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Use of giant-sized flow-through venous flap for simultaneous reconstruction of dual or multiple major arteries in salvage therapy for complex upper limb traumatic injury

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ABSTRACT

Background/Objectives: Salvage repair after complex upper limb traumatic injury is surgically challenging due to underlying major arterial impairment with complicating a large-sized soft tissue defect. The purpose of this study was to evaluate the effectiveness and safety of using a giant-sized ($\geq$100 cm^2) flow-through venous flap for reconstruction of dual or multiple forearm, metacarpal, or digital arteries after complex upper limb traumatic injury.

Methods: Seven patients were consecutively hospitalized for emergency salvage repair after complex upper limb traumatic injury between March 2012 and May 2014. The forearm and palmar artery defects were repaired using the calf great saphenous vein flap and the volar forearm venous flap, respectively.

Results: The flow-through venous flap ranged from 9.5 cm $\times$ 12.0 cm to 12.0 cm $\times$ 20.0 cm (mean, 158.4 cm^2) in size. The flaps and affected limbs survived uneventfully in five patients, with one patient experiencing distal flap marginal necrosis and a second patient requiring amputation of the affected limb. Computed tomography angiography showed patent vessels in all patients. The mean total active motion of the repaired fingers was 199.5° *versus* 258.8° for the contralateral counterpart (77.1%). The sensory return was determined to be S2 in 2 patients, S3 in 3 patients and S3+ in 1 patient. The disability scores for the arm, shoulder, and hand ranged from 4.6–18.2 (mean, 11.3), and the mean Michigan hand outcomes questionnaire score was 7.8 $\pm$ 0.9.

Conclusions: The flow-through venous flap is an effective and safe treatment alternative for salvage therapy of a $\geq$100-cm^2 complex upper limb traumatic injury with dual or multiple major arterial impairment. This technique allows simultaneous reconstruction of dual or multiple artery injuries and an extensive soft tissue defect. Serious surgical site infection remains a major safety concern and necessitates radical debridement in complicating cases.

Introduction

Complex upper limb traumatic injury normally manifests as an extensive soft tissue defect with complicating vascular impairment and destruction of major motor-sensory units, such as nerve, tendon, and bone [1]. This complex defect often results from a high-energy crushing and/or rolling injury and may require amputation of the affected limb in serious cases, which has a significant negative effect on patients' physical and sociopsychological wellbeing. Repair of soft tissue and vascular defects is essential to salvage the affected limb in these patients. A two-staged procedure is usually used, namely, vascular reconstruction followed by wound resurfacing using a free or pedicled skin flap; however, this technique is associated with risks for vascular insufficiency, local infection, and donor site morbidity [2].

Flow-through flap refers to a free flap with the vascular pedicle anastomosed to both the proximal and distal ends for perfusion of the distal tissue, such as a radial forearm flap bridging the external carotid and distal facial arteries [3]. Foucher et al. [4] reported the first case of complex limb reconstruction using a radial forearm flow-through flap. Costa et al. [5] resurfaced and revascularzied major hand and foot

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trauma using a radial mid-forearm fasciocutaneous flap with an uninterrupted arterial and venous flow at a single stage. This technique allows simultaneous repair of soft tissue and vascular defects as a breakthrough treatment modality for reconstruction of a soft tissue defect with complicating segmental vascular injury [6,7]. Common donor sites include a radial forearm flap, anteromedial femoral flap, and thoracodorsal flap, depending on the wound size [8–10]. Major limitations of these flaps include excessive donor site injury for resurfacing a large-sized wound, flap unavailability due to vascular anatomic variation, and insufficiency for repairing a long artery defect [11]. It is clinically more important that a flow-through flap cannot be used for reconstruction of more than one major vessel, such as concomitant radial and ulnar artery injuries as well as complex injuries of metacarpal and common digital arteries.

In 2012, Rozen et al. [12] modified the arterialized saphenous vein flow-through flap by incorporating dual venous drainage for successful repair of a large segmental axial artery defect. We further modified this technique by anastomosing more than one artery using a giant-sized ($\geq$100 cm^2) flow-through venous flap for reconstruction of dual or multiple forearm, metacarpal, and digital arteries. The purpose of this study was to evaluate the effectiveness and safety of using a giant-sized ($\geq$100 cm^2) flow-through venous flap for reconstruction of dual or multiple forearm, metacarpal, or digital arteries after complex upper limb traumatic injury.

Patients and Methods

Patients

The study protocol was approved by the Institutional Review Board of Xuzhou Renci Hospital. Between March 2012 and May 2014, seven patients with a complex upper limb traumatic injury were consecutively hospitalized for emergency repair using a giant-sized ($\geq$100 cm^2) flow-through venous flap. The inclusion criteria were as follows: traumatic upper limb injury with complicating large-size soft tissue defect and segmental loss of major arteries, including radial, ulnar, metacarpal, and common digital arteries. The exclusion criteria were as follows: a mangled upper limb; unrepairable vessels; serious wound contamination or infection; and a complicating serious medical condition. All patients or their legal representatives voluntarily provided informed consent prior to patients' participation in this study.

