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Anatomic bases of medical, radiologicaland surgical techniques

# Transplantation of the proximal fibula based on the anterior tibial artery. Anatomical study and clinical application

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## Abstract

Abstract The purpose of this study was to investigate the feasibility of microvascular transplantation, based on the anterior tibial artery, of the epiphysis and the proximal half of the diaphysis of the fibula. India ink injections into the anterior tibial artery were performed in 13 unembalmed adult cadavers, following which transverse frozen sections were taken. Dye was observed in the fibula, both within the intramedullary cavity and at the level of the periosteum, in all specimens. The average distal limit reached by the dye, measured from the tip of the epiphysis, was 10.4cm in the intramedullary cavity and 11.8cm in the periosteum. Based on these anatomical findings one case of humeral reconstruction has been performed with a fibular transplant, including both the epiphysis and a segment of diaphysis, vascularized solely by the anterior tibial artery.

Fibular transplantation has been used extensively for bone reconstruction since its initial description as a donor site [8]. Vascularization of the fibular shaft is by the fibular artery, which gives several periosteal branches as well as a nutrient artery [3]. Previous studies [6] have shown that the proximal fibular epiphysis is vascularized by two main systems. The lateral inferior genicular artery, from the popliteal artery, mostly supplies the capsule of the proximal tibiofibular joint, while the anterior tibial artery supplies the epiphysis via the posterior and anterior recurrent peroneal arteries. When planning a reconstruction that employs both the epiphysis and the diaphysis of the fibula, it has been suggested that both the peroneal and anterior tibial arteries are used to ensure a good blood supply to the transplant [4]. We postulate, however that due to the anastomoses between both systems a combined epiphyseal/diaphyseal transplant can be vascularized entirely by the anterior tibial artery.

## Material and Methods

Thirteen unembalmed adult cadavers were used in this study. Initially a transverse section of the fibular diaphysis, 13cm above the tip of the distal epiphysis, was made in order to decrease the intramedullary pressure and facilitate intramedullary diffusion of the dye. Using a posterior approach the popliteal artery was exposed and ligated just below the origin of the anterior tibial artery and 50 ml of blue India ink injected directly into the anterior tibial artery. Following injection four specimens (1, 2, 3, 6) were directly frozen without further preparation. In the remaining specimens (4, 5, 7-13) all the soft tissues surrounding the tibia and fibula were removed before freezing. All specimens were kept frozen for 36 hours and then cut transversely at regular intervals, beginning at the proximal tip of the fibula each section was of 1cm uniform thickness. The frozen transverse sections were analyzed for the presence of dye, both in the intramedullary area and in the periosteum.

**Results**

In all specimens dye was detected both within the periosteum and the intramedullary cavity. In the intramedullary cavity perfusion of the dye was present on average 10.4cm (range 8-14.5 cm) from the fibular apex (Fig. 1) the dye was also present in the cancellous bone of the epiphysis in all specimens. Perfusion of the periosteum by the dye was present to an average distance of 11.8 cm (range 10-16cm). The data for all 13 specimens are presented in Table 1. Based on these anatomical data it is concluded that the anterior tibial artery is able to ensure a blood supply not only to the proximal epiphysis but also to the adjacent segment of the diaphysis.

| Specimen | Distal extent of intramedullary dye perfusion | Distal extent of periosteal dye perfusion |
|---|---|---|
| 1 | 9,5 | 11 |
| 2 | 9,5 | 11 |
| 3 | 11 | 12,5 |
| 4 | 10 | 12 |
| 5 | 8 | 10 |
| 6 | 9 | 11 |
| 7 | 10,5 | 11,5 |
| 8 | 12 | 13 |
| 9 | 14,5 | 16 |
| 10 | 10 | 11 |
| 11 | 9 | 10,5 |
| 12 | 11 | 12 |
| 13 | 11,5 | 12,5 |

**Table 1**

**Fig. 1** Transverse section of the fibular shaft 9 cm from the proximal tip of the fibula (specimen 3). Coloured dye (white arrows) is seen within the fibula

**Clinical application**

A 6 year-old female was referred with a Ewing sarcoma of the proximal humerus the tumor was limited to the humeral epiphysis, with no extension to the scapula and no distant skip metastasis (Fig. 2). Preoperative chemotherapy was initiated followed by « en bloc » resection of the tumor the length of the resected humerus being 11 cm.

