Free vascularised fibular flap harvesting in children: An analysis of donor-site morbidity

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**A R T I C L E   I N F O**

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**A B S T R A C T**

Background: The free vascularised fibular flap (FVFF) is widely used to treat bone defects, although it must be harvested from a healthy site. The objective of this study was to assess clinical morbidity and radiological changes at the FVFF donor site in children.

Hypothesis: Distal fibular stabilisation using a tibial strut decreases the prevalence of valgus ankle deformity.

Material and method: Thirty-one children managed at two centres between 1994 and 2014 were included. Mean age was 8.9 years (range, 2–14 years) and mean follow-up was 6.6 years (range, 2–21 years). Early and delayed complications were evaluated.

Results: Of the 17 early complications, 82.4% resolved fully within 7 months. Valgus ankle deformity developed in 6 (19.4%) patients. Age-residual fibula index under 16 was not significantly associated with valgus ankle deformity, although the P-value was borderline (P < 0.058). Residual distal fibula length did not predict valgus ankle deformity. Three techniques were used for fibular reconstruction: syndesmotic screw, tibial strut, and both. None of these techniques prevented the occurrence of valgus ankle deformity.

Discussion: Clinical donor-site morbidity after FVFF harvesting, although noticeable, usually resolved promptly. Taken alone, an age-residual fibula index under 16 did not predict valgus ankle deformity. We recommend a distal tibio-fibular quadrangular syndesmotic screw or combined syndesmotic screw-tibial strut fixation to prevent valgus ankle deformity, which is common when a tibial strut is used alone.

Level of evidence: IV.

**1. Introduction**

Transfer of a free vascularised fibular flap (FVFF) is an option for treating bone defects of 5 cm or more in children [1,2]. The FVFF technique was first developed by Taylor et al. in 1975 [3]. In paediatric patients, the FVFF is used chiefly for bone defects due to a tumour, infection, or trauma, although other indications include congenital pseudarthrosis of the tibia and avascular necrosis of the femoral head [1,2,4,5].

Few studies have focussed on FVFF harvesting in children [6,7]. Although the 82% to 100% healing rate obtained with the FVFF technique is higher compared to the rates seen with isolated allogeneic grafting or the induced membrane technique [5,8–11], a major drawback is graft harvesting from a healthy donor site.

The primary objective of this retrospective study was to assess clinical and radiological FVFF donor site morbidity in children, as well as any impact on residual growth, about which few data are available. The secondary objective was to identify predictors of valgus ankle deformity (VAD). Our working hypothesis for this study was that donor site morbidity, particularly VAD, was decreased by using a tibial strut to stabilise the distal fibula.

**2. Material and method**

2.1. Patients

This retrospective multicentre study was conducted by searching the databases of two paediatric orthopaedic surgery departments. We identified 63 fibula in 59 patients managed.
between May 1994 and December 2014 using the FVFF technique to fill bone defects. Inclusion criteria were FVFF transfer for any reason, open physes at the time of surgery, and follow-up of at least 2 years. These criteria led us to exclude girls older than 12 years and boys older than 14 years. In all, 28 patients were excluded, 22 based on age, 4 because of incomplete follow-up data, and 1 who was lost to follow-up. A female patient died due to the underlying disease and was excluded due to insufficient follow-up duration.

The remaining 31 patients (31 donor sites) were included. There were 20 boys and 11 girls, with a mean age at FVFF harvesting of 8.9 ± 3.6 years (range, 2–14 years) and a mean follow-up of 6.6 years (range, 2–21 years). The bone defects were due to malignant tumours in 25 patients, congenital pseudarthrosis of the tibia in 3 patients, and aneurysmal cysts in 3 patients.

2.2. Operative technique

The same harvesting technique was used in all 31 patients. Surgery was performed in a single stage with two surgical teams, one in charge of FVFF harvesting and microsurgical and the other of preparing the recipient site and achieving internal fixation.

The FVFF was taken from the leg contralateral to the reconstruction site, via the posterolateral approach described by Gilbert [12]. In 22 patients, a septal and cutaneous island was harvested also to allow monitoring of graft viability during the immediate postoperative period [13].

