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Does Distal Radius Reconstruction by Free Epiphyseal Transfer Lead to Inferior Radioulnar Dissociation?

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Abstract

Purpose: The aim of this study is to confirm that free fibular epiphyseal transfer is a suitable option for reconstruction of distal radius after sarcoma resection. In addition the authors discuss the potential inferior radioulnar dissociation that may accompany such type of reconstruction.

Patients and Methods: A retrospective analysis of three cases that underwent distal osteoarticular radial reconstruction using free osteo septocutaneous proximal fibular epiphyseal flaps was conducted. The data on these patients were obtained from the patients' files, photos, and relevant radiological investigations.

Results: All three cases displayed solid union, longitudinal growth (average annual rate=5mm) and hypertrophy (range: 6.6%-100%). The functional outcome for these patients was assessed according to the Enneking functional scoring system. The complications encountered were mainly full-thickness skin paddle necrosis in the case with the smallest skin paddle size (15 cm2), and inferior radioulnar subluxation (all cases).

Conclusions: Free composite proximal fibular epiphyseal transfer is an optimal biological option for distal radial osteoarticular reconstruction in skeletally immature patients with potential inferior radioulnar dissociation.

Keywords: Free epiphyseal transfer; Osteoarticular reconstruction; Inferior radioulnar dissociation

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Introduction

Free vascularized bone transfer is considered a well recognized discipline in the reconstructive community. It provides rapid and reliable bony union in the most unfavorable scenarios (scarred, irradiated, or infected beds), graft hypertrophy, and resistance to infection. In addition, it preserves two additional major advantages in skeletally-immature patients, namely continuous bone growth and remodelling in response to loads and stresses [1].

The proximal fibula meets all the biologic and biomechanical requirements for epiphyseal reconstruction of long bones in children and is unquestionably the appropriate choice of procedure [2]. Current indications for free vascularized proximal fibular epiphyseal transfer include trauma, tumor, and congenital disorders involving the growth plate of a long bone in children. This donor site is optimal both anatomically [3,4] and biomechanically for the reconstruction of osteoarticular defects in the distal radius. Previous studies have shown comparable growth of the fibula ipsilateral or contralateral to the radius [3].

In this study one centre's experience with free composite proximal fibular epiphyseal transfer for distal radial osteoarticular reconstruction in skeletally-immature patients is presented. In this study the authors aim to highlight the potential distal radioulnar joint dissociation that accompanies such modality of reconstruction.

Methods

Human ethical committee approval from Universiti Sains Malaysia (USM) was obtained on May 17, 2009. Each of our patients underwent full preoperative assessment in both clinical and radiological terms. This assessment involved the donor site, recipient site and the patient as a whole. Preoperative planning was a routine procedure and included marking the fibula and skin paddle as well as mapping the perforators using a hand-held Doppler. General anaesthesia was used in

Table 1: Preoperative data of the patients.

	Case (1)	Case (2)	Case (3)
Age	9	6	9
Sex	F	M	F
Side affected	LT	LT	RT
Bone affected	Radius	Radius	Radius
Diagnosis	Osteosarcoma	Osteosarcoma G2B	Ewing sarcoma G2
Adjuvant therapy	Chemotherapy	Chemotherapy	Chemotherapy & radiotherapy
Number of previous surgeries	1	1	1

Table 2: Intraoperative data.

	Case (1)	Case (2)	Case (3)
Size of soft tissue defect (cm^2)	9	15	80
Size of bony defect (cm)	11	8	16
Adjuvant reconstructive procedures	1.5 cm of the biceps femoris tendon was used to reconstruct the lateral collateral ligament of the wrist.		
Number of cutaneous perforators	7	10	4
Size of skin paddle (cm^2)	72	15	76.5
Length of vascular pedicle	1	3	3
Ischemic time (minutes)	310	380	180
Reexploration			Due to hematoma formation
Methods of graft fixation	One small 3.5 DCP	One small 3.5 DCP	Two cortical 3.5 mm screws
Duration of surgery (hours)	18	11	15
Hospital stay (months)	0.5	1.2	1.5

Table 3: Postoperative data and follow up.

