The Phrenic Nerve as a Motor Nerve Donor for Facial Reanimation with the Free Latissimus Dorsi Muscle

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ABSTRACT

Free functional muscle transfer for acquired facial paralysis most often involves two stages. In this report, we describe single-stage free muscle transfer using the phrenic nerve as the donor motor nerve. Six patients with unilateral facial paralysis underwent single-stage facial reanimation using a free latissimus dorsi muscle with the ipsilateral phrenic nerve as the donor nerve. These cases were retrospectively studied to review technique and to determine outcomes including time to muscle reinnervation, patient satisfaction, smile symmetry, and complications. The mean age was 33 years. Five patients had complete unilateral facial paralysis and one had incomplete. There was no flap loss. The transferred muscle demonstrated active contraction in all patients at a mean of 14 weeks postoperatively (range, 12 to 16 weeks). Good dynamic symmetry was achieved by 6 to 9 months in all patients. All patients underwent rehabilitation including nerve reeducation. No clinically significant pulmonary morbidity was observed after the unilateral transection of the phrenic nerve. Using the phrenic nerve in free muscle transfer for facial paralysis allows a single-stage procedure with no requirement for nerve grafting and a rapid reinnervation time, shortening the time required for restoring facial animation.

KEYWORDS: Facial reanimation, phrenic nerve, facial paralysis

A wide variety of techniques has developed for the treatment of facial paralysis. Free functional muscle transfer has been a good option since Harii[1] and his colleagues first reported a successful gracilis muscle transfer to provide oral commissure elevation in 1976. Since then, numerous similar procedures[2–4] have been reported with encouraging results. Many muscles have been used including the latissimus dorsi, pectoralis minor, gracilis, rectus femoris, serratus anterior, and the rectus abdominis.[4–9]

Donor nerves for reanimation, however, are relatively limited. The ipsilateral hypoglossal nerve[9,10] and the ipsilateral masseteric branch of the trigeminal nerve have been used by some authors.[11–13] Although the masseteric branch of the trigeminal nerve is becoming more widely used, most authors continue to use the contralateral buccal branch of the facial nerve as the donor motor nerve.[2,4,6,13–15] Utilization of the contralateral facial nerve can recreate symmetry of facial expression by motoring the muscles of both sides through one

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facial nerve. Reconstruction is performed in two stages. The first stage is a cross-facial nerve grafting, followed 6 to 12 months later by neurovascular muscle transfer.[2,4,6,13,14] There are, however, three disadvantages to this technique. First, because of the two stages, there is a lapse of almost 2 years before return of facial movement in most cases.[4,14,15] Second, the interposition nerve graft increases the chance of misgrowth of nerve axons.[16] Last, exploring the contralateral facial nerve creates a scar on the healthy side of the face and risks injury to or weakening of the normal side.

In an attempt to complete the operation in one stage, some authors have used an extra-long neurovascular muscle pedicle.[17,18] The longer nerve pedicle, however, results in a longer time to reinnervation, causing more muscle atrophy and a lower success rate. In addition, dissection of a long neurovascular pedicle results in a higher chance of injury to the nerve and vessels of the muscle being harvested. Moreover, this long pedicle still requires dissection of a contralateral facial nerve.

We have extensive experience using the ipsilateral phrenic nerve for reconstruction of brachial plexus injuries. The length of the ipsilateral phrenic nerve makes it possible to use it as a donor motor source for facial reanimation; this has become our donor nerve of choice. This avoids a two-stage operation, decreases the time for nerve regeneration, and eliminates scarring and risk of a facial nerve injury on the unaffected side of the face. The purpose of this study is to describe our surgical technique, review cases, and analyze outcomes to further stimulate research into use of this nerve for reanimation procedures.

PATIENTS AND METHODS

From February 2001 to July 2004, all consecutive patients who underwent single-stage free muscle facial reanimation using the phrenic nerve as the motor nerve donor were identified. Patient charts, operative notes, and photographs were analyzed for patient demographics, cause and duration of facial palsy, and outcomes. Flap complications, time to active muscle contraction, patient satisfaction, and symmetry of the smile were determined. Postoperative pulmonary function due to phrenic nerve transaction was assessed by surveying patients regarding symptoms of pulmonary dysfunction and changes in exercise tolerance.

