Total calcaneal reconstruction using a massive bone allograft and a distally pedicled osteocutaneous fibula flap

A novel technique to prevent amputation after calcaneal malignancy

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Summary

In patients with primary calcaneal malignancies, such as Ewing’s sarcoma, radical treatment with amputation of the foot can result in serious functional impairment and chronic pain. Total calcanectomy followed by reconstruction of the calcaneal defect offers an alternative treatment to amputation. Capanna et al. described a technique for successfully reconstructing long limb segmental bone defects using a free fibula flap placed within the intramedullary canal of an allograft.

We present both a review of the literature on calcaneal reconstruction and describe how the principles of Capanna can be adapted to reconstruct the calcaneus.

Total calcanectomy due to Ewing’s sarcoma and the subsequent application of this novel reconstructive technique was performed in two young patients aged 5 and 16 years. The reconstruction was achieved by inserting a distally pedicled osteocutaneous fibula flap within the reamed canal of an allograft and placing the composite in the calcaneal defect. Reconstruction was successful with complete bone union between the allograft and the adjacent bone. There were no fractures nor infections and both flaps survived. Functional outcome was assessed with a physiotherapist at follow-up 2 years postoperatively showing near-normal ambulation.

This novel technique proved excellent as a limb salvage procedure, avoiding amputation, and offering a satisfactory oncological and functional outcome.

Keywords: Microsurgery; Reconstruction; Pedicled Flap; Fibula Flap; Lower Limb; Pediatric; Sarcoma; Oncology; Calcaneal Reconstruction; Heel; Orthoplastic Approach;
Introduction

Primary calcaneal malignancies are rare and account for less than 1% of primary bone tumors. [1] Amputation of the foot is often the preferred treatment as it is difficult to achieve wide surgical margins and the reconstructive options for complex hindfoot defects are limited. Although no difference has been reported in patient survival, when comparing amputation and total calcanectomy as a limb salvage procedure for sarcomas, the prevalence of chronic pain related to amputation, and the potentially steep learning curve for ambulation with a prosthesis, favors limb salvage procedures as the preferred surgical treatment. [2–4]

The calcaneus and overlying soft tissue play an important role in weight bearing, gait and maintenance of the natural foot arches. Due to the indispensable role of the calcaneus in ambulation, total calcanectomy warrants appropriate reconstruction to achieve a satisfying functional outcome. Calcaneal defects after total calcanectomy have previously been reconstructed with calcaneal prostheses, bone allografts, regular pedicled fibula flaps and free fibula flaps. [5–11] Capanna et al. originally described a technique for treatment of long limb segmental bone defects using a free fibula flap placed within the intramedullary canal of an allograft (Figure 1). [12] Incorporating a massive bone allograft in combination with a vascularized bone flap ensures both a malleable and adequate osseous bulk and a vascularization that will enhance primary bone healing and reduce risk of local infection. [13]

We present how the principles of Capanna can be adapted to reconstruct the calcaneus, by using both a massive bone allograft and a distally pedicled osteocutaneous fibula flap as a limb salvage procedure, hereby avoiding amputation and providing a satisfactory oncological and functional outcome.
Patients and methods

Patients

Two girls aged 5 years and 10 months (patient 1) and 16 years (patient 2) at the time of surgery both presented with a histopathologically verified Ewing’s sarcoma of the calcaneus. The patients were without any signs of metastatic disease at diagnosis and received both pre- and postoperative chemotherapy. A limb sparing total calcanectomy and succeeding reconstruction with a composite of an allograft and a vascularized distally pedicled osteocutaneous fibula graft was performed.

Surgical technique

Almost the same surgical procedure was performed in both patients. The preoperative planning was done incorporating handheld Doppler, Computer Tomography (CT), CT-angiography and Magnetic Resonance Imaging (MRI). Extraosseous tumor component was assessed for resectability with attention to medial neurovascular invasion. A calcanectomy with wide surgical margins was performed using a lateral approach including resection of the skin around the biopsy canal (patient 1 also had a medial biopsy scar removed). The calcaneus was located and extirpated with a brim of soft tissue (in patient 2 the most posterior part of calcaneus with insertion of the Achilles tendon was spared). The medially situated neurovascular bundle was unaffected and spared to preserve vascularization and innervation of the foot. A distally pedicled osteocutaneous fibula flap was raised. The skin paddle was outlined and dissected through a posterior approach preserving the cutaneous perforators. The fibula bone was then marked at proximal and distal sites for the planned osteotomy. The proximal ends of the peroneal vessels were ligated and perfusion of the flap was hereby based on the distal vascular connections between the peroneal and anterior tibial vessels as well as the cutaneous perforators. The vessels and periosteum were rougined from the excess distal fibula bone and the excess bone was removed, leaving a flexible vessel and periosteal bundle.
In patient 1, part of an adult femoral head allograft from our local bone bank was fitted to replace the removed calcaneus. Patient 2 had a calcaneal allograft from the Rizzoli Institute Cell and Musculoskeletal Tissue Bank (Bologna, Italy) inserted. The allografts were canalized and fixed as an arthrodesis to the talus and cuboid bone using screws. In patient 2 the posterior part of the calcaneus was reattached to the allograft with a screw, while in patient 1 the Achilles tendon was fixated to the reconstructed heel using nonabsorbable sutures. The vascularized fibula bone was fitted into the allograft canal as a vascularized inlay and fixed using staples. (Figures 1-4)

Results

The patients were allowed weight bearing in an ankle brace when CT confirmed bone healing of the arthrodesis between calcaneus and talus (and for patient 2 between the calcaneus allograft and the posterior part of the patient’s own calcaneus with the Achilles tendon insertion) and incorporation of the fibula bone into the allograft at 3½ months (patient 1) and 6 months (patient 2). Full weight bearing without brace was allowed after 8 months in both cases when the arthrodesis between the allograft and talus had healed and showed complete bone union with substantial callus formation (Figure 5).