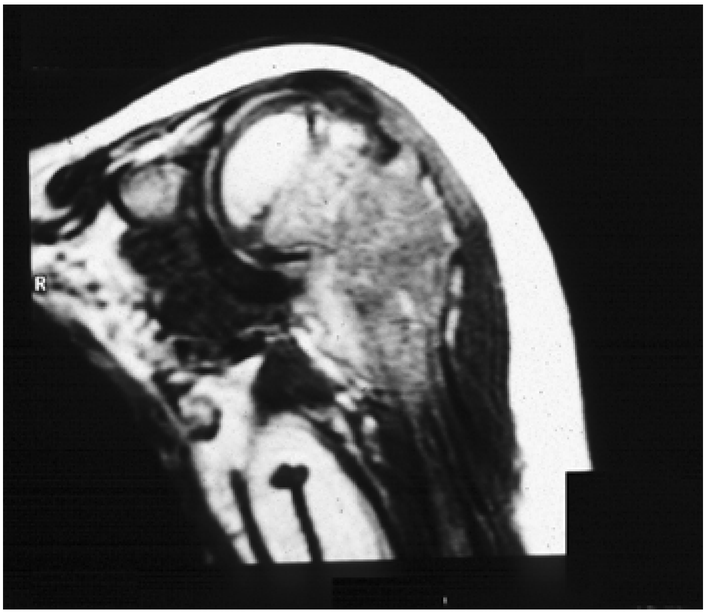


**Fig. 2** Ewing Sarcoma of the proximal humerus (MRI)

Using an external approach the contralateral fibula was raised, based on the anterior tibial artery the total length of the harvested fibula was 11 cm, corresponding to 50% of the total fibular length. A strip of the biceps femoris tendon was also harvested with the fibula and sutured to the remnants of the rotator cuff at the recipient site. A vein graft was used to increase the length of both the artery and the vein (Fig. 3), and anastomosed end-to-side to the brachial artery and vena commitantes respectively. Osteosynthesis was achieved distally by means of a small fixation plate. Continuity of the anterior tibial artery was not restored. The total operative time was six hours. The patient was immobilized with the shoulder abducted for 2 months postoperatively. Bone healing was observed after three months.

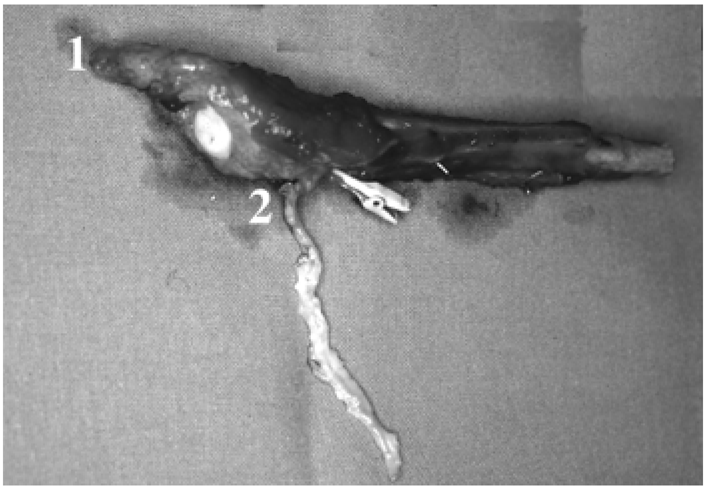


**Fig. 3** The fibular transplant vascularized by the anterior tibial artery after harvesting. A strip of biceps femoris tendon has been raised to be sutured to the remnants of the rotator cuff (*1*). A vein graft (*2*) has been used to lengthen the pedicle

Shoulder function was assessed as "good" at 21 months follow-up (Fig. 4). Remodelling of the transplanted fibula was demonstrated radiographically at 36 months, seen as hypertrophy of the fibular shaft, which matched the diameter of the humerus, and modification of the fibular head, which appeared rounded in shape (Fig. 5). At maximum follow-up the length discrepancy between right (uninvolved) and left humerus was 2 cm.

