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ORIGINAL ARTICLE • TUMORS - MICROSURGERY

Microsurgical reconstruction with vascularized fibula and massive bone allograft for bone tumors

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Abstract

Introduction Combining massive bone allograft and vascularized fibula in intercalary reconstruction following resection of bone tumors represents a complex reconstructive procedure that requires specialists in microvascular surgery as well as orthopedic surgery. The purpose of our study was to examine the outcomes using this surgical technique in patients with bone tumors in terms of oncologic results, complications related to surgery, Musculoskeletal Tumor Society (MSTS) scores and duration of surgery.

Materials and methods We analyzed 81 patients with femoral or tibial sarcomas who underwent intercalary resection and microsurgical reconstruction with massive bone allograft and vascularized fibula. There were 56 boys and 25 girls with a mean age of 13.4 years at the time of surgery. The patients' medical records were reviewed for clinical and functional outcomes as well as postoperative complications. The study group was comprised of 33 patients who underwent reconstruction of the femur with massive bone allograft and free vascularized fibula and 48 patients who underwent reconstruction of the tibia with massive bone allograft and free or pedicle vascularized fibula. The mean length of resection was 15.9 cm (8–31 cm). The functional evaluation of the patients was done at the end of the follow-up using MSTS score for the lower limb. All patients had at least a 2-year follow-up.

Results The overall limb salvage rate was 94%, although many patients required re-operation after the procedure. Complications occurred in 24 patients, 18 of which underwent additional surgical procedures. They included fractures of the massive bone allograft-vascularized fibula construct with or without implant failure (19) and deep infection (5). After surgical or conservative treatment, all the fractures successfully healed. The overall MSTS functional score was good to excellent in 91% of patients.

Conclusions The combination of massive bone allograft and vascularized fibula seems to be a reasonable option for reconstruction of diaphyseal defects following intercalary resection of bone tumors. Although there was a high rate of complications and therefore re-operations, the biology of vascularized fibula was able to save the reconstruction in most of the cases that had complications.

Keywords Bone tumors · Osteosarcoma · Ewing sarcoma · Limb salvage surgery · Skeletal reconstruction · Capanna technique · Vascularized fibula · Free fibula · Pedicled fibula · Massive bone allograft · Intercalary reconstruction · Diaphyseal resection

Introduction

The reconstruction of massive bone defects following tumor resection remains a challenging problem for orthopedic oncologists [1–4]. The goal in reconstructing skeletal defects is long-term function and durable fixation [5, 6]. The use of a massive bone allograft and vascularized fibula, supplied by the peroneal vessels in intercalary fibular grafts, could be an option in the treatment of diaphyseal bone tumors [2, 7]. Intercalary vascularized fibula provides a

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biological reconstruction of diaphyseal defects. Although the diaphyseal defects can be reconstructed in the upper extremities with vascularized fibula alone, in the lower extremities weight-bearing stresses require the use of additional structural allograft. Thus, diaphyseal defects of the lower extremities require a combination of vascularized fibula and massive bone allograft, in which the fibula is inserted into the medullary canal of the massive bone allograft (concentric assembly) or beside the massive bone allograft (parallel assembly) [8]. Experience in microvascular surgery, careful preoperative plan and postoperative care are mandatory for the success of this procedure [2].

Because of the rarity of bone sarcomas, there are only a few articles in international literature reporting results of these demanding procedures [2, 9–11]. The purpose of this paper is to report results among patients undergoing microsurgical reconstruction for bone sarcomas with a massive bone allograft and vascularized fibula in terms of oncologic results, complications related to surgery, Musculoskeletal Tumor Society (MSTS) scores and duration of surgery.

Table 1 Summary of data in 81 patients treated with diaphyseal resection of bone tumors and reconstruction with combination of massive bone allograft and vascularized fibula

Age (years)	13.4		
Gender			
Male	56		
Female	25		
Site			
Femur	33		
Tibia	48	23	Free fibula
		25	Pedicle fibula
Diagnosis			
Osteosarcoma	46		
Ewing sarcoma	31		
Adamantinoma	4		
Type of reconstruction			
Femur	33	23	Concentric assembly
		10	Parallel assembly
Tibia	48	47	Concentric assembly
		1	Parallel assembly
Length of resection	15.9 (8–31 cm)		

