Received: 27 November 2019 | Revised: 25 February 2020 | Accepted: 4 March 2020

DOI: 10.1002/ccr3.2810

CASE REPORT

Clinical Case Reports Open Access WILEY

Long-term results of vascularized proximal fibula epiphyseal transfer based on the anterior tibial artery in retrograde fashion

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Abstract

Injury of bone growth plates can result in severe disability in children. We report the long-term results of successful vascularized proximal fibula epiphyseal transfer based on the anterior tibial artery in retrograde fashion.

KEYWORDS

fibula flap, growth plate transfer, reverse flow flap, vascularized proximal fibula epiphyseal transfer

1 | INTRODUCTION

Reconstruction of pediatric upper extremities after resection of bone malignant tumors requires longitudinal growth of transferred bone. The purpose of this report is to present long-term results of two cases in which vascularized proximal fibula epiphyseal transfer based on the reverse-flow anterior tibial artery was performed.

Reconstruction of pediatric upper extremities after resection of bone malignant tumors requires a 4-dimensional concept: considering bone structure, joint function, and axial limb growth. For skeletally matured patients, bone defects can be reconstructed in several ways. Vascularized/ nonvascularized autogenous or allogenic bone grafts and prostheses are usually chosen for repairing bone defects; however, in cases of children such reconstructed bone cannot keep up with their normal body growth. With the development of microsurgery and investigation of the role of epiphyseal plate and surrounding anatomies, vascularized proximal fibula epiphyseal transfer (VFET) has emerged as a reliable technique to solve this unique problem.[1-3]

The first free VFET was introduced by Weiland in 1975.[4] After his report, several plastic surgeons developed modified VFET procedures to grow longer bone.[5-7] We also reported a modified VFET procedure designed on reverse anterior tibial artery in 1991.[8] Between October of 1996 and March of 2017, 2 patients with bone defects of the upper extremity were reconstructed with this technique in our institute. The purpose of our study is to provide long-term results of these two cases of VFET designed on the reverse anterior tibial artery and present a historical review of the literature investigating the development of the VFET.

2 | CASE PRESENTATIONS

2.1 | Patient 1

A 12-year-old boy developed an osteosarcoma on the head of the right humerus. A wide resection induced a 7 cm bone defect of the head and proximal shaft. A vascularized proximal fibula epiphyseal flap was elevated including stripped biceps femoris tendon (Figure 1). The anterior tibial artery and veins were anastomosed end-to-end with 10-0 nylon to the posterior circumflex humeral artery and vein, and the brachial vein in retrograde fashion (Figure 2). The distal end of the fibula in the flap was fixed to the humerus with a plate, and the fibula head was joined to the coracoid process by wrapping

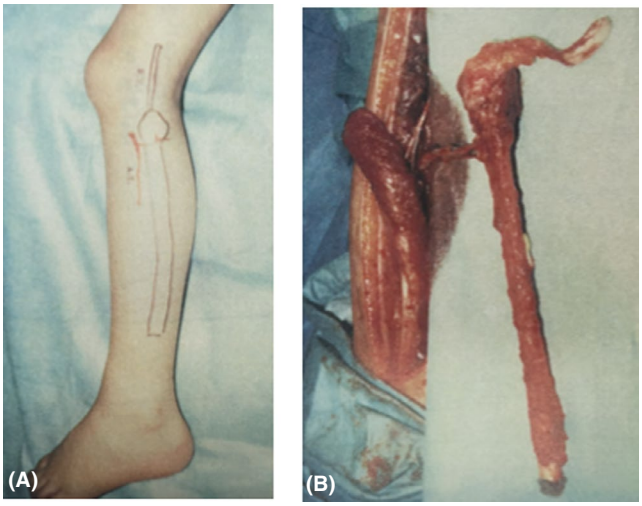

FIGURE 1 Intraoperative photographs. A, Design of the vascularized proximal fibula epiphyseal flap. B, The flap harvested