Surgical Procedure

Under general anesthesia, the patient is placed in the lateral decubitus position and the latissimus dorsi muscle is harvested from the same side as the facial palsy. An incision is made in the midaxillary line, and the lateral portion of the latissimus dorsi muscle, thoracodorsal vessels, and the entire thoracodorsal nerve are dissected and harvested. A 4- to 6-cm length of the neurovascular pedicle is dissected. The transferred portion of the muscle is 8 to 10 cm in length and 4 to 5 cm in width. The distal muscle is divided into two slips: one will be fixed to the nasolabial fold and the other to the oral commissure.

Five incisions are made in the recipient site (Fig. 1). A subcutaneous tunnel is created by undermining the cheek to provide access from the tragus region to the nasolabial fold and oral commissure. The distal one-third of the muscle is split to create a *Y* shape as described above. The transferred muscle is passed through the tunnel. The proximal end of the muscle is sutured to the zygomatic arch. The distal ends are sutured to the dermis of the nasolabial fold and the muscle and dermis of the oral commissure. The thoracodorsal artery and vein are anastomosed to the facial artery and vein.

An incision is made at the superior edge of the clavicle, and the phrenic nerve, which originates from the C4 root, is identified over the anterior scalene muscle and dissected inferiorly. The distal end of the phrenic nerve is transected and tunneled to the submandibular incision. The size of the thoracodorsal nerve is very close to that of phrenic nerve. The two stumps of nerves are approximated with an epineurial repair using 9–0 nylon sutures.

RESULTS

From February 2001 to July 2004, six patients (mean age, 33 years) underwent single-stage free muscle facial reanimation using the ipsilateral latissimus muscle and the phrenic nerve as the motor nerve donor (Table 1). Five patients had unilateral complete facial palsy and one (patient #6) had unilateral incomplete, lower-facial paralysis.

All patients were available for follow-up from 1 to 5 years postoperatively. There were no flap losses, hematomas, or wound infections. All patients had evidence of active contraction in the transplanted latissimus muscle by 12 to 16 weeks postoperatively (mean, 13.8 weeks; Table 2). All patients achieved good, improved dynamic symmetry by 6 to 9 months. All patients underwent rehabilitation including nerve reeducation. All patients developed independent control of the transferred muscle; they were able to smile effortlessly without coughing or inspiration. One patient continues to have subtle transplanted muscle action with inspiration and coughing but this no longer occurs in the other five patients.

On survey, five patients were very happy with their results and one patient was not satisfied with her result. No clinically significant pulmonary morbidity or changes in exercise tolerance were observed or reported

