VASCULARIZED TIBIAL PERIOSTEAL GRAFT IN COMPLEX CASES OF BONE NONUNION IN CHILDREN

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Bone nonunion in the pediatric population usually occurs in the context of highly unfavorable biological conditions. Recently, the vascularized fibular periosteal flap has been reported as a very effective procedure for treating this condition. Even though a vascularized tibial periosteal graft (VTPG) was described long ago and has been successfully employed in one adult case, there has been no other report published on the use of this technique. We report on the use of VTPG, pedicled in the anterior tibial vessels, for the treatment of two complex pediatric bone nonunion case: a recalcitrant supracondylar femoral pseudarthrosis secondary to an infection in an 11-year-old girl, and a tibial nonunion secondary to a failed bone defect reconstruction in a 12-year-old girl. Rapid healing was obtained in both cases. In the light of the data presented, we consider VTPG as a valuable surgical option for the treatment of complex bone nonunions in children. © 2014 Wiley Periodicals, Inc. Microsurgery 35:239–243, 2015.

Bone nonunion is an infrequent posttraumatic problem in the pediatric age group.[1] When it does occur, it poses a serious challenge due to its association with a complex biological context.[2] It mainly affects patients with large bone defects, reconstructed with non-vascularized bone—morcellated or structural—and it can also be congenital, or due to long-standing infections.[2–5] An ideal treatment plan for such conditions would need to provide both angiogenic and osteogenic potentials.[6] The use of a medial femoral condyle corticoperiosteal flap (i.e., Sakai's flap) should be disregarded in the pediatric age group as it would damage the femoral physis.[7] The Vascularized Fibular periosteal graft (VFPG) was designed as an alternative to the medial femoral condyle corticoperiosteal flap (Sakai's flap) in children, so as to preserve the femoral physis; it has shown powerful healing capability in clinical cases.[2]

The surgical anatomy of a vascularized tibial periosteal graft (VTPG), a flap based on the anterior tibial vessels (ATV), was described long ago.[8] It has been applied successfully in one adult case.[8] However, no other report has been published of this technique's use.

We report the use of VTPG in two pediatric cases of complex bone nonunion.

CASE 1

An 11-year-old girl presented with a severe acquired hypoplastic left femur secondary to panfemoral osteomyelitis which she suffered at the age of 20 months (Fig. 1A). She had a residual limb-length discrepancy of ~18 cm. The femur showed a highly mobile recalcitrant pseudarthrosis at the supracondylar level, while the knee was stiff and fixed in extension. The ankle was also rigid and held in plantar flexion and thus, a Van Ness rotationplasty procedure was disregarded.[9] An ischial weight-bearing prosthesis was necessary to walk. With the aim of improving both gait and quality of life, our prosthetic team proposed a femoral weight-bearing prosthesis with a dynamic knee. To effect this solution we needed to tackle the supracondylar nonunion and perform a transtibial amputation. The level of tibial amputation was calculated so as to position the prosthetic knee joint at the same level as the contralateral knee at final growth. A vascularized pedicled tibial periosteal graft, obtained from the amputated segment, was planned for treatment of the femoral pseudarthrosis.

A cutaneous midtibial fish-mouth incision was performed and extended laterally to and then above the distal femur (Fig. 1B). The ATV were identified between the tibialis anterior muscle and extensor digitorum comunis/extensor hallucis longus. They were dissected from the fibularis profundus nerve. The muscular collaterals originating distal to the recurrent tibial vessels were ligated, while the recurrent tibial vessels were preserved. The periosteal vessels, arising from the medial side of the ATV and running over the interosseous membrane, were preserved.[8] The interosseous membrane was