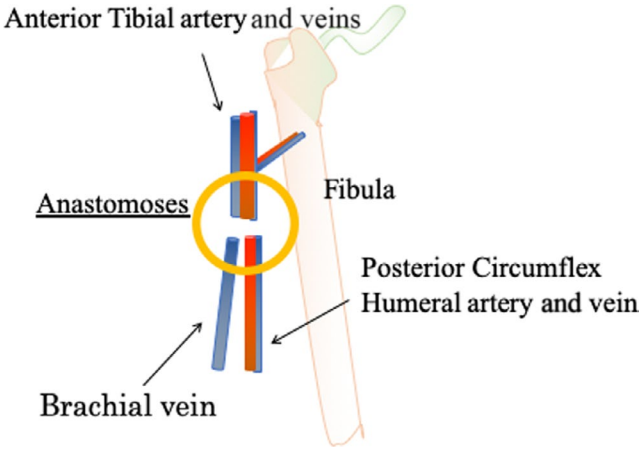

FIGURE 2 Schema of anastomoses

with the biceps femoris tendon. The supraspinatus and infraspinatus were sutured to the fibula head. Prior to surgery, the patient received preoperative chemotherapy. No radiation therapy was performed. In the postoperative period, no anticoagulation therapy such as heparin was administered. Bony union was completed 6 weeks postoperatively. Twenty-nine months after the operation, bone growth was measured at 30mm and then stopped (Figure 3). The patient went on to achieve a successful career in fine arts.

2.2 | Patient 2

A 7-year-old boy developed Ewing sarcoma on the head of the left humerus. Wide resection induced a 9 cm bone defect of the head and proximal shaft. A vascularized proximal fibula epiphyseal flap was elevated including stripped biceps femoris tendon (Figure 4). The anterior tibial artery and veins were anastomosed end-to-end with 10-0 nylon to the posterior

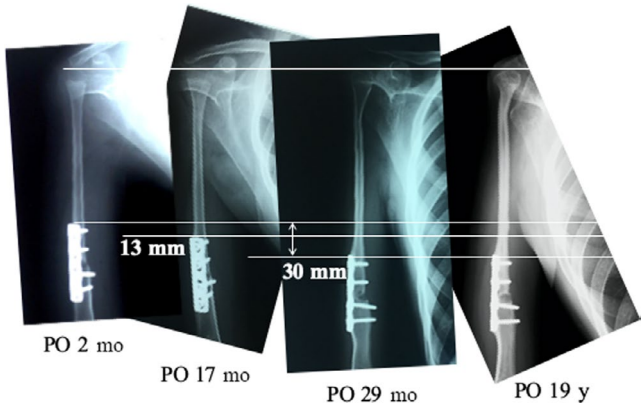

FIGURE 3 Radiographs showing postoperative longitudinal growth of transferred fibula in case one

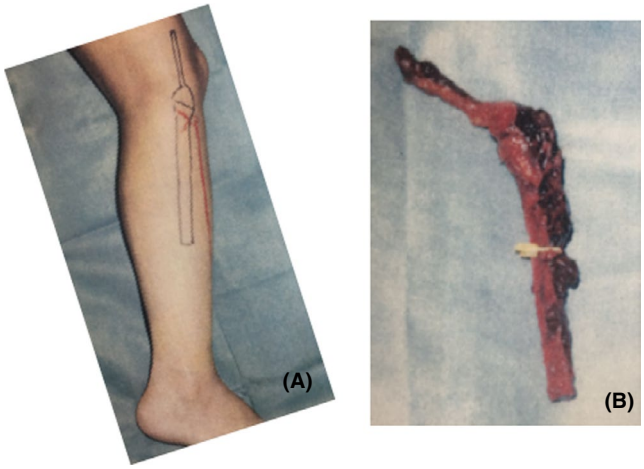

FIGURE 4 Intraoperative photographs. A, Design of the vascularized proximal fibula epiphyseal flap. B, The flap harvested

circumflex humeral artery, vein and the anterior circumflex humeral vein in retrograde fashion (Figure 5). The distal end of the fibula in the flap was fixed to the humerus with a plate, and the fibula head was joined to the coracoid process by wrapping it with the biceps femoris tendon. The supraspinatus and infraspinatus were sutured to the fibula head. Before surgery, this patient received preoperative chemotherapy. No radiation therapy was performed. In the postoperative period, no anticoagulation therapy like heparin was administered. Bony union was completed 6 weeks postoperatively. One hundred seventeen months after the operation, bone growth was measured at 61 mm and then stopped (Figure 6). The patient resumed playing table tennis and proceeded to a successful career in administration.