Stabilisation of the distal donor fibula was performed in 23 patients. As recommended by Gilbert [14,15], tibial struts were implanted in 12 (52.2%) of these patients. The other stabilisation methods were syndesmotic screw in 4 (17.4%) patients and combination of a tibial strut and syndesmotic screw in 7 (30.4%) patients. All tibial struts were harvested from the donor leg.

The donor leg was immobilised in a walking cast for 6 to 8 weeks.

3. Method

Follow-up was at least 2 years after the harvesting procedure to allow an assessment of early complications and any growth disturbances at the ankle. Antero-posterior and lateral weight-bearing radiographs of both legs were taken to evaluate proximal and distal tibial strut union and to measure the lateral distal tibial angle (LDTA) (Fig. 1). Significant VAD was defined as an at least 5° difference with the other side [7,16,17].

Proximal fibular migration was assessed as suggested by Macnicol and Catto [18] based on the distance between two parallel lines, one travelling through the tip of the medial malleolus and the other through the tip of the lateral malleolus. Proximal fibular migration was reflected by the change between two measurements of this distance at different points in time [19]. Limb length discrepancy was not considered in this study, because the underlying disorder often involved the lower limb. The age-residual fibula index (A-RFI) was computed as described by Nathan et al. as the sum of age in years and residual distal fibula length in centimetres [20]; 16 is the cut-off between low and high values. A-RFI values under 16 may predict VAD [20,21].

Each patient underwent a physical examination and radiological parameter measurement preoperatively then 45 days, 3 months, 6 months, and 1 year postoperatively and, finally, at last follow-up.

3.1. Statistical analysis

The data were analysed using Microsoft Excel® (Microsoft, Redmond, WA, USA) and BioStatGV® (free of charge at http://marne.u707.jussieu.fr/biostatgv/). Quantitative variables were compared using Student’s t-test and qualitative variables using Fisher’s exact test and linear regression. Values of \( P < 0.05 \) were considered significant. To identify independent predictors of significant VAD, we performed a multivariate analysis taking into account age at FVFF harvesting, residual distal fibula length, the sum of both (A-RFI), the percentage of total fibular length harvested, and the method used for distal fibular stabilisation (if any).

3.2. Ethical considerations

The study was conducted in compliance with recommendations of French ethics committees in charge of human clinical research and with the 1975 Declaration of Helsinki as revised in 2000.

4. Results

No intraoperative donor site complications were recorded. Mean harvested fibula length was 17.0 ± 4.5 cm (range, 11.0–26.4 cm), i.e., 56% of the total fibular length. Mean residual distal fibula length was 7.0 ± 2.2 cm (range, 3.2–11.3 cm), i.e., 22.2% of the total fibular length. Unsurprisingly, age correlated positively with residual distal fibula length (Fig. 2).

A total of 17 early complications occurred in 12 (38.7%) patients. They consisted of claw toe deformity (\( n = 4 \), 12.9%), delayed skin healing (\( n = 4 \), 12.9%), common fibular nerve impairment (\( n = 8 \), 25.5%), and ankle pain (\( n = 1 \), 3.2%). Among these early complications, 14 (82.4%) resolved fully, within a mean of 7.5 months. The persistent complications were hallux claw toe (\( n = 2 \)) and neurological impairment (\( n = 1 \)).

VAD developed in 6 (19.4%) patients. Among the patients whose distal fibula was stabilised by a tibial strut alone or with a syndesmotic screw, 9 developed nonunion, but only 1 (3.2%) required revision surgery to treat this complication.

No patient had residual knee laxity, deficient downstream vascular supply, superficial or deep surgical-site infection, or a haematoma at the donor site.

Revision surgery on the donor site was performed in 5 (16.1%) patients (Table 1). In 2 of these patients, the reason for revision surgery was residual VAD.
Fig. 2. Relation between age and residual distal fibular length (linear regression curve).

Fig. 3. Example of fibular reconstruction using a tricortical syndesmotic screw and a tibial strut: screw breakage and nonunion at the distal junction of the strut.

