diaphysis and metaphysis, it was 24.00. There was no statistical significance among these two ($p = 0.351$) (Mann–Whitney test) (→Fig. 3). The range of movement and power were satisfactory among all cases.

Adjuvant Radiation

Only one patient (Ewing's sarcoma) with doubtful margins received adjuvant radiotherapy following surgery. Surgery alone was used as local therapy in all other Ewing's sarcoma patients.

Discussion

Free fibular graft is an established method for large humeral defects resulting from trauma, infection, and tumor resection. The vascularized graft obviates the process of creeping

Points	Pain	Function	Emotional acceptance	Hand positioning	Manual dexterity	Lifting ability
5	None(no pain medications)	No restriction	Enthusiased (recommend to others)	Unlimited (180 degree elevation)	No limitation	Normal load
4	Immediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
3	Modest,non disabling	Recreational restriction (minor disability)	Satisfied (would again)	Not above shoulder or pronosupination	Loss of movement	Limited (minor load)
2	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate (gravity only)
1	Moderate, intermittently disabling	Partial occupational restriction (major disability)	Accepts (would repeat reluctantly)	Not above waist(30 degree elevation)	Cannot pinch(major sensory loss)	Helping only(cannot overcome gravity)
0	Severe, continuously disabling	Total occupational restriction	Dislikes (would repeat)	None(0 degree elevation)	Cannot grasp (anaesthetic hand)	Cannot help(cannot move)

Fig. 1 Musculoskeletal Tumor Society (MSTS) scoring.

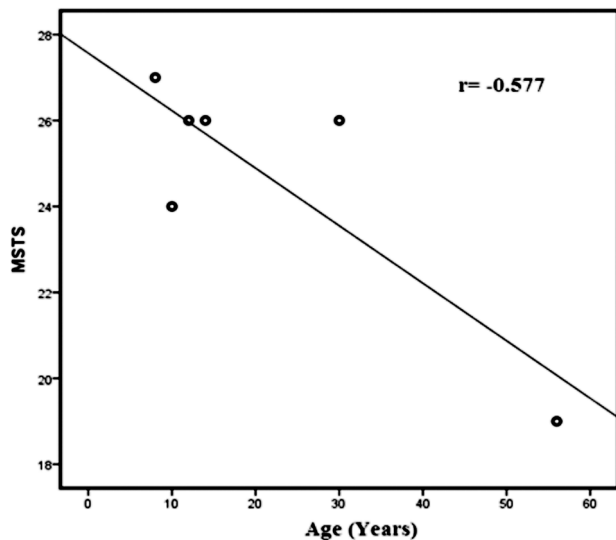


Fig. 2 Co-relation of age with Musculoskeletal Tumor Society (MSTS) score.

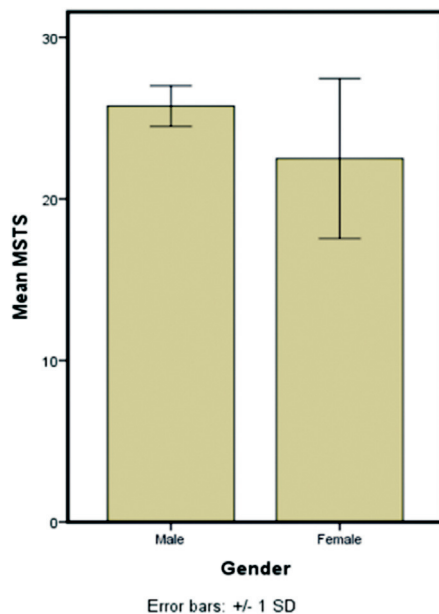


Fig. 3 Correlation of gender with Musculoskeletal Tumor Society (MSTS) score.

substitution that conventional bone graft undergoes and therefore improves healing and strength.⁵ Adani et al reported 13 cases of traumatic segmental humerus defect reconstruction with free vascularized fibula.⁶ Their one patient had flap loss wherein second free fibula flap was performed to achieve the reconstructive goal. In our series, we had six cases and there was no flap loss. Onoda et al reported a series of four patients of humerus head reconstruction with vascularized fibular head.⁷ They also mentioned the need for meticulous dissection in harvesting fibular head and increased risk of common peroneal nerve injury in that study. In our series, we harvested free fibula in a conventional manner (without taking fibular head), donor

site morbidity was nil. To see the vascularity of the flap in this series we routinely did nuclear scan postoperatively (after 2 weeks) and in all the six cases, the perfusion was excellent.