Case	1	2	3
Average longitudinal growth per year (cm)	0.5 cm	0.5 cm	0.5 cm
Total longitudinal growth (cm)	2.6 cm	1 cm	0.5 cm
Degree of hypertrophy	6.6%	100%	100%
Enneking functional scoring system	28	24	20
Time of radiological union (months)	7	6	11
Number of subsequent surgeries	0	2	3
Duration of follow up (months)	52	12	23
Complications	Postoperative cardiomyopathy Inferior radioulnar dissociation	Full thickness necrosis of skin paddle Inferior radioulnar dissociation	Reexploration Delayed donor site SSG healing Rt sided wrist dorsal subluxation and hand stiffness. Left sided Peroneal nerve neuropraxia

all patients where oral intubation was preferred. To guard against irreversible vasospasm of the microanastomosis, hypothermia, hypovolemia and pain were routinely monitored and controlled. The transection of the donor vascular pedicle was not performed until the patient temperature was ≥34°C [5].

Under tourniquet control the calf was approached laterally with the incision performed on a line directly over the planned skin paddle. It was extended proximally to expose the lateral inferior genicular blood vessels. The lateral intermuscular septum was identified in the plane between the peroneal muscles and soleus. On the anterior surface of the lateral intermuscular septum, dissection proceeded extraperiosteally until the interosseous membrane was encountered. This membrane was subsequently incised. Posteriorly, after the deep fascial layer was incised the flexor hallucis longus was visible. The pedicle enclosed within the posterior crural septum was directly under this muscle, so care was taken during its release. Proceeding proximally, the proximal fibers of the peroneus longus were detached from the proximal fibula together with the flexor hallucis longus to achieve better visualisation and access to the proximal pedicle and tibiofibular joint. The pedicle was then dissected proximally until the trifurcation of the popliteal artery was reached and the recurrent branch of the anterior tibial artery was traced to the head of the fibula. The lateral inferior genicular artery was traced in a freestyle exposure [6] through the proximal extension of the incision. The head of the fibula was released from the lateral collateral ligament of the knee with preservation of part of the tendon of the biceps femoris tendon which was used for subsequent wrist reconstruction. Care was taken to meticulously reconstruct the lateral collateral ligament of the knee. A power oscillating saw was then used to cut the fibula in the preoperative determined level. The dissection plane was then carried up through the membrane with care paid to the deep perforators. The fibula was swung in the wound during dissection so that no perforators were missed. Careful sharp dissection can be carried

down to the bifurcation of the pedicle. The fibular graft was then freed from the leg. The tourniquet was then deflated to check for bleeding, and the wound was packed with wet lap pads.

All arterial and venous anastomoses were performed in an end-to-end fashion. In each case the peroneal and the inferior lateral genicular arteries were the donor arteries. These vessels were anastomosed to the radial artery and anterior interosseous artery. This method of anastomosis allows double arterial flow through anastomoses.

Results

In the period from 2004 to 2009, three patients underwent free vascularized proximal fibular epiphyseal transfer for distal radial osteoarticular reconstruction after sarcoma resection.

The summary of the preoperative data for the patients is in Table 1. The details of the operative and post-operative data are represented in Tables 2 and 3.

Case Presentation

Case 1

A 9-year-old female [right-handed] student presented with progressive swelling of the distal left forearm since March 2004. On April 2004 she was diagnosed as osteosarcoma of the distal left radius following trucut biopsy (Figure 1). Chemotherapy was given as 3 preoperative cycles followed by 3 postoperative cycles. Wide surgical resection of the tumor was performed, followed by free vascularized osteo septocutaneous proximal fibular epiphyseal transfer from the right leg. The graft was fixed to the remnant of the radius using small 3.5 DCP. The surgery was uneventful except for immediate postoperative cardiomyopathy, which was managed successfully. The period of follow-up was 52 weeks. Late complications included inferior radio-ulnar subluxation (Figure 2). At the patient's last visit, the Enneking functional score was 28. Host-graft union was achieved 7 months postoperatively with a hypertrophy rate of 6.6%.

Case 2

A 6-year-old male patient presented with painful and progressively increasing swelling at the distal part of the left forearm for 3 years. Biopsy confirmed the diagnosis of osteosarcoma grade 2B at the distal end of the left radius (Figure 3). Three cycles of neoadjuvant chemotherapy were administered, followed by 3 cycles

Figure 1: Preoperative radiograph of the left forearm bones showing classic osteosarcoma of the distal radius; AP view.