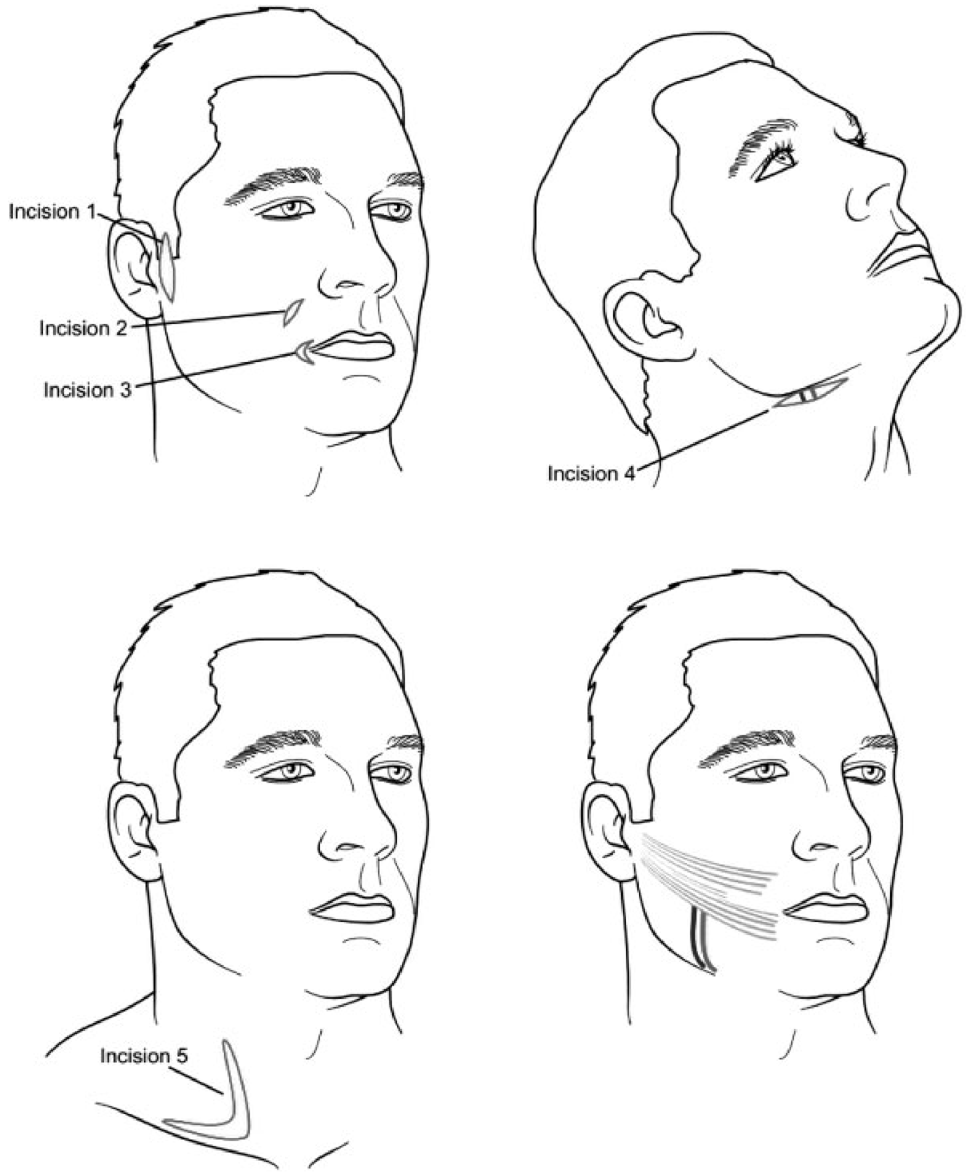

Figure 1 Five incisions are made in the recipient site. The first incision is anterior to the tragus for fixation of muscle origin to the zygomatic arch. The second incision is in the nasolabial fold for fixation of the superior slip of the muscle. The third incision is at the oral commissure to attach the inferior slip of the muscle to the orbicularis oris. The fourth incision is at the intersection of the inferior border of the mandible and anterior margin of the masseter muscle for the anastomosis of the vessels and the nerve. The fifth incision is at the superior edge of the clavicle for harvesting the phrenic nerve.

Table 1 Patient Demographics and Details of Facial Paralysis

Patient	Age/Sex	Site of Facial Paralysis	Etiology of Facial Palsy	Duration of Palsy (y)
1	18/F	Unilateral	Unknown viral illness	13
2	38/F	Unilateral	Parotidectomy	2
3	36/F	Unilateral	Trauma	2
4	17/M	Unilateral	Parotidectomy	10
5	50/F	Unilateral	Facial nerve tumor resection	8
6	36/F	Unilateral	Bell's palsy	3

Table 2 Time to Reinnervation

Patient	Start of Muscle Contraction (Weeks Postoperatively)
1	13
2	13
3	14
4	12
5	16
6	15

Figure 2 (A, B) Preoperative views show mild facial asymmetry at rest and a more significant asymmetric smile due to right-sided facial nerve paralysis. (C, D) At 9 months postoperatively, the frontal views of the patient at rest (C) and smiling (D) show improved symmetry of the angles of the mouth. (E) On oblique view, there is a well-formed nasolabial fold and nearly normal commissure elevation when the patient smiles. Note excess bulk that needed debulking.

by the patients. A second-stage debulking operation was required in one patient.

Clinical Cases

CASE 1

Patient #1 is an 18-year-old girl who developed right lower-facial paralysis after a high fever when she was 5 years old. The girl had undergone an oral suspension sling procedure when she was 12 years old but the result was unsatisfactory. Therefore, she underwent one-stage reconstruction with a free latissimus neurovascular muscle transfer using the phrenic nerve as a donor motor nerve. The pre- and postoperative images are shown in Fig. 2. The transferred muscle began to contract 13 weeks following surgery. During the early stages of reanimation, the muscle contracted on inspiration. The patient gradually began to develop independent control of the muscle. At 7 months, the patient began nerve reeducation, and after 2 months of nerve training, facial symmetry was greatly improved and the patient could control both sides when smiling intentionally. Ten months following surgery, a debulking procedure was performed on the muscle flap.

CASE 2

Patient #4 is a 17-year-old boy who developed complete facial nerve paralysis after a parotidectomy and postoperative radiation. Ten years later, he underwent one-stage reanimation with a free latissimus neurovascular muscle transfer using the phrenic nerve as a donor motor nerve. The pre- and postoperative images are demonstrated in Fig. 3. Muscle contraction was present at 12 weeks postoperatively.

