Use of the Facial Artery for Free Functioning Muscle Transfers: An Alternative Pedicle for Salvage in Brachial Plexus Lesions with Vascular Injuries

Anil Bhatia[1]   Kaustubh Prabhune[2]   Alex De Carvalho[3]

[1]Department of Brachial Plexus Surgery, Deenanath Mangeshkar Hospital, Kothrud, Pune, India
[2]Department of Plastic Surgery, Deenanath Mangeshkar Hospital, Kothrud, Pune, India.
[3]Department of Plastic Surgery, Hospital of the Federal University of Sergipe, Sergipe, Brazil

Address for correspondence Anil Bhatia, MS, Deenanath Mangeshkar Hospital, Kothrud, Pune, 411004, India
(e-mail: agbhatia63@gmail.com).

Abstract

Free functional muscle transfer (FFMT) is a salvage procedure recommended in cases of brachial plexus injury with late presentations or failures of primary nerve reconstruction. The workhorse for most authors is the gracilis, and the most common indication is the restoration of elbow flexion. For successful revascularization of the muscle, donor vessels must be in proximity of the site of the muscle fixation and allow direct coaptation to a donor nerve, ideally without the use of nerve grafts. A major problem occurs when patients have sustained concomitant vascular injuries to the subclavian and/or axillary arteries and had previous surgical dissections in the area where the most common vascular pedicles are located. The authors report the use of the rerouted facial vessels as donors in these complex cases. The surgical technique is presented, along with three cases where the procedure was used. The flaps survived in all the patients and grade > 3/5 muscle contraction was observed in the two patients who had adequate follow-up. Conclusion: the use of the facial vessels as donor vessels is an option to revascularize a FFMT in the setting of severe vascular injury to the subclavian and axillary arteries.

Keywords
► free functional muscle transfer
► brachial plexus
► gracilis
► elbow flexion
► facial artery

Introduction

Nerve reconstruction in extensive brachial plexus injuries is a challenge as the roots are often completely avulsed.[1-3] In such instances, the spinal accessory, and phrenic and intercostals nerves are frequently utilized to restore important functions about the shoulder (rotator cuff) and the elbow (biceps).[4,5] The outcomes of such procedures depend on two main factors–the age of the patient and the delay since the accident.[4,6] There is a general agreement that nerve transfers should not be attempted in patients presenting beyond 12 months from the injury.[6,7] In such cases, most authors prefer to utilize the available nerve donors to innervate free functioning muscle transfers (FFMT).[6,7]

Such salvage operations demand the availability of an intact vascular pedicle adjacent to the area where the muscle will be inserted for proper revascularization of the transferred muscle. The motor branch to the muscle must also reach the available donor nerve such as the spinal accessory, and phrenic and intercostals nerves.[8,9] The thoracoacromial and the thoracodorsal vessels are the most commonly utilized donor vessels.[8-10]

However, these pedicles are difficult to dissect if the patient has scars from previous operations over the deltopectoral and axillary regions. In addition, such patients have in many instances suffered vascular injuries at the subclavian or axillary levels in the original accident.[11-16] Narakas[1] reported an incidence of approximately 20% of subclavian injuries among patients with supraclavicular injuries with root avulsion and an incidence of approximately 40% of lesion to the axillary artery in infraclavicular lesions. Arterial injuries associated with brachial plexus often go unnoticed

and, thus, a high-index of suspicion is required for the diagnosis.[13,16] Collateral circulation maintains the vascularity of the paralyzed upper limb, and distal ischemia is rare even with complete obstruction of these arteries.[13,16,17] Yet, in our opinion, the flow to the branches distal to the level of the arterial block may be inadequate or unreliable to sustain a free muscle transfer.

These pitfalls associated with salvage operations made us look for an alternate pedicle that could be relied upon. We noted that, even in cases of vascular injuries at a very proximal level, the common carotid artery and its branches were not affected. Thus, the terminal branches of the external carotid artery (ECA) could serve as potential pedicles. Drawing on the experience with microvascular flap reconstruction for head and neck malignancies, where the facial artery is commonly used as a donor vessel, we describe a technique that allows for those vessels to revascularize a free functional muscle flap used in order to restore elbow flexion. The purpose of this article is to describe the technique and present three cases where it was used. Approval from the institutional review board was obtained to conduct the present study. The British Medical Research Council (BMRC) scale was used to evaluate muscle strength.[18]

Surgical Technique

The procedure was performed by the senior authors in all the cases (A.B. and K.P.).