Materials and methods

Between March 1994 and December 2013, we treated 81 patients (56 boys and 25 girls) with femoral or tibial sarcomas undergoing intercalary resection and microsurgical reconstruction with a massive bone allograft and vascularized fibula. The mean age of the patients at the time of surgery was 13.4 years. The most common oncologic diagnosis was osteosarcoma (46) followed by Ewing's sarcoma (31) and adamantinoma (4). The study group was comprised of 33 patients who underwent microsurgical reconstruction of the femur with a massive bone allograft and free vascularized fibula and 48 patients who underwent reconstruction of the tibia with a massive bone allograft and free or pedicle vascularized fibula. Neoadjuvant chemotherapy according to protocols used at the time of treatment was provided to all patients except for three with low-grade osteosarcoma and four with adamantinoma (Table 1). The mean length of resection was 15.9 cm (8–31 cm). After the tumor resection, a massive bone allograft was selected to match the defect. The massive bone allograft was selected from the musculoskeletal tissue bank of our institute and was chosen the most suitable structural allograft according to size and shape based on radiographs. The fibula was then harvested through a lateral approach with the preservation of the peroneal artery with its feeding vessels. In most cases, the ipsilateral fibula is harvested to allow for easier postoperative mobilization. The amount of fibula harvested depends on the size of the defect, keeping the fibular grafts at least 2–4 cm longer than the defect to be reconstructed to allow for any overlap of the osteotomy site of the recipient bone, all the while maintaining sufficient distal fibula to prevent ankle instability. The fibula was then passed into the medullary canal of the massive bone allograft (concentric assembly) or beside the massive bone allograft (parallel assembly). The composite massive bone allograft and fibula was fixed at the host bone with internal fixation using plates with combining compression and locking capability. The microvascular anastomoses were then performed after bony fixation. The anastomosis was done between the donor peroneal artery to the anterior tibial in the leg or deep femoral artery in the thigh (Fig. 1). After surgery, the leg of the donor site was placed in a cast for 4 weeks. For tibia reconstructions, the recipient site was immobilized in a short cast or splint for 4–6 weeks. Femoral reconstructions were immobilized in a long-leg cast or splint for 4–6 weeks. This was followed by a period of joint rehabilitation with the patient wearing a removable splint. Patients were allowed to begin partial weight-bearing at a mean of 3–4 months postoperatively, and full weight-bearing was delayed until a mean of 10 months. Surveillance for local and systemic recurrence consisted of clinical and radiologic assessments every 3 months for the first 2 years, then every 6 months up to 5 years, and then annually thereafter. Follow-up consisted of clinical and radiologic evaluation: radiographs and computed tomography (CT) of the limb and CT of the chest. The mean follow-up of the patients was 96 months (26–265 months). The functional evaluation of the patients was done at the end of the follow-up using MSTS score for the lower limb. Patient data were retrieved from the electronic medical records system at the study institution.

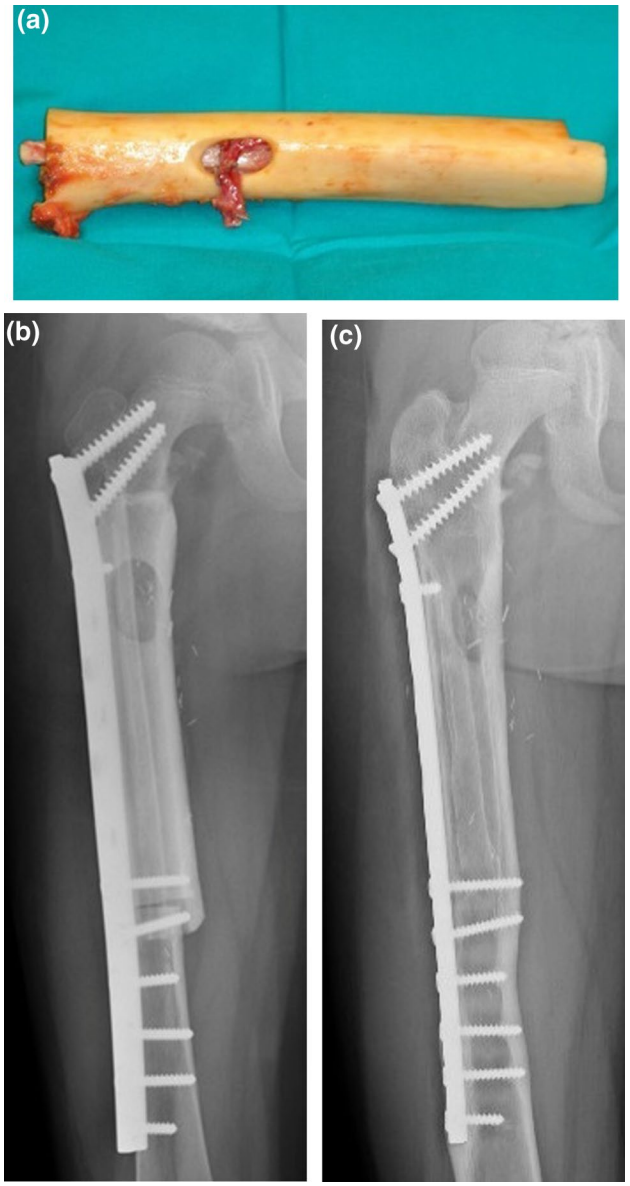

Fig. 1 Diaphyseal reconstruction of right femur with a vascularized fibula and massive bone allograft. **a** Intraoperative photograph of the graft composite before insertion into the recipient site. **b** Immediate postoperative radiograph of the reconstruction. **c** Anteroposterior radiograph 5 years after the surgery showing hypertrophy of the graft

Results

At the last follow-up, 66 patients presented no evidence of disease and 15 died due to disease (13) or to drug toxicity (2). Seven patients had a local recurrence: Four of these patients underwent an amputation, and the remaining 3 underwent removal of the whole biologic construct and reconstruction with modular prosthesis.