Table 1
Reasons for surgical revisions and types of procedures performed.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Reason for revision</th>
<th>Type of revision procedure</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Valgus/LDTA 59.5°</td>
<td>Supra-malleolar varus osteotomy</td>
<td>LDTA 82.6°</td>
</tr>
<tr>
<td>2</td>
<td>Valgus/LDTA 68°</td>
<td>Syndesmotic screw</td>
<td>LDTA 77.8°</td>
</tr>
<tr>
<td>3</td>
<td>Nonunion at both ends of the tibial strut</td>
<td>Autografts</td>
<td>Healing of both humeral autografts</td>
</tr>
<tr>
<td>4</td>
<td>Impaired skin healing</td>
<td>Fat tissue transfer</td>
<td>Good</td>
</tr>
<tr>
<td>5</td>
<td>Neurological complication</td>
<td>Release of the CFN, lengthening tenotomy of the hallucis longus</td>
<td>Poor: residual denervation of the CFN and TN</td>
</tr>
</tbody>
</table>

LDTA: lateral distal tibial angle; CFN: common fibular nerve; TN: tibial nerve.

4.1. Valgus ankle deformity (VAD)

Mean LDTA was 83.1° ± 7.2° (range, 59.5°–90.0°), with a mean 4.5° (range, 0°–28°) difference compared to the normal side. Mean LDTA on the normal side (87.9°) was significantly different from LDTA on the donor-site side (P<0.02). However, this difference was not greater than the 5° cut-off used in this study to define VAD.

In the 6 patients with VAD, mean LDTA was 73.6° ± 8.3° (range, 59.5°–82.0°) and showed a mean difference of 14.3° (range, 9°–28°) compared to the normal side. All 6 patients had proximal migration of the distal fibular physis and atrophy of the distal lateral tibial physis. Fibular reconstruction had been performed initially in these 6 patients, using a syndesmotic screw (n = 1), a tibial strut (n = 4), or both (n = 1).

A-RFI was under 16 [21] at 17 donor sites. However, A-RFI under 16 did not significantly predict VAD, although the association was of borderline significance (P < 0.058, Fisher’s exact test). Patients with VAD were not younger than patients without VAD (mean age, 6.3 years and 9.2 years, respectively; P < 0.09, Student’s t-test).

Residual distal fibula length considered alone did not significantly predict VAD (P < 0.09); the value was 5.4 cm (range, 3.8–8.6 cm) in the 6 patients with VAD and 7.1 cm (range, 3.2–11.3 cm) in the 25 patients without VAD.

4.2. Reconstruction of the fibula

Fibular reconstruction was performed in 23 patients, using a tibial strut (n = 12), a syndesmotic screw (n = 4), or both (n = 7). Age was not significantly different between the groups with and without fibular reconstruction (9.7 years and 11.2 years, respectively; P = 0.18, Student’s t-test).

Among the screws, 10 were tricortical and 1 was quadricortical. Of the 19 patients managed with a tibial strut alone or combined with a screw, only 10 (52.6%) achieved healing at both junctions. Nonunion developed in 2 patients at both junctions, at the proximal junction in 1 patient, and at the distal junction in 6 patients.
Screw breakage occurred in 3 patients. Among them, 2 had tibial strut nonunion (Fig. 3). The remaining patient developed VAD after fibular reconstruction using a screw alone.

LDTA values were not significantly different between the groups with and without fibular reconstruction (82.6° and 86.7°, respectively; *P*<0.3). Of the three reconstruction methods, none was superior over the others in preventing VAD (Fisher’s exact test) (Fig. 4). Isolated tibial strut nonunion was not associated with the development of VAD (*P*<0.63).

5. Discussion

This study used a retrospective two-centre design. A single patient was lost to follow-up. Nevertheless, the small sample size limits the statistical power of some of our analyses.

FVFF transfer in children was associated with a high rate of early complications. However, 82.4% of these resolved spontaneously within 7.5 months. Only 5 early complications required revision surgery.

Neurological complications are common, with rates of up to 26% and 30% in studies by Xijing et al. [22] and Lee et al. [23]. Permanent neurological impairments have been reported in 0 to 3.3% of cases [17,22], in keeping with the 3.2% (1/31) rate in our study.