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Figure 1. ***A:*** *Post-infectious hypoplasic femur with severe limb length discrepancy associated to a supracondylar femoral recalcitrant nonunion needing an ischial bearing prosthesis.* ***B****: Intraoperative images showing the marked surgical incisions (above). A VTPG (*) pedicled proximally on the ATV (arrow) was obtained from the tibia (+) before amputation. C: Radiographs showed a completely ossified large callus and a complete femoral supracondylar nonunion healing two months postoperatively (arrow) allowing to walk early with a femoral weight-bearing prosthesis. Eleven months postoperatively the radiographs showed a complete callus ossification and remodelation.*

detached from the fibula. Muscular insertions were circumferentially detached from the tibia. A longitudinal periosteal incision was performed over the anterior border of the tibia. Approximately 20 cm of the tibial periosteum was detached from bone with the use of an elevator. The periosteal flap was significantly thick, measuring ~15 cm in length and 4 cm in width after harvesting, due to an elastic retraction. The ATV were ligated distally and the vascularized periosteal flap was pedicled proximally (Fig. 1B). The tibia was amputated at midlevel.

The atrophic-type nonunion focus was debrided and then stabilized with a 3.5 mm T-plate. The pedicled vascularized periosteal graft was placed longitudinally, covering the lateral aspect of the femoral condyle, the nonunion focus and the distal femur. It was secured in situ with local sutures. No bone graft was added. Patellar and femoral trochlear cartilages were resected. In order to achieve a patellofemoral fusion, we used two 3.5 mm screws.

Clinical examination at three weeks after surgery showed a large lateral femoral mass which corresponded to the large immature periostial callus shown in the radiograph. A radiograph performed two months postoperatively showed a completely ossified large callus and a nonunion healing (Fig. 1C).