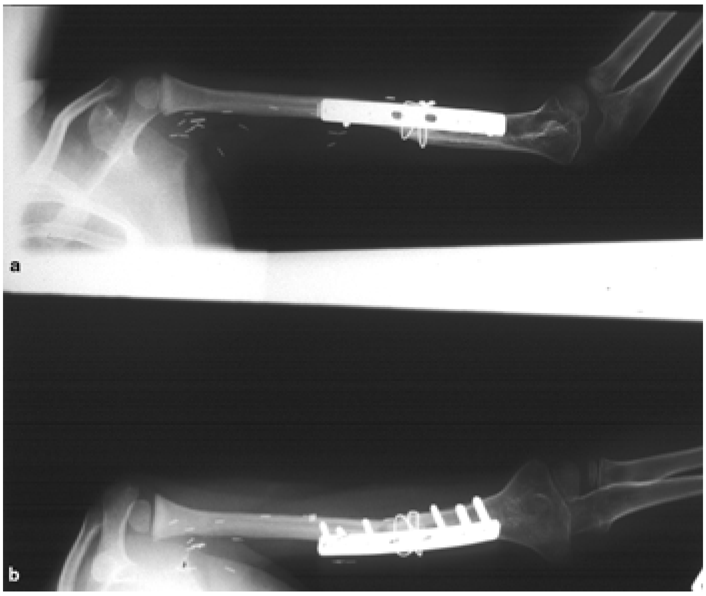


**Fig. 4a, b** Radiographic view at two years of the reconstructed fibula

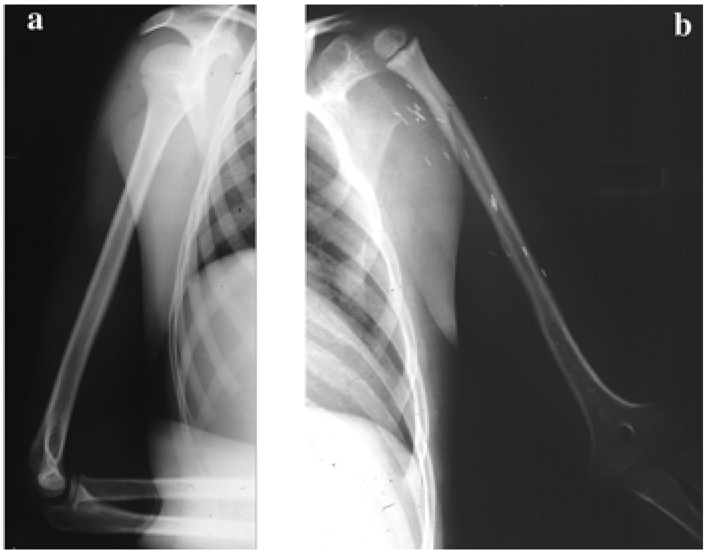


**Fig. 5a, b** Radiograph at 3 years follow-up showing remodelling of the fibular head (**a**) compared to opposite humerus (**b**)