3 | DISCUSSION

The first free autogenous epiphyseal plate transfer was reported by Helferich in 1899.[9] His trial was a free nonvascularized

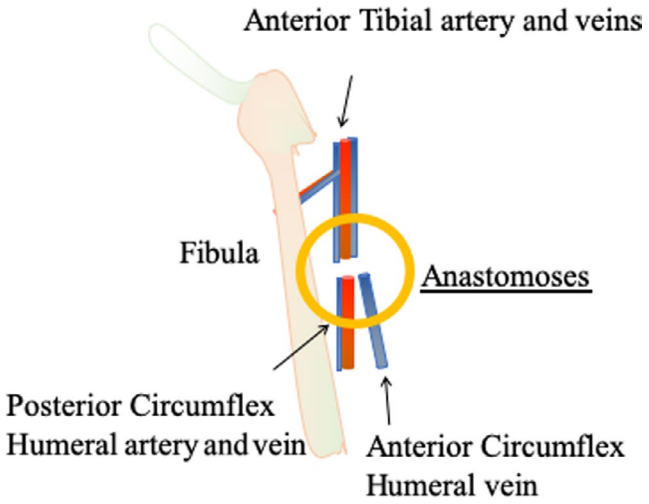

FIGURE 5 Schema of anastomoses

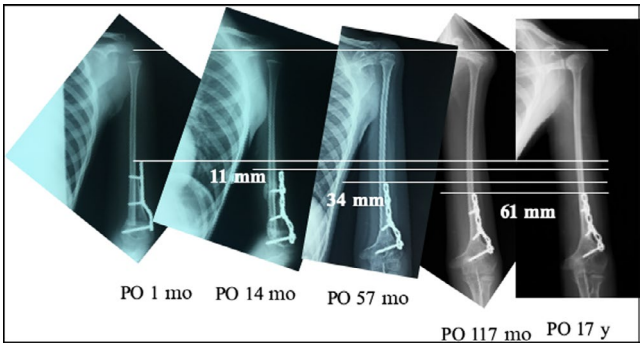

FIGURE 6 Radiographs showing postoperative longitudinal growth of transferred fibula in case two

ulnar epiphysis transfer in a dog. Straub described the first clinical use of free nonvascularized tibial epiphyseal transfer for a 6-year-old boy with osteomyelitic destruction of the left tibial shaft in 1929.[10] However, both trials resulted in no significant longitudinal growth in the transferred bone grafts. After Taylor's success of free vascularized bone transfer,[16] the first VFET was introduced by Weiland in 1975 and he also reported the first successful "grow-up" VFET in 1979.[4]

After Weiland's success, surgeons' interest in VFET changed to how long VFET would grow longitudinally. Several surgeons and researchers began to study the role and blood supply of the epiphyseal plate in transferred bone. Donski studied the growth of transferred ulnas in young puppies.[17] Tomita reported the role of the epiphyseal and metaphyseal circulations on longitudinal growth in immature canines.[18] It was gradually revealed that the selection of the pedicle vessel was contributing to longitudinal growth.[17-19] Tsai adopted a bipedicled method.[20] In his modified VFET, the lateral inferior genicular artery and the anterior tibial artery or the posterior tibial-peroneal trunk were anastomosed as pedicled vessels. Meanwhile, Pho reported the peroneal artery based modified VFET.[6] Taylor studied the role of the tibial and peroneal arteries in epiphyseal and diaphyseal transfer of the fibula in cadavers and identified the main supply to the transferred epiphyseal bone.[7] His VFET modification was in the manner of harvesting the flap with the anterior tibial artery as a pedicle vessel. With the dynamic vascular supply, his VFET obtains certain longitudinal growth. In 1991, we reported the procedure to use the anterior tibial artery in retrograde fashion as a modified Taylor's procedure (Table 1).[8]

TABLE 1 History of vascularized proximal fibula epiphyseal flaps pedicles

Author	Year	Pedicle
Weiland	1979	Peroneal artery
Tsai	1986	LIGA & ATA or Posterior tibial-peroneal trunk
Pho	1988	Peroneal artery & LIGA
Taylor	1988	ATA
Sawaizumi	1991	Reverse ATA

Abbreviations: ATA, Anterior tibial artery; LIGA, Lateral inferior genicular artery.

VFET based on the anterior tibial artery in retrograde has some technical advantages. Though bipedicled procedures occasionally require position change, our procedure can be harvested in spine position only. Furthermore, in contrast to bipedicled procedures, it requires preparation of only one pedicle and flap harvesting time is relatively short. Taylor's procedure is based on the same pedicle as ours; however, the pedicle is anastomosed in antegrade fashion. In his procedure, the obtained pedicle is short and close to the bone. Depending on the recipient vessels, anastomosis is sometimes performed in deep surgical sites and occasionally it requires vein grafts. To overcome this disadvantage, in our modified procedure, VFET is harvested with the anterior tibial artery in retrograde fashion to obtain a long pedicle. The pedicle length can be harvested as long as 8 cm. These benefits provide a degree of freedom in fixing of the flap and also shorten the ischemic time of the flap. Possibly, the cause of failures and complications in this procedure is a problem of the flap perfusion. Depending on flaps, retrograde fashion is regarded as the unsettled vascularity method. Poor perfusion of the flap can lead to failure of synostosis or even total flap loss. In 2015, Aldekhayle et al reported a systematic review of the literature about VEFT.[22] In their study, VFET based on the anterior tibial artery in reverse fashion was studied in 9 cases and the only complication reported was skin necrosis in one donor site. The number studied was small; however, the trouble with the flap perfusion can be considered rare. Because of rareness of VFET after resection of pediatric malignant tumors in long bone and evaluation of results requiring long-term follow-up, VFET has not been investigated in detail. Further

research and clinical experience are required to establish an optimal VFET procedure.