There were no fractures nor infections, but the second patient had delayed wound healing on the lateral aspect of the foot. Functional outcome was assessed at 2 years postoperative follow-up showing near-normal ambulation. The first patient had a slight in-toeing of the affected foot, while the second patient had normal gait. The slight in-toeing was assumed to be due to decreased eversion of the foot due to affection of the peroneal muscles.

Patient 1 is now 10 years postoperatively undergoing bone elongation of the femur of
approximately 3 cm due to a height reduction in the neo calcaneus and reduced longitudinal growth of the tibia. Patient 2 is 7 years postoperative with a fully functional lower extremity.

Discussion

Primary calcaneal malignancies, and especially Ewing’s sarcoma of the calcaneus, are rare and reports on limb sparing reconstructive options after oncological extirpation are scarce. Most studies on calcaneal reconstruction have been due to osteomyelitis or traumas. [10,14–16] Reported reconstructive treatment options encompass bone allografts, calcaneal prostheses, regular pedicled fibula flaps and free fibula flaps. [5,6,10,11,17,18] Over the past decades different microsurgical techniques have arisen for calcaneal and hindfoot reconstruction and some authors have reported the use of free vascularized bone grafts as the fibula and iliac crest flaps with acceptable results. [9,18]

Reconstruction of the heel is a complex procedure and should ideally aim at achieving the anatomical, biomechanical and morphological properties of the natural heel.

The fibula flap is a solid choice in calcaneal reconstruction as it provides strong and linear cortical bone with the prospect of progressive bone hypertrophy in response to increased weight loading. [7,14,15,19,20] It thereby enables the reconstructed heel to withstand increasing load and also allows for reconstruction of surrounding soft tissue. [20,21] The pedicled and free fibula flap have in various studies been reported as successful options in limb salvage surgery for calcaneal malignancies, osteomyelitis or trauma. [14–16,22]
Lin et al. found that fibular flaps have less donor-site morbidity, less recipient-site morbidity, better survival rates, and better functional results than other flaps in post-traumatic reconstruction of the heel. [21]

Using a distally pedicled fibula flap incorporated in a massive bone allograft, as in this study, has several benefits.

Vascularized bone flaps as the pedicled and free fibula flaps may increase resistance to infection, enhance primary bone healing and tolerate mechanical stress better due to their superior circulation compared to regular bone allografts.

A crucial determinant of the success of the distally pedicled fibula flap is therefore the integrity of the vascular connections between the peroneal and the anterior tibial arteries.

A bone allograft provides a natural osteoconductive material which serves as a structural spacer that can support migrating host cells and result in progressive bone union with the adjacent bone. [13] Incorporating a vascularized flap into a massive bone allograft therefore attains the benefits from both structures. The allograft provides a shapeable and strong osseous bulk that will increase the likelihood of early mobilization and, collectively with the vascularized pedicled fibula flap, increase long term weight bearing capability.

This study reports to the best of our knowledge, the first applications of the adapted Capanna technique in calcaneal reconstruction.

This novel technique of inserting a distally pedicled osteocutaneous fibula flap into the reamed canal of a massive bone allograft proved excellent as a reconstructive option for calcaneal defects after total calcanectomy due to primary calcaneal malignancy. The adapted Capanna technique achieved successful limb salvage of the foot, offering both a satisfactory oncological and functional
outcome. This technique could also prove beneficial as a reconstructive option for calcaneal defects arising due to trauma or osteomyelitis.

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Figure legends

**Figure 1** demonstrates the basic idea behind our technique. The vascularized cortical bone of the fibula flap is fitted into the intramedullary canal of an allograft as a vascularized inlay.

**Figure 2** provides an anatomical drawing of the osteotomized pedicled fibula flap showing its flexibility obtained by removal of the excess distal fibula bone.

**Figure 3** Intraoperative photographs in patient 1 show a) placing of the femoral head allograft into the hindfoot, b) the reamed canal in the femoral head allograft as well as the dissected vascular pedicle for the fibula flap, c) placing of the distally pedicled osteocutaneous fibula flap in the canal of the femoral head allograft, d) four intraoperative photographs in patient 2 demonstrating oncological extirpation through a lateral approach with extensive debridement and following hindfoot defect.

**Figure 4** Postoperative X-rays that demonstrates the initial fixation of the allograft with vascularized fibula inlay to the talus and cuboid bone in a) patient 1 and b) patient 2.

**Figure 5** Clinical photographs of the reconstructed hindfoot eight months postoperatively in a) patient 1 and b) patient 2. Corresponding X-rays showing solid healing of the arthrodesis between talus and calcaneus but no healing between calcaneus and the cuboid bone in c) patient 1, and healing of both arthrodeses and the attachment of the Achilles tendon in d) patient 2.