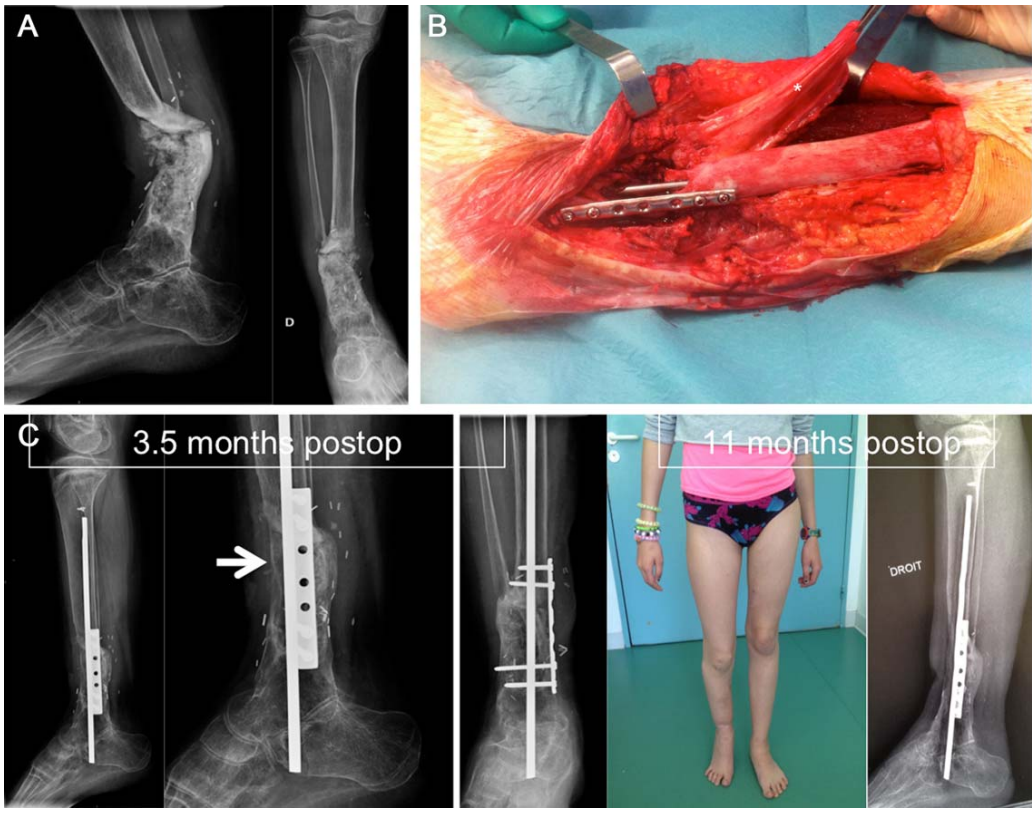

Figure 2. ***A:*** *Distal-third tibial nonunion following a segmental bone defect reconstructed with an induced membrane technique.* ***B****: VTPG (*) harvested from the proximal tibia (+) and pedicled distally to cover the anterior part of the debrided nonunion focus. No bone graft was added.* ***C****: Radiographs showing a complete bone healing 3.5-months after surgery with an anterior bone callus formation (arrow). Full weight bearing was allowed afterwards uneventfully with no reported complications 11 months after the surgery. Preoperative equinus deformity partially compensated a 4 cm limb length discrepancy. Eleven months postoperatively the radiographs showed a complete callus ossification and remodelation.*

Prosthetic fitting was uneventful and allowed the child to walk with a femoral weight-bearing prosthesis with no problems reported 11 months after the surgery (Fig. 1C).

CASE 2

A 12-year-old girl presented with a distal tibial shaft nonunion following the reconstruction of a distal tibial segmental bone defect with an induced membrane technique (Fig. 2A).[4] Initially, a one-third distal tibial resection with tibiotalar disarticulation had been done to resect a tibial osteosarcoma, at the age of 10.5 years. She could achieve appropriate ankle fusion but failed to obtain a proximal fusion with the host tibial bone interphase. Ankle fusion was obtained in an equinus position, which partially compensated a 4 cm limb length discrepancy. The patient refused treatment of these deformities.

Reconstruction with a retrograde VTPG, harvested from the remaining proximal tibia, was planned. A preoperative Doppler ultrasound was done so as to demonstrate the patency of both the anterior and posterior tibial vessels. The surgical incision was performed on the previous surgical scar, which was longitudinal over the anteromedial leg. This incision was prolonged proximally and curved toward the anterior tibial tuberosity. Tibial periosteal harvest differed from case no. 1, as the VTPG was designed in a retrograde fashion. The ATV were ligated proximally (below the anterior recurrent vessels); the muscular insertions were detached from the anterolateral tibia, preserving the periosteal branches. Then the periosteum was incised proximally and longitudinally at the level of the medial and lateral border of the tibia, to harvest the anterolateral and anteromedial tibial periosteum, preserving the posterior periosteum. The vascularized flap was pedicled distally to cover the anterior part of the debrided nonunion focus (Fig. 2B).

The nonunion focus was debrided; no bone grafts were added. It was stabilized with a retrograde endomedullar Steinman rod, and a lateral 3.5 mm third tube

plate was added to provide rotational stability. A below-knee plaster cast was applied after surgery and left in place for one month. Complete radiographic healing occurred 3.5 months after surgery (Fig. 2C). Full weight bearing was allowed afterward, proceeding uneventfully with no reported complications 11 months after the surgery. No clinical or radiological signs suggesting tumoral recurrence were present at any stage during reconstruction.

DISCUSSION

The VTPG was effective in the treatment of two complex pediatric bone nonunions and provided very rapid healing.

The periosteum in children is quite thick, relatively easy to harvest, and exhibits greater osteogenic power than in adults.[2,10] Several vascularized periosteal grafts have recently been described for the treatment or prevention of recalcitrant bone nonunion and osteonecrosis, or for enhancement of massive bone allograft integration in children.[2,5,11–13] The angiogenic and osteogenic properties of vascularized periosteal flaps at pediatric age, attributed to the presence of stem cells in the cambium layer, lead to excellent results in these extremely unfavorable biological scenarios.[14,15] Qi et al. described a vascularized periosteal flap obtained from the greater trochanter as a coadjuvant treatment in pediatric femoral neck fractures.[11] This flap prevented femoral head osteonecrosis after femoral neck fracture. Soldado et al. described a VPG in a child, harvested from the first metatarsal and successful in revascularization and prevention of bone collapse in a talar osteonecrosis.[13]