The access to the facial vessels was obtained through a standard transverse incision parallel to and below the mandible (►Figs. 1a, 1b, 1c, 2a, 2b). The superior edge was raised as a skin and platysma flap to expose the mandible and the insertion of the masseter. The facial vessels could be easily isolated at the anterior border of the masseter. As the vessels were traced proximally, branches to the adjacent structures were clipped and divided. The submandibular salivary gland was retracted. The tendon of the digastric muscle was divided and the hypoglossal nerve was carefully protected. The artery was freed up to its origin from the ECA. Similarly,

the accompanying vein was protected. The vessels were divided distally and delivered to the pivot point (origin of the vessel at the ECA. They could, then, be turned to the posterior triangle (deep to or superficial to the sternocleidomastoid [SCM] muscle) (►Fig. 1b).

In the meanwhile, a second team harvested the gracilis muscle flap, utilizing the standard technique.[19]

The proximal part of the gracilis muscle was sutured to the bellies of the SCM and trapezius at the apex of the posterior triangle (►Fig. 2a). The muscle was placed anterior to the clavicle and over the deltopectoral region. In the arm, the muscle was passed anteriorly to the biceps in the subcutaneous plane to reach the biceps tendon at the elbow. The tendon could reach the biceps easily.

A skin island may be included while harvesting the muscle to facilitate closure of the neck wound and to monitor the flap.

Reinnervation of the muscle could be achieved using either the spinal accessory nerve or the phrenic nerve. End-to-end vascular anastomosis were performed in the facial artery and vein and/or to a vein found in the vicinity (►Fig. 2b).

This technique was modified in the last case (►Fig. 1c). In this patient, the facial artery and vein were traced up to the ECA and internal jugular vein, respectively. The ECA was then ligated superiorly to the emergence of the facial artery and dissected until the bifurcation of the external and internal carotid arteries. Thus, an arterial pedicle of sufficient length was achieved, so that the end of the vessel could be passed between the SCM and the internal jugular vein and brought to the level of the clavicle. The gracilis muscle was inserted in the clavicle and end-to-end anastomosis were performed to the facial artery and local vein(s).

Case 1

A 50-year-old man was operated for a right-sided C567 brachial plexus injury at 2 months after the accident. No useful root was found and nerve transfers were performed to attempt reinnervation of the supraspinatus (spinal accessory
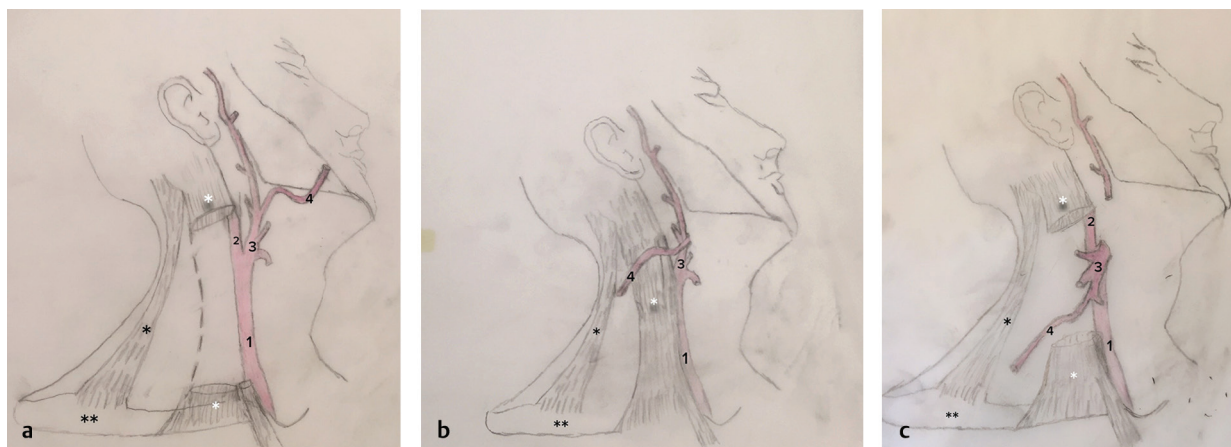