4 | CONCLUSIONS

Vascularized fibula epiphysis transfer based on the anterior tibial artery in retrograde fashion can be used for pediatric upper extremity reconstruction to preserve long-term growth and function.

CONFLICT OF INTEREST

None declared.

AUTHOR CONTRIBUTIONS

MS: served as the plastic surgery consultant who performed the surgery and conceived and designed the study. RI: served as the clinical fellow who collected the data and wrote the paper. All authors checked the manuscript for important intellectual content and approved the final version of manuscript.

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REFERENCES

1. Boyer MI, Bray PW, Bowen CV. Epiphyseal plate transplantation: An historical review. *Br J Plast Surg*. 1994;47:563-569.
2. Mathes SJ, Buchannan R, Weeks PM. Microvascular joint transplantation with epiphyseal growth. *J Hand Surg Am*. 1980;5:586-589.
3. Kurlander DE, Shue S, Schwarz GS, Ghaznavi AM. Vascularized fibula epiphysis transfer for pediatric extremity reconstruction. *Ann Plast Surg*. 2019;82:344-351.
4. Weiland AJ, Daniel RK, Riley Jr LH. Application of the free vascularized bone graft in the treatment of malignant oraggressive bone tumors. *Johns Hopkins Med J*. 1977;140:85-96.
5. Tsai TM, Ludwig L, Tonkin M. Vascularized fibular epiphyseal transfer. A clinical study. *Clin Orthop Relat Res*. 1986;228-234.
6. Pho RW, Patterson MH, Kour AK, Kumar VP. Free vascularised epiphyseal transplantation in upper extremity reconstruction. *J Hand Surg Br*. 1988;13:440-447.
7. Taylor GI, Wilson KR, Rees MD, Corlett RJ, Cole WG. The anterior tibial vessels and their role in epiphyseal and diaphyseal transfer of the fibula: Experimental study and clinical applications. *Br J Plast Surg*. 1988;41:451-469.
8. Sawaizumi M, Maruyama Y, Okajima K, Motegi M. Free vascularised epiphyseal transfer designed on the reverse anterior tibial artery. *Br J Plast Surg*. 1991;44:57-59.
9. Helferich H. Versuche uber die Transplantation des Intermediarknorpels wachsender Rohrenknochen. *Dtsch Z Chir*. 1899;51:564-573.
10. Straub GF. Anatomical survival, growth, and physiological function of an epiphyseal bone transplant. *Surg Gynecol Obstet*. 1929;48:687-690.
11. Taylor GI, Miller G, Ham FJ. The free vascularized bone graft: a clinical extension of microvascular techniques. *Plast Reconstr Surg*. 1974;55:553-544.
12. Donski PK, Carwell GR, Sharzer LA. Growth in revascularized bone grafts in young puppies. *Plast Reconstr Surg*. 1979;64:239-243.
13. Tomita Y, Tsai TM, Jupiter JB, Ogden L. Canine epiphyseal growth: a study of the effects of variations in the vascular pedicle and accompanying bone grafts. *J Hand Surg*. 1986;11A:375.
14. Innocenti M, Delcroix L, Manfrini M, Ceruso M, Capanna R. Vascularized proximal fibular epiphyseal transfer for distal radial reconstruction. *J Bone Joint Surg Am*. 2004;86A:1504-1511.
15. Tsai TM, Ludwig L, Tonkin M. Vascularized fibular epiphyseal transfer. A clinical study. *Clin Orthop Relat Res*. 1986;210:228-234.
16. Aldekhayel S, Govshievich A, Neel OF, Luc M. Vascularized proximal fibula epiphyseal transfer for distal radius reconstruction in children: a systematic review. *Microsurgery*. 2016;36:705-711.

How to cite this article: Ishiura R, Sawaizumi M. Long-term results of vascularized proximal fibula epiphyseal transfer based on the anterior tibial artery in retrograde fashion. *Clin Case Rep*. 2020;8:1069–1072. https://doi.org/10.1002/ccr3.2810