Soldado et al. also described a vascularized fibular periosteal graft (VFPG) successful in the treatment and prevention of nonunion in children, and showing a mean nonunion healing time of 4.8 months.[2,5,7,16]

The VTPG, which was observed to be very thick, showed rapid callus formation and ossification associated with very brief healing time. No bone graft, decortication, or compression was added at the nonunion focus; thus bone healing should arise exclusively from the periosteal callus formed from the periosteal graft. The authors' conjecture is that the tibia might have a stronger periosteal osteogenic potential than the fibula, owing to higher mechanical solicitations and a higher basal remodeling rate. The size of the tibial periosteum might be another advantage.

Thus, the VTPG might be an alternative to the VFPG, with the theoretical advantages of being a more powerful bone former and being greater in size. These theoretical advantages, however, need to be clinically demonstrated.

Providing vascularized tissue was necessary in these complex biological scenarios, to provide the needed angiogenic and osteogenic resources.[6] A vascularized bone graft following a segmental bone resection, combined with internal or external fixation, might have been an alternative treatment. The advantage of vascularized periosteal grafts is that they provide the nonunion focus and surrounding tissues a more extensive contact with the cambium layer and its stem cells. The cambium layer, in intimate contact with the nonunion focus and the poorly vascularized surrounding tissues, might promote bone revascularization and healing more efficiently.[2] We prefer to use a VFPG without bone graft, as we did in our two cases, if there is moderate bone loss, since the periosteal callus is rapidly formed, filling the nonunion focus and its periphery, leading to rapid consolidation.[2]

It has been reported that corticoperiosteal flaps in the adult population are more efficient for bone production than pure periosteal flaps, due to better preservation of the regenerative cambium layer.[13] The corticoperiosteal Sakai's flap, a reliable flap with little morbidity, is the preferred periosteal flap in adults, leaving other periosteal flaps as a second option. In children, the thickness and easy detachability of the periosteum might protect the cambium layer from injury during the process of harvesting and explain the consistent bone production of "pure" periosteal flaps.[2]

A drawback of the VTPG technique is the sacrifice of a main vascular axis of the leg. [6,8] Hence, patency of the posterior tibialis vessels should be verified before harvesting this flap. In addition, the potential devascularization of the muscles of the anterior compartment of the leg after ligation of the muscular vessels from the ATV might be avoided by limiting the length of the flap. We preserved the proximal part of the ATV, and thus the anterior recurrent tibial vessels, which are a main vascular source for the anterior compartment.[17] Finally, another inconvenience of this flap might be the potential for injury to the deep peroneal nerve branches, which should be avoided through meticulous dissection.

These drawbacks were not relevant in case 1 since the leg was to be amputated. We availed the periosteal tissue before the amputation. In case 2, the sacrifice of the ATV may be justified as this flap successfully solved a very unfavorable clinical scenario without the need of a free flap. Anterior tibial muscle denervation–devascularization was not an issue since there was a previous tibiotalar fusion. In both cases the flap was used in a pedicled fashion, distally or proximally. The VTPG, although not so reported as yet, could be used as a free flap.

The effects of stripping the tibia of its periosteum are unknown. However, no complications have been described after tibial periosteal harvest in newborns for the treatment of palatine cleft, or in young children for the treatment of congenital pseudarthrosis of the tibia.[18,19] In addition, no complications have been

reported in connection with the fibula after harvesting the VFPG.[2] Until further evidence is available, we prefer to preserve at least the posterior tibial periosteum, as was done in case 2.

VTPG may be considered a relevant surgical option for the treatment of complex bone nonunions in children, with potential advantages over other previously described vascularized periosteal flaps.

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