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Massive Bone Defects of the Upper Limb: Reconstruction by Vascularized Bone Transfer

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The use of free microvascular bone segment transfer has become an accepted and, in many instances, the preferred technique for reconstructing massive defects of bone. This is true in either the upper or lower limb. The advantages of this technique are thought to be more rapid bone union, more rapid bone hypertrophy, and fewer instances of late stress fracture because of osteolysis. In addition, some authors suggest that free bone grafts may be used under adverse surgical conditions including a septic field or in an irradiated field. The disadvantages of this technique are that microvascular bone transfer is a technically demanding procedure and requires a donor site that may result in some degree of morbidity. This article will focus on the indications and technique of microvascular bone transfers in the upper limb, with illustrative case examples.

History

The suggestion of at least partial sustained viability of cellular elements within bone segments transferred with an intact soft tissue vascular pedicle dates to at least a century ago. Huntington [1] in 1905 described the successful healing of a large tibial defect by a pedicled shift of the ipsilateral fibula. Bone segments based on an intact vascularized soft tissue pedicle lacked any widespread clinical application, however, because they were limited by the arc of rotation of the donor bone segment. It was not until the clinical feasibility of microvascular anastomosis was demonstrated in the early 1960s that the concept of free vascularized bone grafting emerged. The earliest experimental work using a rib as the model was by McCulloch and Fredrickson in 1973 [2]. This was followed by the more comprehensive work of Östrup and Fredrickson [3]. Several investigators subsequently confirmed earlier findings of at least partial preservation of intraosseous cellular elements, a mechanism of bone union more similar to fracture union than nonvascularized bone graft incorporation and more rapid bone remodeling [4–10]. Even today, however, there remains a controversy about what the most important advantage of a microvascular bone transfer is—whether it is retained intraosseous cellular viability or whether it is the immediate reestablishment of intraosseous blood flow that permits immediate re-seeding of the bone segment with osteoprogenitor cells.

Clinical applications of microvascular bone transfer have been reported over the past 3 decades. For long bone reconstruction, the fibula is clearly the preferred donor site. Taylor and colleagues [11] is credited with the first report of a successful fibula transfer in 1975. However, Ueba and Fuyikawa [12] reported in 1983 what seems to be the first actual successful clinical application. Regardless of who was the first to carry out free fibular transfer, in the past 20 years, numerous large series have been reported that have confirmed the value of this technique for reconstructing massive bone defects [13–27]. The authors' personal series, reported by Han and colleagues [16], resulted in an overall primary union rate of 61%, a secondary union rate of

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81%, with the best results occurring in nonseptic reconstructions with a union rate of 84%.

Upper limb bone defect—indications for vascularized bone transfer

In general, most authors suggest that the strongest indications for the use of vascularized bone graft include situations that are prone to failure or complications with technically less demanding techniques such as nonvascularized bone autografts or allografts. These situations include massive defects and/or an unfavorable surrounding soft tissue milieu related to prior failure of conventional bone grafting failure, infection, radiation, or other causes of extensive scarring.

Specific indications

1. Recipient site considerations. In the upper limb, reconstruction of the humerus probably represents the most compelling indication for the use of vascularized fibula transfer. This is because, other than massive allografts, there are few techniques available to reconstruct a large missing segment of the humeral shaft. Although large defects of the radius and ulna may also be excellent indications for reconstruction by vascularized bone transfer, the option of forearm salvage by a one-bone forearm conversion always merits consideration (Fig. 1) [28]. Moreover, more limited defects of the proximal radius or distal ulna may be consistent with an acceptable level of upper limb function.
2. Large bone defects. The precise length of a bony defect that would lead one to select a vascularized bone graft for reconstruction is not particularly well established. Many authors [6,11,14,17,19,20,22,24,27] have suggested that a 6-cm gap is the point where vascularized bone reconstruction should be chosen in place of a nonvascularized autograft. However, it is important to recognize that with sufficient mechanical protection over several months, and when dealing with a well-vascularized surrounding soft tissue milieu, bone defects exceeding 10 cm may be healed with cancellous autograft [29] or nonvascularized cortical bone segments [30]. Moreover, massive allografts may be a suitable option for reconstructing very lengthy defects [31,32]. However, it should be recognized that massive allografts have limited ability to be revascularized and hence a limited capacity to be replaced by "creeping substitution" of host osteoprogenitor cells [33]. In general, the authors believe that a defect as short as 6 cm in the presence of a poor surrounding soft tissue bed and for all defects greater than 10 cm, the selection of vascularized bone transfer for reconstitution is justifiable.
3. Prior bone reconstruction failures. Bone defects in the upper limb, without regard to length, that have failed to heal with nonvascularized autograft may be candidates for a vascularized bone graft. This is particularly the case when there is no readily apparent explanation for the initial failure (ie, inadequate bone graft material, inadequate stabilization, use of allograft or xenograft, and so forth).
4. Infected bone defects. The use of vascularized bone grafts for reconstructing infected bone defects is particularly attractive for a number of reasons. Probably of most importance is that such bone grafts are inherently a vehicle for local blood supply [13,25]. However, also of importance is that a vascularized fibula is a generous source of bone length and it makes little difference from the technical perspective if one transfers a 6- or 16-cm graft segment. Thus, a more aggressive debridement of infected bone ends may be performed with less regard to

Fig. 1. Radiograph depicting one-bone forearm construct for proximal radius defect.