DISCUSSION

There are several advantages in using the phrenic nerve as the donor nerve source for facial reanimation. The phrenic nerve is easy to dissect, contains a large number of motor axons,[19] and avoids the need for a distal donor site. The resulting scar is relatively inconspicuous. The ipsilateral phrenic nerve is long enough to be easily repaired primarily to the thoracodorsal nerve of the muscle transfer. The operation can be completed in one stage and on one side of the face, thus decreasing patient morbidity. Most importantly, only a single neurorrhaphy is performed, leading to a higher probability of axonal regeneration. Interpositional nerve grafting is not required, which significantly shortens recovery time.[2,16,20,21]

Phrenic nerves have been widely used in the reconstruction of brachial plexus injuries and have proven to be an excellent motor nerve source.[19,22,23] Authors have reported that the transection of one phrenic nerve did not clinically affect pulmonary function in healthy adults.[24,25] Exercise tolerance and clinical symptoms are unchanged after unilateral phrenic nerve transaction,[24] and most pulmonary function parameters recover to preoperative levels within 1 year.[25] However, there may be negative effects to pulmonary function in young children and the elderly.[26] From our extensive experience in phrenic nerve transfer for biceps function, we have not found any pulmonary problems in healthy adults; we have used the phrenic nerve in patients over the age of 65 years with no adverse pulmonary effects. We only use the phrenic nerve in adults with normal pulmonary function. We recommend preoperative evaluation of lung function via history, physical exam, and possibly pulmonary function testing.

In our series, muscle function was restored quickly and reliably in all six patients. Muscle function was evident within 3 to 4 months in all patients. This rate of reanimation is significantly more rapid than the outcomes reported in other series.[4,10,13,14,17,27] This is because the time of regeneration is directly related to the distance of nerve regeneration. The phrenic nerve can be dissected to a viable length of 6 to 7 cm. This allows for a short (3 to 4 cm in length) nerve pedicle in the transferred muscle. Therefore, the distance for the nerve to regenerate is greatly decreased, resulting in quicker reinnervation. This also avoids the decrease in number and size of regenerated myelinated fibers at the distal end of cross-face nerve grafts. Also, the phrenic nerve and the thoracodorsal nerve are both motor nerves of similar diameter, which may account for the rapidity of the recovery of muscle function in this study.[16,19]

Successful muscle function, facial symmetry, and independent control of the transferred muscle were good following this transfer. In the authors' prior experience, patients with brachial plexus traction injuries who underwent nerve transfer from the phrenic nerve to the musculocutaneous nerve would initially have to inspire to flex the elbow. Gradually the patients could control the biceps voluntarily and did not need to inspire to obtain muscle function. This successful nerve reeducation[28,29] was repeated in this group of patients with facial paralysis. Early facial animation required inspiration. Within a few months, all patients in this study developed independent control of the transferred muscle. All patients achieved improvement in facial symmetry and coordinated dynamic animation. During nerve reeducation, patients are taught to use a mirror to exercise the transferred muscle in an attempt to have the muscle match the healthy side; they work closely with our therapists. In our experience, this leads to an improvement in the ability to form a spontaneous smile. Obviously, this may never achieve the same results as a transferred muscle connected to a cross-facial nerve graft in regards to an emotionally mediated spontaneous smile.

Figure 3 (A, B) Preoperatively, frontal view shows facial asymmetry with a left-sided facial nerve paralysis, and lateral view shows a deficient nasolabial fold. Note loss of volume from his parotidectomy. (C) At 4 months postoperatively, the patient is shown at rest. (D) The two sides are more symmetric when smiling. (E) The oblique view shows a formed nasolabial fold when the patient smiles. Note improved facial volume and contour.

One disadvantage in our technique is the excess bulk that it creates in the face in some patients. However, this excess bulk can be an asset in patients who have undergone parotidectomy or tumor resection. A second-stage debulking operation was required in one patient in this study. Alternatively, the bulk can be offset by partial or complete removal of the buccal fat pad at the time of muscle inset.

Overall, the phrenic nerve as a donor motor nerve for facial reanimation holds promise. There are definite limitations in our study. A more formal study with a greater number of patients, measurements of the degree of muscle excursion, and a case-controlled cohort having the traditional two-staged procedure for comparison should be performed. The advantage of this technique over other single-stage techniques—namely, the nerve to the masseter—has to be substantiated with more experience. However, these data should stimulate more research into the use of the phrenic nerve in facial reanimation.

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