Claw toe deformity is due to flap dissection with removal of a strip of flexor hallucis longus muscle. This complication occurred in 12.9% of our patients, compared to only 4.3% of 1270 donor sites studied by Gaskill et al. [24]. We have no explanation for this higher rate, which might warrant a change in our technique (e.g., minimising the amount of muscle removed).

No objective deficiencies in blood supply downstream from the donor site were found in our study, in keeping with reports by Xijing et al. [22] and Shan et al. [25]. The potential impact of fibular artery removal on residual distal segmental growth in children has not yet been fully evaluated.

The prevalence of VAD was 19.4% in our study. We found a strong but non-significant association between an A-RFI under 16 and VAD (*P*<0.058) [20,22]. Taken in isolation, neither age younger than 6 years nor residual distal fibula length predicted VAD. In contrast, Nathan et al. reported that, regardless of age, residual distal fibula length shorter than 6 cm was associated with the risk of VAD [21].

Thus, the risk factors for developing VAD are fairly well established and the A-RFI remains a good predictor that helps not only to inform the family, but also to identify patients requiring particularly close monitoring of this limb segment.

All 6 patients in our study who developed VAD had proximal fibular migration combined with atrophy of the lateral physis and distal tibial epiphysis. Saleh et al. [26] also reported proximal fibular migration after tibial lengthening. Park et al. stated that proximal fibular migration was associated with the development of VAD [27]. The proportion of the load borne by the fibula when the inter-osseous membrane is intact ranges from 6% to 17% [26,23]. However, the cause of VAD in children (3%–40%) remains unclear [17,20]. Wiltse stated that the development of VAD was related to shortness of the residual distal fibula, with loss of lateral support to the talus, which tilts in valgus due to the excessive loads through the lateral tibial epiphysis [28,29]. We agree with the vascular hypothesis put forward by Nathan et al. [20]: division of the fibular artery during graft harvesting may result in premature closure of the distal fibular physis with deficient growth of the distal...
fibula. In support of this possibility is our finding that all 6 patients with VAD in our study had an LDTA difference between the ankle on the donor side and the ‘healthy’ ankle, combined with atrophy of the lateral tibial physis and epiphysis. These abnormalities are consistent with a defective blood supply to the territory of the distal tibial artery. However, this mechanism remains hypothetical and needs to be confirmed by anatomical findings.

Given that VAD is widely reported, and despite the lack of agreement on the causative factors, many teams recommend implanting a distal tibio-fibular syndesmotic screw to protect the ankle joint [7,17,19,26]. A quadriradiocortical screw should be used, as a triradiocortical screw does not provide sufficient mechanical anchoring. Anchoring of the triradiocortical screw is confined to the lateral side and therefore results in proximal migration of the distal fibula, which results in valgus of the ankle [19]. Of the 11 syndesmotic screws used in our patients, only 1 was quadriradiocortical, and 3 broke. Nevertheless, these facts are not sufficient to explain the development of VAD in our study. Prophylactic tibio-fibular syndesmosis has been advocated in patients with a residual distal fibula length shorter than 7 cm [6,21] and in those who are younger than 9 years [30].

To stabilise the fibula, we mainly used the tibial strut method, which is the most widely recommended [14,30,31]. However, with tibial strut stabilisation alone, the prevalence of VAD was 33.3%, in keeping with a report by Fragnière et al. [7]. This finding invalidates our working hypothesis: none of the three fibular stabilisation methods used was effective in preventing VAD.

6. Conclusion

FVF transfer is an effective method for the reconstruction of large bone defects. Initial clinical donor site morbidity is substantial but resolves promptly without leaving any major residual abnormalities. VAD development is directly related to younger age and shortness of the residual distal fibula. Several hypotheses regarding the pathogenesis of VAD deserve to be investigated, such as a deficiency in the residual blood supply to the distal fibular physis. The prevention of VAD involves stabilisation of the distal fibula using a quadriradiocortical syndesmotic screw alone or combined with a tibial strut. However, neither method ensures complete protection against VAD.

Disclosure of interest

The authors declare that they have no competing interest.

References