Fig. 1 (**a**) Drawing of the posterior neck triangle, depicting the common carotid (1), internal carotid (2), external carotid (3), and facial (4) arteries. Single black asterisk: trapezius; single white asterisk: SCM; double black asterisk: clavicle. The central part of the SCM muscle was removed to demonstrate the carotid artery. (**b**) The facial artery was dissected from the origin in the external carotid up to the masseter, ligated distally, and turned inferior and posteriorly to reach the posterior neck triangle. (**c**) The facial artery was dissected until the bifurcation of the external and internal carotid arteries, ECA was ligated superiorly to the facial artery, and the vessels turned inferior, posteriorly reaching the proximity of the clavicle. Abbreviation: ECA, external carotid artery; SCM, sternocleidomastoid.
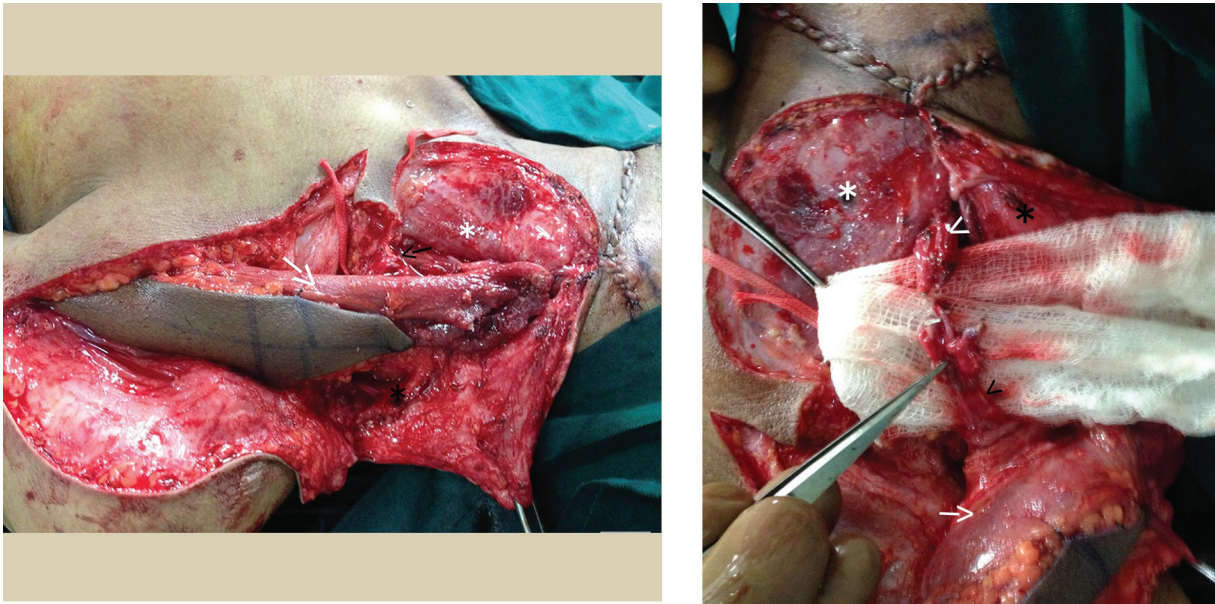
Fig. 2 (**a**) Picture 2a and 2b are from a case not included in this series and were used to illustrate the technique. The facial vessels (white arrowhead) were dissected and brought to the posterior neck triangle, where it was anastomosed to the vascular pedicle of the gracilis (black arrowhead). White asterisk: ECM; black asterisk: trapezius; white arrow, gracilis muscle flap. (**b**) Gracilis muscle flap sutured to the trapezius and ECM at the apex of the posterior triangle. Vascular anastomosis (black arrow).

to the suprascapular nerve), biceps and brachialis (using fascicles of the ulnar and median nerves to the respective branches of the musculocutaneous nerve), pectoralis major and triceps (intercostals 3, 4, and 5). At a year from the operation, weak function was noted in the supraspinatus while the biceps remained paralyzed. At this stage, only a free muscle transfer could be offered as a salvage procedure (Steindler's flexorplasty was not considered as the hand function was incomplete and the shoulder was unstable). We decided to reuse the spinal accessory nerve by sacrifice of the feeble supraspinatus function regained from the earlier operation. The shoulder was fused with the patient in the lateral position (with transfixing cancellous screws across the glenohumeral joint and neutralization using a contoured dynamic compression plate applied to the spine of the scapula and the shaft of the humerus). Then, the patient was turned supine. Exploration of the deltopectoral region revealed that the thoracoacromial vessels were not suitable for anastomoses (the

first operation had included a dissection of the infraclavicular plexus). The transverse cervical vessels were evaluated and were found to have poor flow (indicating a lesion of the subclavian artery at a proximal level). Thus, it was decided to use the facial vessels. These were harvested as described above and brought to the posterior triangle. The left gracilis muscle was harvested without a skin island. The muscle was anchored to the trapezius and the tendon was sutured to the biceps tendon and the lacertus fibrosus. The facial artery and its accompanying vein were used to vascularize the transferred muscle. The spinal accessory nerve was identified at its exit from the SCM muscle and divided distally for transfer to the motor nerve of the gracilis. The flap was covered with a split skin graft.