Figure 2: X-ray of the recipient site 4 years postoperatively (complete radiological union and hypertrophy of the host-graft junction are obvious) with evident inferior radioulnar dissociation.

Figure 3: Preoperative X-ray showing osteosarcoma grade 2B at the distal end of the left radius.

Figure 4: 12 months postoperative X-rays showing the solid union and hypertrophy of the graft-host junction and inferior radioulnar dissociation.

Figure 5: Preoperative X-ray showing sarcoma grade 2 at the distal end of the right radius.

postoperatively. Wide surgical resection of the tumor was performed, followed by free vascularized osteo septocutaneous proximal fibular epiphyseal transfer from the right leg. The graft was fixed to the remaining part of the radius proximally using small 3.5 AO-DCP (Figure 4). The surgery was complicated by full-thickness necrosis of the skin paddle, which was managed by wound debridement and SSG (Split Thickness Skin Graft) to the necrosed skin paddle. At the patient's last visit, the Enneking functional score was 24. The inferior radioulnar joint showed dissociation. Host-graft union was achieved 6 months postoperatively with a hypertrophy rate of 100%.

Case 3

A 9-year-old female patient presented with painless progressive swelling at the distal right forearm for two months since December 2005. Ewing sarcoma grade 2 was diagnosed after trucut biopsy (Figure 5). Three cycles of neoadjuvant chemotherapy and 25 cycles of 2000cGy postoperative radiotherapy were administered. Wide surgical resection of the tumor was performed (the whole radius was resected) followed by free vascularized fibular epiphyseal transfer from the left side. The graft was fixed to the ulna proximally using two 3.5 AO cortical screws. The surgery was complicated by venous congestion due to hematoma formation which necessitated re-exploration and vein grafting, dorsal wrist subluxation with inferior radioulnar dissociation (Figure 6), and transient peroneal nerve neuropraxia at the donor site (which recovered completely after three months postoperatively). The host-graft union was achieved 11 months postoperatively with 100% hypertrophy rate. The Enneking functional score was 20 at the last follow up. Notably, the patient, at present, has profound radial deviation of the wrist with decreasing function. Wrist arthrodesis is to be performed.

Discussion

Free vascularized epiphyseal transfer exhibits three well-distinguished advantages over the non vascularized transfer: firstly, it provides predictable longitudinal growth; secondly, it achieves anatomically and biomechanically accepted joint reconstruction; lastly, it responds to normal stress loading with bony hypertrophy. These advantages are confirmed by other studies [2,7]. The proximal fibular epiphysis has been accepted as the most favorable site for reconstruction of the distal end of the radius, humerus, or femur in growing children. This site has surpassed previously suggested potential donor sites such as the iliac crest and the inferior angle of the scapula [2] due to well-pronounced advantages. These include the tubular configuration of the proximal fibula, the articular cartilage covering the head of the fibula, in addition to the use of a

Figure 6: 18 months postoperative X-ray showing union and hypertrophy of the graft with subluxation of the inferior radioulnar joint.

true epiphysis in contrast to the previously mentioned sites, which represent apophasis.

Use of the vascular pedicle for proximal fibular epiphysis has been studied on clinical as well as anatomical bases. Taylor's anatomical investigations confirmed the role of the anterior tibial artery (ATA) in the vascularity of the fibular proximal growth plate as well as the proximal diaphysis. Thus, the ATA is able to supply the graft, provided that both the epiphyseal vessels and the diaphyseal periosteal vascular network are preserved during the dissection [4].

In a more recent study, three vascular origins were identified: the artery of the neck of the fibula (from ATA with trifurcation of ascending, descending and transverse branches), lateral inferior genicular artery (LIGA) (from the popliteal artery); and an artery in between the previous two, arising from popliteal artery. Therefore, to achieve free epiphyseal transfer, the vascular basis could be: bipedicled transfer combining both the LIGA and the peroneal artery or a single vascular pedicle dependent on ATA providing a branch to the proximal fibular physis and anastomotic branches with peroneal artery to the diaphysis, allowing transfer of up to 13 cm from the diaphysis [8].