The overall limb salvage rate was 94%, although many patients required re-operation after the procedure. Complications occurred in 24 patients, 18 of which underwent additional surgical procedure. They included fractures of the massive bone allograft-vascularized fibula construct with or without implant failure (19) and deep infection (5). Eighteen additional procedures were performed to treat these complications: re-osteosynthesis for fracture of the massive bone allograft-vascularized fibula construct with implant failure (13), change of the construct for deep infection (4) and debridement for deep infection (1). In the remaining 6 patients with a massive bone allograft-vascularized fibula fracture without implant failure, the treatment was conservative with a cast for 4–6 weeks. After surgical or conservative treatment, all the fractures successfully healed. Overall in this study group of 66 patients without evidence of disease at the last follow-up, 62 patients maintained their original biological reconstruction.

Hypertrophy of the fibula was assessed on radiographs and CT scans. Radiograph and CT monitoring of the reconstructed limb was performed until complete graft incorporation was noted. The density of the fibular cortical bone decreased during the first postoperative year. After the first postoperative year, as the patients progressively increased their physical activity, the vascularized fibula showed a progressive increase in both the total and medullary diameters with a low-density cortex. All patients had an osteointegration between vascularized fibula and the massive bone allograft at the last follow-up.

The overall MSTS functional score was good to excellent in 91% of patients who were available for evaluation. The mean surgical length was longer in the free vascular fibula and massive bone allograft group 9.4 ± 1.7 h compared with that of the pedicle vascularized fibula and massive bone allograft group at 5.7 ± 1.3 h.

Discussion

Limb salvage surgery has become the treatment of choice for bone sarcomas of the extremities [9, 12]. Current options for limb salvage surgery include massive bone allograft, modular prostheses and vascularized fibula [9, 12]. Following intercalary resection, massive bone allografts have been most frequently used for limb reconstruction. However, complications such as infection or fracture are common as a result of an avascular nature of the massive bone allograft [9]. In our series, the association of a vascularized fibula with massive bone allograft seems to reduce these complications thanks to the biology of vascularized fibula. The overall limb salvage rate was 94% with all but four patients maintaining their original reconstruction. The overall complication rate of 30% was comparable to rates reported for vascularized fibula and massive bone allograft reconstruction [10, 13, 14]. The rate of retention of their original

reconstruction observed in our study shows greater results than previous articles regarding the use of massive bone allograft alone [13, 15]. In addition, all surviving patients were able to return to their previous activities.

The use of massive bone allografts in diaphyseal skeletal reconstruction for bone tumors in children has been reported to have a high rate of complications as a result of the avascular nature of the graft, including nonunion, fracture and infection [9, 12]. Previous studies have shown that a massive bone allograft is acellular and lacks blood supply, so when complications such as a fracture and infection occur, it is unable to heal the injury [9]. Massive bone allograft fractures, following resection of bone sarcomas [10], occur in up to 20% of patients [16]. Although fractures were common in our series (23%), the vascularized fibula allowed the fractures to heal with re-osteosynthesis or conservative treatment in all cases, which could not occur in a massive bone allograft alone. Bone healing can be accomplished in a short period, even in a difficult environment such as a scarred or irradiated bed, thanks to the biologic property of vascularized fibula [1]. During the first year after surgery, the density of the fibula decreases because of stress shielding by the allograft; the fibula develops a cancellous appearance and becomes incorporated into the medullary canal of the massive bone allograft. When the allograft fractures, the fibula hypertrophies to support the weight-bearing forces [2].

Infection has been shown to occur in up to 18% of massive bone allografts alone [15, 16]. In our series, we had a 6% rate of postoperative infectious complications with only five patients that had a deep infection. In addition, we were able to save the reconstruction in one of these cases, showing that the biology of vascularized fibula could not only prevent complications but also heal injury when it occurs. Vascularized fibula had superior material properties and can tolerate infection [1].

Our data confirm the results of previous few reports showing that the combination of massive bone allograft and vascularized fibula following the resection of bone tumors provides biologic reconstruction with long-term viability of the graft.

The combination of massive bone allograft and vascularized fibula seems to be a reasonable option for reconstruction of diaphyseal defects following intercalary resection of bone tumors. Although there was a high rate of complications and so re-operations, the biology of vascularized fibula was able to save the reconstruction in most cases that had complications. Biologic intercalary reconstruction involving massive bone allograft and vascularized fibula can attempt to mitigate the complications associated with the use of a massive bone allograft alone [9]. Vascularized fibula provides gradual revascularization and incorporation, showing evidence of change in density and viability on regular follow-up [8]. Thanks to the biology of vascularized fibula, complications are salvageable and so it is possible to preserve the original construct. However, the complexity of the reconstructive procedure requires specialists in microvascular surgery as well as orthopedic surgery [2].

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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