The wound healed uneventfully. The patient had regained elbow flexion (grade 4/5) at the last follow-up at 3 years from the operation. Data from the reported cases are summarized in ►**Table 1**.

Table 1 Summary of demographic and surgical data of the three cases presented

Case	Age	Sex	Side	Total/partial palsy	Primary surgery/ revision	Recipient vessels	Associated procedure	Nerve
1	50	M	Right	Partial	Revision	Facial vessels at sternomastoid	Shoulder fusion	Reuse of spinal accessory
2.	24	M	Right	Partial	First operation (3 years from accident)	Facial vessels at sternomastoid + external jugular vein	None	Spinal accessory nerve
3.	26	M	Left	Total	Primary nerve operation	Facial artery at clavicle, external jugular and cephalic veins	None	Spinal accessory nerve

Case 2

A 24-year-old male presented to the office 3 years after a right C5–C7 brachial plexus injury sustained in a motorcycle accident. Physical examination revealed: trapezius 5/5, serratus anterior 0/5, spinati 0/5, deltoid 0/5, pectoralis major ⅗, biceps ⅔, triceps ⅘, brachioradialis 0/5, extensor carpi radialis longus and brevis 0/5. The remaining radial innervated muscles were normal. Function in the ulnar and median innervated muscles (apart from flexor carpi radialis that was 0/5) were retained. The right radial pulse was considered normal, but computed tomography (CT) angiography revealed an obstruction of the subclavian artery.

The recommendation was a FFMT to augment elbow flexion, and another operation for shoulder fusion.

Since the patient had a major arterial injury, we opted to use the facial vessels as donors. They were turned at the ECA and brought to the posterior triangle superficial to the SCM muscle. The muscle (harvested without a skin paddle) was anchored to the sternomastoid and edges of the trapezius at the apex of the posterior triangle. It was passed anterior to the clavicle and pectoralis major and the tendon was woven to the biceps tendon at the elbow. The artery was anastomosed to the facial artery, and the veins were anastomosed to the facial vein and external jugular vein. The spinal accessory nerve was divided distal to the branches to the upper trapezius and transferred to the nerve to the gracilis.

The flap survived and the wound healed without complications. At his last follow-up 13 months after surgery, he had grade ⅗ flexion of the elbow. (►Fig. 3; ►Video 1)

Case 3

A 26 year-old-male presented at 6 months following a motorcycle accident with a complete paralysis of the left upper limb. Associated injuries included a left humerus fracture which was treated with surgical fixation. In addition, he had suffered an injury to the left axillary artery. The artery was explored primarily and reconstructed using a vein graft from the great saphenous vein. An osteotomy of the clavicle had been performed at that time to facilitate the dissection and repair. The clavicle had been stabilized with a plate and screws. Clinical examination at 6 months showed a flail left upper limb with preserved trapezius function and absent serratus anterior function. The Horner sign was positive. There were scars of surgery over the left clavicle and deltopectoral region as well as over the posterior aspect of the left arm. The left radial pulse was felt but was feeble. Surgical exploration of the left brachial plexus was recommended but the patient did not follow through. He presented to the office again only 9.5 months after the injury. In view of the delay from the accident, nerve reconstruction was not considered feasible and a FFMT was recommended. CT angiography showed complete obstruction of the left axillary artery.

In this complex case, we decided to use the facial vessels as donors and opted to use the variation of the technique described above. The facial vessels were isolated anterior to the masseter and divided distally. The branches

Fig. 3 Bulge in the lateral aspect of the neck noticed during contraction of the gracilis muscle.