When blood supply is based on the peroneal artery, long term results of the free vascularized fibula head transfer are diverse. They depend on the growth plates and the length of the transplanted fibula. If growth plates are closed at the time of procedure or the grafted fibula is long enough to ensure anastomotic flow, results are good. If any of these two conditions is not fulfilled, vascular supply to the epiphysis is insufficient. Long bone deviation, bone necrosis, and severe loss of function will result [9].

The need to achieve negative surgical margins after sarcoma excision almost always results in the creation of major anatomical and functional defects. This has been overcome by the development of limb salvage techniques that have allowed comparable results to those obtained with the amputation procedures used in the past [10]. Today, more than 90%-95% of patients treated by surgeons with expertise in musculoskeletal oncology undergo successful limb-sparing procedures [11]. The components of limb-sparing surgery for bony sarcoma are wide surgical resection of the bony tumor and reconstruction of bony and soft tissue defects. Obviously, this

procedure requires extensive planning, prolonged operative time and causes more morbidity to the patient due to the use of more than one donor site. To overcome such problems, the use of free composite osteocutaneous flaps has been suggested by many authors [12,13].

Three cases of free osteo septocutaneous proximal fibular epiphyseal transfers were analyzed. All cases involved reconstruction of the distal radius and incorporated well, exhibiting solid union and hypertrophy. However, these cases also exhibited certain peculiar complications which included postoperative acute cardiomyopathy (case 1) and full-thickness skin paddle necrosis (case 2). Despite the fact that longitudinal growth continued, it was disproportionate to either the contralateral bone or the ipsilateral adjacent bone with subsequent inferior radioulnar dissociation or dorsal wrist subluxation.

Our three patients had postoperative disease-free survival until last follow-up which emphasizes the adequacy of resection and reconstruction. This correlates with the previous reports which revealed the variety of indications for vascularized epiphyseal transfer in trauma, tumor and congenital disorders involving the growth plate of a long bone in children [1-3].

The results of this study confirm the predictable longitudinal and transverse growth of live proximal fibular epiphyseal transfer in addition to remodelling in response to loading and normal daily living activities. The longitudinal growth was estimated by measuring the distance between the distal edge of the used implant and the distal end of the graft. All three cases exhibited the same rate of annual longitudinal growth which was 5 mm/year. This is relatively low compared to the rate recorded by other authors [2,10]. However, this was less than the annual growth of the ipsilateral sound ulna with subsequent inferior radioulnar dissociation in all cases. Another contributing factor for this complication is the inadequate soft tissue reconstruction. The third case was complicated by dorsal radiocarpal subluxation due to the same causes as well as complete ablation of the radius with proximal fixation of the graft to the proximal ulna, which halted the proximal participation in longitudinal growth. Some other studies have shown volar carpal subluxation [7].

In this study the incorporation of a skin island was performed to monitor the free osseous flap with the additional advantage of providing thin coverage appropriate for the reconstruction of the distal forearm precluding the need for further secondary reconstructive procedures. By revising the complications of such cases, it can be noted that the only case of full-thickness skin paddle necrosis was encountered in case (2). In this case, the skin paddle size was 15 cm^2, which is the smallest among the three cases, with, prolonged ischemic time (380 minutes).

The viability of the graft was confirmed by the viability of the skin paddle, the continuity of the opening of physeal plate and lastly the incorporation and hypertrophy of the osseous graft. The results of this study confirmed good wrist joint motion and persistence of the articular cartilage with less pronounced degenerative changes.

In all cases we managed to evaluate the final functional outcome according to the Enneking functional scoring system [14]. The score ranged from 20-28. The low score of the third case can be attributed to the fact that the method used in fixation was two cortical screws fixing the radius to the ulna thus preventing supination/pronation movements leading to subsequent difficulty with manual dexterity and normal hand function. In addition, the same case exhibited both dorsal wrist subluxation and inferior radioulnar dissociation.

Conclusions

Free composite proximal fibular epiphyseal transfer is an optimal biological option for distal radial osteoarticular reconstruction, providing continuous remodelling and moulding of the articular surface and limiting chondrolysis. It is preferable to include a large-sized skin paddle to avoid skin paddle necrosis. The results of this study emphasize the need for adequate soft tissue reconstruction at the recipient site in addition to including a longer diaphyseal portion of the fibula to lessen the risk of inferior radioulnar dissociation.

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