VASCULARIZED FIBULAR GRAFT RECONSTRUCTION OF LARGE SKELETAL DEFECTS AFTER TUMOR RESECTION

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Limb-sparing resection of musculoskeletal tumors has been well-demonstrated to have similar oncologic outcomes to amputation. However, large skeletal defects which are the result of such resections remain a challenge to reconstruct in a way that preserves function of the limb. Current options include:

- Irradiation and replacement of the affected bone
- Massive osteochondral allograft
- Endoprosthetic reconstruction
- Vascularized bone autograft reconstruction

Patients with sarcomas, whether human or small animal, are often young and will subject their reconstructed limbs to high functional demands. For this reason, there is a premium on durability of reconstruction. Because endoprosthetic reconstructions are only as durable as the materials composing the endoprostheses, they are subject to mechanical failure as well as failure to integrate into host bone. Allograft and irradiated bone are not living tissue and therefore are slowly incorporated into the host skeleton by a process known as “creeping substitution” – a process of simultaneous osteoclastic and osteogenic activity. This gradual process weakens these grafts and renders them particularly susceptible to nonunion, fracture, and infection.

As biologically favorable alternatives to allograft reconstruction have evolved, reconstruction techniques using free vascularized bone have become well-described and well-established. Unlike cortical allograft and nonvascularized autograft, vascularized bone grafts do not depend on gradual revascularization. Of the multiple osseous donor sites, the free vascularized fibular graft (FVFG) has become the most commonly transferred vascular autograft for reconstructing large segmental bone defects. The process of microvascular free fibular transfer was first reported in 1975 by Taylor et al. who described two patients with limb-threatening lower extremity trauma. In 1977, Weiland et al. reported the first reconstruction of long bones with vascularized fibula after tumor resection.
Vascularized autografts, such as the FVFG retain their biologic and mechanical properties, heal by primary union, and can hypertrophy in response to load (Fig. 1).

Fig. 1A–B (A) A radiograph shows an AP projection of the humerus of a 15 year-old boy taken 9 years after FVFG reconstruction of the proximal diaphysis following resection of an osteosarcoma. (B) A lateral view of the same humerus is shown. Note that the fibula has hypertrophied to the approximate size of unresected portions of the distal diaphysis.

This capacity for hypertrophy in response to load after transfer to a new location is seen to greater extent with the fibula than with other bones. The fibula has a particularly robust blood supply with a large arborescent network of nutrient endosteal vessels and six to nine periosteal vessels. The dual nature of its blood supply (extensive endosteal and extensive periosteal networks) renders it amenable to transverse and longitudinal splitting if such modification is deemed necessary (e.g. recreating the angle of the mandible). Reconstructions using FVFG have
the potential for rapid union and are more resistant to infection in hostile environments than allografts. This offers the potential to minimize complications in patients whose underlying physiologic milieu may be compromised due to chemotherapy, immunosuppression, or radiation therapy.

In this presentation, we review some of the technical factors which have made FVFG reconstruction of large skeletal defects successful in humans:

- Careful harvest of the fibula to preserve the peroneal artery and the periosteum
- Availability of a donor artery and vein near the site of resection that can be divided and utilized for anastomosis with the graft.
- Careful choice of osteosynthesis (usually plate and screws) for fixation of the fibula to the ends of bone remaining after resection.
- Availability of either high-powered loupe magnification or an operating microscope and appropriate instruments for performing anastomosis of the graft peroneal artery and vein with

We also review the Duke University Medical Center experience which includes the largest series of FVFG used to reconstruct large oncologic skeletal defects. This series included 30 patients with a variety of musculoskeletal malignancies. The mean length of the reconstructed segment was 14.8 cm (range 7-22 cm). Limb salvage succeeded in 29 of 30 patients (97%). However, complications were common with an overall complication rate of 53% (16 of 30 patients) and a reoperation rate of 40% (12 of 30 patients). The most common complications (shown below in Table 3) were nonunion of the graft (23%), fracture of the graft as shown in Fig. 2 (20%), and infection (10%).

Table 3. Summary of complications

<table>
<thead>
<tr>
<th>Complication</th>
<th>% of complications</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flap loss</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nonunion</td>
<td>23</td>
<td>7</td>
</tr>
<tr>
<td>Fracture</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Posttraumatic fracture</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Stress fracture</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Infection</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Total patients with complication</td>
<td>53</td>
<td>16</td>
</tr>
<tr>
<td>Total patients requiring reoperation</td>
<td>40</td>
<td>12</td>
</tr>
</tbody>
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Fig. 2A–F Fractures of the fibular graft occurred in six of thirty patients (20%). Three fractures occurred after trauma. Four of the six fractures were in patients with plate osteosynthesis of the graft. These radiographs show the arm of a 10 year-old boy who underwent FVFG reconstruction of a proximal humeral defect after resection of an osteosarcoma. (A) The incorporated graft is seen 6 months postoperatively. (B) Lateral and (C) AP views show a fracture through the grafted fibula at the most proximal screw 10 months postoperatively after a fall. (D) AP and (E) lateral views show a healed fracture after 6 months of nonoperative management. (F) A radiograph shows the appearance of the humerus 3 years after the index procedure and almost 2 years after the fracture occurred.

In summary, we conclude that FVFG in humans can be performed successfully, albeit with a high rate of complication and reoperation. However, the result is a living, biological reconstruction which will hypertrophy to match the size of the bone it is replacing and which is more resistant to infection and fracture than irradiated non-vascularized autograft or allograft. This technique should be explored as a reconstructive technique in canine patients with musculoskeletal malignancies. It will require the technical capabilities outlined above, commitment on the part of the owner, and, of course, the right patient to be considered for limb salvage.