MSTS scoring system is a well-known scoring system used for assessing the functional outcome of a limb reconstruction. Wittig et al published their data on endoprosthetic reconstruction of upper end of the humerus, average score in their series ranged from 24 to 27.⁸ In 2016, Parag et al published their article on limb salvage with free fibular flap (10 patients) following sarcoma excision, they included both upper and lower limb malignancies, average score in their series was 26.⁹ In our series we had six patients of humerus reconstruction with free fibular osseous flap and our average score was 24.7. We did not find any statistical significance between sex and location of the tumor with the MSTS score. Except one patient in our series, all the patients can perform their daily activities easily; they can eat, dress up, comb, and lift moderate weight comfortably. Limitation of the shoulder abduction beyond 90 degrees was observed in all patients. We observed a negative correlation between age and MSTS scoring, with increasing age a significant decrease in mean MSTS score, by 0.134 times ($p = 0.035$), was seen.

In the postoperative period we found that if the peroneal nerve was preserved no significant disability or morbidity associated with fibular graft harvest occurred. Moreover, with the use of contralateral fibula, surgeries for primary resection and graft harvest could proceed simultaneously, and either side could be used safely for fibular graft harvesting.

Late postoperative complications of free vascularized fibula include nonunion, delayed union, and stress fracture. In a review series of Mayo Clinic, primary union of the vascularized fibula grafts to long bones occurred in more than 70%.⁵ The mean time to vascularized fibular graft healing was 6 months. A cancellous autograft at the ununited junction was usually sufficient to induce union in nonunion cases.⁵ In our study, one case presented with nonunion on follow-up.

Vascularized bone grafts have low incidence of stress fractures, but they do occur. Ou et al published their data of stress fracture at the transferred fibula ranging from 7.7 to 35%. Delayed union rates at the upper and lower extremity were 14 to 45% and 20 to 45%, respectively. They found inadequate fixation, infection, compromised vascularity of the graft, and inadequate preparation of the recipient as contributing factors of delayed union and nonunion. According to them, chemotherapy and radiotherapy do not contribute to nonunion.¹⁰ On the contrary, the Mayo Clinic series reported 9% stress fracture with higher incidence in the lower extremity and in tumor patients who received postoperative chemotherapy and radiotherapy.⁵ Most fracture occurred within the first year of surgery, when the bone had insufficient time to hypertrophy. If the graft had adequate vascularity, nondisplaced upper extremity fractures would heal with nonoperative treatment, but displaced fractures would require fixation with or without bone grafting.⁵ In our study, one female patient presented with fracture of the native humerus during follow-up, while her grafted fibula bone remained intact.

The functional returns following vascularized fibula graft are as good as prosthesis. Children with narrow diaphyseal canal will require custom-made prosthesis, which is not a case for autologous fibula graft. Experience has shown that the grafted fibula is capable of hypertrophy and remodeling to match the recipient bone. Long-term functional outcome of an incorporated vascularized fibula may be advantageous over reconstruction with prosthesis. The mechanical stability and movement of the arm over time will be evident later. However, reconstruction with prosthesis requires a significantly shorter operative time than osseous flaps (→ **Supplementary Figs S1–S4**, available online only).

Conclusion

Free vascularized fibular graft is an important option for bony reconstruction following tumor resection. In our small series we find it very effective in humerus reconstruction particularly in younger patients if microvascular expertise is present. With an initial positive experience in humerus reconstruction with free fibular osseous flap, larger number of cases with multicentric experiences will throw more light on the acceptance of the procedure.

Ethical Approval

Taken.

Conflict of Interest

None declared.

Acknowledgment

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