Surgical technique

The patient was positioned supine with the blood flow of the affected limb interrupted using a pneumatic tourniquet. Under general anesthesia, radical debridement was performed (Figure 1a) prior to reduction and fixation of the bone fracture. The tendons were repaired using Kessler sutures. The skin and vascular defects were measured for outlining of the donor site. The forearm and palmar artery defects were repaired using the calf great saphenous vein flap (n = 3) and the volar forearm venous flap (n = 4), respectively. The flaps were further outlined, in accordance with the number, length, and anatomic profile of the arterial defects, after interrupting the donor site venous backflow. A 10% oversized flap was harvested by sharp dissection from the deep fascia, including at least more than one vein at either the proximal or distal end along with as many subcutaneous veins as possible. The flap venous main trunks were anastomosed with the debrided arteries at the recipient site, whereas the flap subcutaneous veins were anastomosed with the subcutaneous veins of the wound (Figure 1b). The nerves were repaired using flap cutaneous nerves

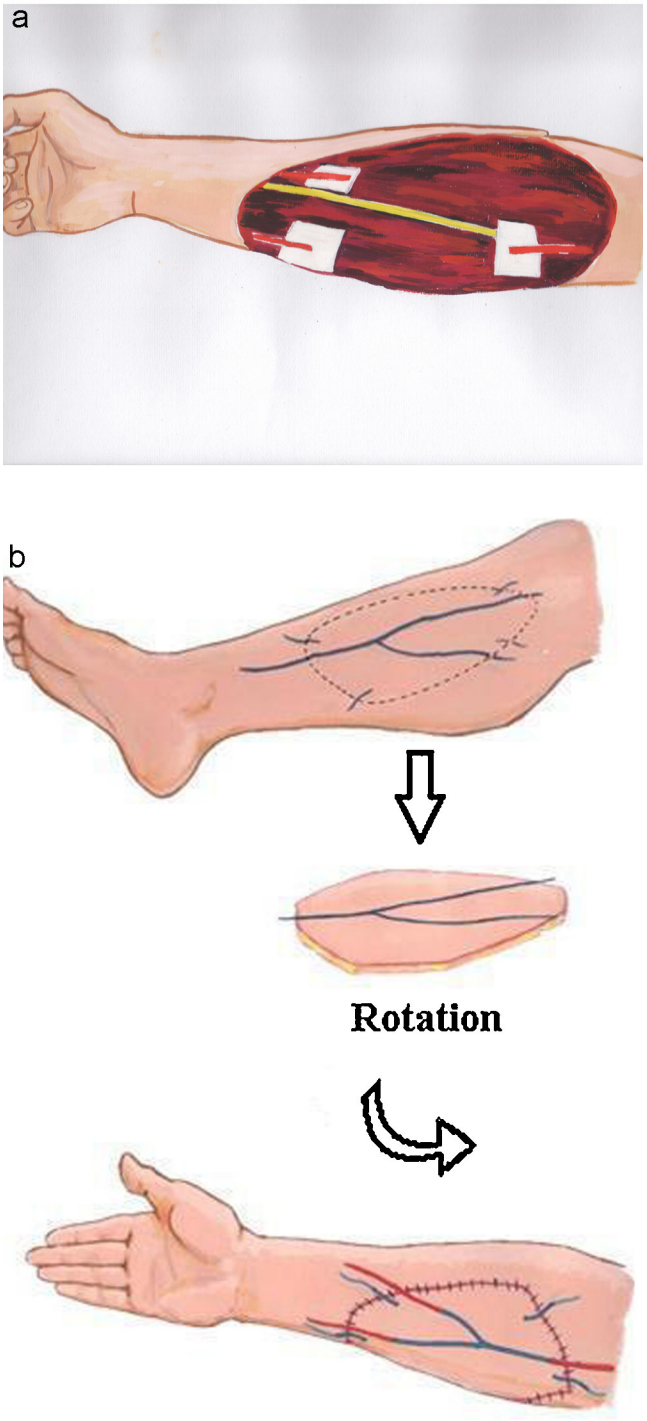

Figure 1. Schematic of the operative procedure: (A) complex forearm soft tissue defect with complicating long-segment loss of ulnar and radial arteries; (B) outlining of the medial calf great saphenous vein flap; the distal end of the great saphenous vein was anastomosed to the distal stump of the brachial artery and the distal branches were anastomosed to the ulnar and radial arteries, with the flap subcutaneous veins anastomosed with the subcutaneous veins in the recipient site.

(n = 3) or a sural nerve graft (n = 2). The donor site was resurfaced using a free full-thickness abdominal flap.

Postoperative care and follow-up

The repaired limb was elevated and kept warm after the operation, and prophylactic antimicrobial and anticoagulant