Video 1

Video 1 Functional result of Case 2, demonstrating good elbow flexion 3/5. Online content
including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0040-1708587.

were carefully divided, and the artery was traced along the submandibular salivary gland till its origin from the ECA. The carotid sheath was opened, and the ECA was traced to the bifurcation of the common carotid artery. The ECA was clipped distal to the origin of the facial artery and the ECA and the facial artery were turned distally and passed between the sternomastoid muscle and the internal jugular vein to reach the clavicle. The gracilis was harvested and anchored proximally in the clavicle with trans-osseous sutures and distally to the lacertus fibrosus. The motor nerve was sutured to the spinal accessory nerve, artery to the facial artery, and vein to the external jugular vein (►Fig. 4).

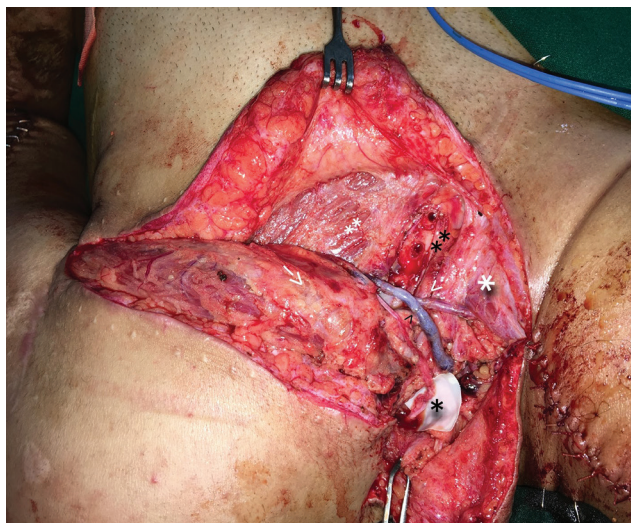The flap survived and the wound healed without problems. This patient, however, developed a neuropraxia of

Fig. 4 Case 3. This patient underwent the technique demonstrated in **Fig. 1c**. The facial artery reached just above the clavicle (double black asterisk) where it was anastomosed to the gracilis artery (white arrowhead). The gracilis vein was anastomosed to the external jugular vein (black arrowhead). The gracilis motor nerve was sutured to the spinal accessory nerve (black asterisk). White asterisk: ECM; double white asterisk: pectoralis muscle.

the mandibular marginal branch, which caused a sag in the corner of the mouth. This complication resolved within a month. He was last seen at 2 months from the operation.

Discussion

Late presentation of patients with brachial plexus injuries is still seen despite efforts to increase awareness about the need for early surgery.[7,20] In such patients, an elaborate surgical strategy is not warranted as considerable time has already been lost.[20,21] Restoration of the elbow flexion is the main goal for control of the paralyzed upper limb.[7,22-24] In our practice, we prefer to transfer the gracilis muscle for elbow flexion. The technique is well-described in the literature.[19,25] We anchor the muscle to the clavicle and suture the tendon to the biceps tendon and lacertus fibrosus. The thoracoacromial pedicle (along with the cephalic vein) are the preferred vessels to revascularize the flap. The spinal accessory nerve is divided distal to the branches of the upper trapezius and transferred to the motor nerve of the gracilis anterior to the clavicle. Alternatively, we may utilize the thoracodorsal vessels or the transverse cervical vessels as the donor pedicle. The intercostals or the phrenic nerve can be used if the spinal accessory nerve is not available or has already been utilized in previous reconstructions.

This plan is derailed in the presence of a lesion of the subclavian artery and/or a previous dissection in the deltopectoral area and axilla when those vessels may have been injured or rendered heavily scarred.

According to the literature, collateral circulation develops in the setting of complete obstruction of either the subclavian or axillary arteries due to the extensive communication between these two vessels. So, limb ischemia is a rare occurrence.[13,16,17]

Hattori et al[8] investigated the pattern of collateral circulation that developed after subclavian or axillary artery obstruction and the potential vessels for free muscle transfer reconstruction in 20 patients. They found that the suprascapular artery was the major stem artery for collateral circulation, and the circumflex scapular and subscapular arteries were major reentry arteries. All their patients had patent thoracodorsal and thoracoacromial arteries.

They reported the successful use of the free double muscular transfer technique using those vessels in three patients.

Nevertheless, disrupting vessels that might form a part of the collateral circulation that sustains the blood supply to the distal portion of the upper limb, particularly in patients who have undergone previous brachial plexus exploration, is a potential concern.