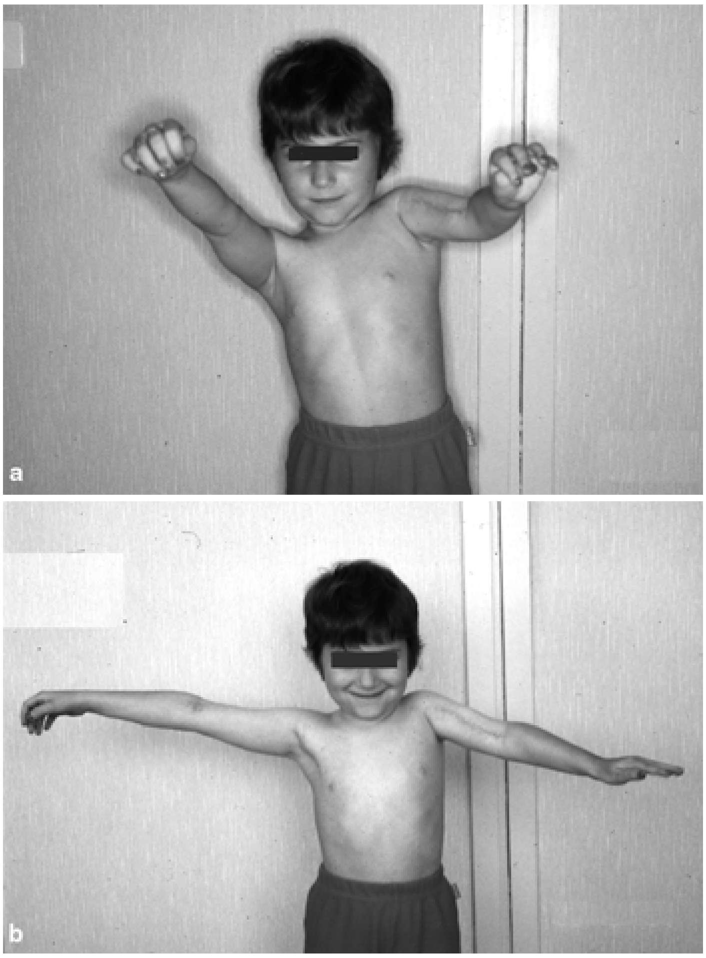


**Fig. 6a, b** Functional result following transplantation

**Discussion**

Transplantation of the fibula, including the proximal diaphysis, based solely on the fibular artery alone has been previously reported [2, 7]. However, it has been demonstrated that both the metaphyseal and epiphyseal blood supply of a transplanted epiphysis are of equal importance to achieve growth and remodelling [5].

When both the epiphysis and diaphysis of the fibula are required for reconstruction, the first option is to harvest the transplant on two separate pedicles [3, 5], however this has many disadvantages. The two pedicles have to be dissected and two sets of anastomoses performed at the recipient site. As it is not reasonable to sacrifice two major arterial vessels of the lower extremity, it has been suggested that only the segment of the anterior tibial artery that give the posterior and anterior recurrent peroneal arteries needs to be dissected [4]. Following dissection the anterior tibial artery should be reconstructed either by end-to-end suture or by a vein graft. Taylor et al. [9] in 1988 reported one case of fibular head and shaft transfer using only the anterior tibial artery as the vascular pedicle 40 mm of bone growth occurred after 4 years.

The same fibular transplantation technique vascularized by the anterior tibial artery has been used by Capanna [1] in a series of reconstructions of the proximal humerus (10 cases) or distal radius (2 cases). Other authors have also used only the fibular artery to vascularize a transplant, including both the epiphysis and diaphysis of the fibula [2].

Based on the results of the current anatomical study it is possible to harvest the proximal fibula based on the anterior tibial artery alone, since the blood supply to the diaphyseal part of the transplant is via anastomoses between branches of the anterior tibial and fibular arteries. However, one question that remains unanswered is what length of diaphysis can be safely harvested using only the anterior tibial artery. In the present study using adult cadavers the dye was visible in the intramedullary cavity on average 10.4 cm from the apex of the fibula. Similarly, perfusion of the periosteum was noticeable on average 11.8 cm from the tip of the fibula. These observations suggest that the proximal third of the fibula can be safely vascularized by the anterior tibial artery alone. In the clinical case presented an 11 cm segment of the humerus was resected and reconstructed 11 cm represented 50% of the total length of the fibula. During the procedure and after completion of the anastomoses bleeding was clearly seen from the distal cut end of the transplanted fibula. Furthermore, bone healing was achieved in 3 months showing that good vascularisation of the diaphyseal part of the transplant had been achieved. It is, therefore postulated that, at least in children, the proximal 50% of the fibula is vascularized by the anterior tibial artery alone. Because of possible anatomical variations in the origin and course of the anterior tibial artery, arteriography should be considered as a preliminary step in the planning of this procedure.

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Back to the SRA-EE Home Page

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