Most case series of FFMT include late presentation cases or cases in which patients had failed nerve reconstruction, but with intact subclavian and axillary arteries.[11,22-28] Hattori et al [8] reported on FFMT in three patients with subclavian injury, but who had intact thoracodorsal and thoracoacromial arteries and had not undergone any previous nerve reconstruction. Bertelli[29] and Chin et al[30] presented series of patients with partial brachial plexus injuries in which the gracilis was reversed, so that its motor branch could be innervated by motor branches of the median or ulnar nerve in the distal aspect of the arm, and revascularized by the radial artery and cephalic vein, with good results. Although none of the authors reported the use of the technique in patients with proximal vascular injury, the procedure could be used in those instances, if the radial artery has good blood flow through collateral circulation and the hand function permitted the use of median/ulnar fascicles as donor nerves.

The cases presented here are particularly challenging since all of them had sustained severe vascular injuries and two of them had already undergone surgical dissections in the area where the usual vascular pedicles for a FFMT are located (►**Fig. 5**).

Our technique offers an alternative pedicle to revascularize a free muscle transfer since the integrity of the carotid artery and its branches can be relied upon. In addition, the facial vessels have similar caliber to the vessels of the gracilis and are extensively used as donors for functional gracilis muscle transfer in facial reanimation.[31,32] Thus, the facial vessels provide a safe and secure escape route in these difficult situations.

The short length of the gracilis vascular pedicle imposes a proximal anchorage of the muscle to enable direct approximation to the rerouted facial vessels. Traditionally, FFMTs are anchored proximally to the clavicle and distally to the biceps tendon (for restoration of elbow flexion). Suturing the muscle to muscle bellies raised doubts about the strength of the proximal anchorage. However, the alternative would have involved interposition of a vein graft for the artery with an additional risk of failure of the procedure.[33] So, we chose to suture the gracilis muscle to the bellies of the SCM and trapezius at the apex of the posterior triangle of the neck. This insertion point was used in the first two patients (►**Fig. 2b**). However, the resultant bulge observed in the neck, when the gracilis contracted, was aesthetically unappealing (►**Fig. 3**).
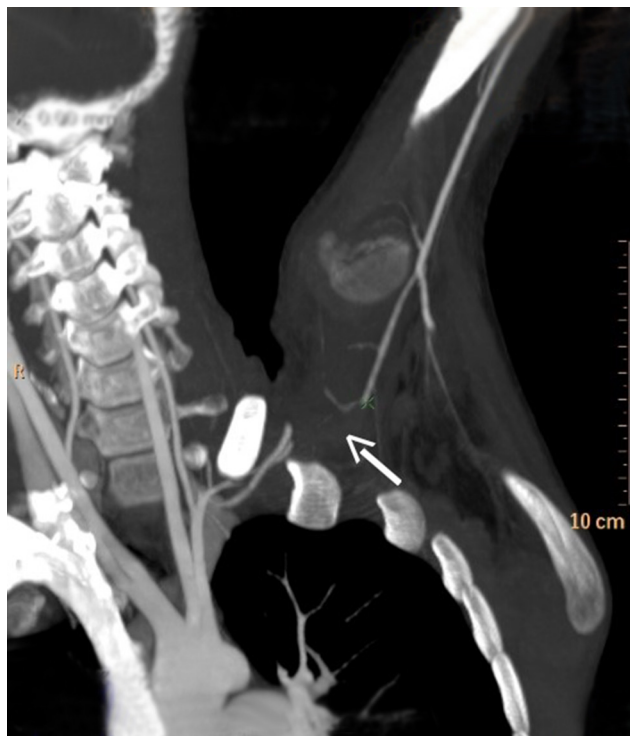
Fig. 5 CT angiogram of a patient with obstruction of the subclavian and axillary artery (white arrow). There is no visualization of the thoracoacromial and thoracodorsal arteries or any other suitable branch for microvascular anastomosis.

The authors felt the need to improve the cosmesis by placing the gracilis origin at the clavicle. This necessitated a more distal dissection of the facial artery and a proximal pivot point at the bifurcation of the common carotid artery. In this endeavor, retraction of the marginal mandibular branch of the facial nerve produced a temporary weakness that resolved in a month. This technique was used in Case 3.

In conclusion, although this is a small series of cases, the survival of the flaps attests to the reliability of the facial vessels, and the successful restoration of elbow flexion in the patients who had adequate follow-up encourages us to continue using this technique as a bail out in complex cases where the commonly used vessels are not available.

Conflict of Interest
None.

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