The Surgical Management of Facial Nerve Injury

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ABSTRACT

The surgical management of facial nerve injuries is dependent upon a thorough understanding of facial nerve anatomy, nerve physiology, and microsurgical techniques. When possible, primary neurorrhaphy is the "gold standard" repair technique. Injuries resulting in long nerve gaps or a significant delay between the time of injury and repair requires alterative techniques, such as nerve grafts, nerve transfers, regional muscle transfers, free tissue transfers, and static procedures. Scrupulous technique, selection of the appropriate surgical management, and aggressive physiotherapy with motor reeducation are all critical to obtaining a functionally and aesthetically acceptable result while minimizing synkinesis and facial asymmetry. This review of the literature provides an overview of current concepts in the surgical management of facial nerve injuries.

KEYWORDS: Facial nerve, reanimation, nerve repair

Facial nerve damage leads to both functional and cosmetic deficits. The goals of facial reanimation are to restore facial symmetry, restore voluntary control of the facial musculature, allow the patient to express emotion via the facial musculature, protect the eye, and provide oral continence.

Today's peripheral nerve repair techniques are based on concepts outlined as early as 1821, when Sir Charles Bell first attempted to repair the facial nerve.[1] Nerve transfers and partial nerve transfers utilizing end-to-side neurorrhaphy had been described by the early 1900s, and by 1936 surgeons had employed free nerve grafts to bridge large gaps following acoustic neuroma resection.[2–7] Over the past 30 years, advances in optics, microsurgical techniques, and the understanding of neuromuscular anatomy and physiology have led to significant improvement in treatment options for extensive and long-standing facial nerve injuries. Canine studies in 1970 described free neuromuscular flaps,[8–10] and by 1971 these tissue transfers had been described in the clinical setting.[11–14] Concurrently, Scaramella was demonstrating the utility of cross-facial nerve grafting.[15,16] As we gain a better understanding of facial nerve fascicular anatomy and corresponding muscular territory,[17] as well as the tonicity of various facial muscles[18] and the unique properties of facial muscle motor end plate distribution,[19] we continue to refine surgical techniques to produce more functional, symmetric, and natural-appearing results.

SURGICAL MANAGEMENT OF ACUTE FACIAL NERVE INJURIES

Primary Neurorrhaphy

When the proximal and distal cut stumps of the facial nerve are available for repair, acute injuries to the extratemporal facial nerve should be repaired as early as possible to facilitate identification of the transected nerve stumps. After 72 hours, the neurotransmitter stores required for motor end plate depolarization are irreversibly depleted and the target muscles no longer respond

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to stimulation of the distal nerve stump. A tension-free end-to-end repair is the "gold standard" technique.

Nerve grafts are indicated when the proximal and distal cut stumps of the facial nerve are clearly identifiable but the intervening gap is too wide to effect a tension-free repair. Once the facial nerve stumps have been dissected and trimmed to the level of healthy fascicles, the nerve may be repaired in an end-to-end fashion with an interposed free nerve graft. The sural, greater auricular nerve and medial antebrachial cutaneous (MABC) or lateral antebrachial cutaneous (LABC) nerve are all acceptable donors. Our current preference is the anterior branch of the MABC.

The facial nerve has a variable spatial arrangement, which has direct clinical implications.[20–22] The internal topography of the facial nerve becomes less complicated as it proceeds peripherally, and even though the senior author has acutely repaired transected nerve branches medial to a perceived line drawn from the lateral corner of the eye to the lateral corner of the lip with excellent success, facial function tends to recover spontaneously in injuries to this region. In addition, individual facial muscle fibers can possess multiple motor end plates that arise from different branches of the facial nerve.[19,23] This duplicity in innervation and more consistent facial nerve topography lead to a greater degree of recovery with more medial, or peripheral, injuries and also contribute to greater success with nerve repair.[24] In some cases, dormant branches of the trigeminal nerve may reinnervate denervated facial muscles as seen in rare cases of delayed spontaneous return of facial animation without surgical intervention.[25]

Facial nerve repair is frequently complicated by synkinesis or dyskinesis. Synkinesis is defined as the abnormal, simultaneous contraction of a group of muscles with voluntary or involuntary facial expression. This phenomenon occurs when regenerating axons innervate unintended targets. Dyskinesis refers to unintended facial muscle contractions that occur when axons inappropriately innervate the intended target. These phenomena are more likely to occur with more proximal injuries to the facial nerve, especially intratemporal injuries.

Cross-Facial Nerve Graft

When the proximal facial nerve stump is unavailable for primary repair, the reconstructive surgeon may employ a cross-facial nerve graft.[15,26–28] Axons from the contralateral facial nerve are diverted to the injured distal facial nerve stump via a free nerve graft. Selecting a donor nerve with function similar to and synchronous with that of the injured nerve, such as the contralateral facial nerve, leads to a natural functional outcome and minimizes synkinesis. Branches of the contralateral facial nerve are exposed through a standard preauricular incision, and nerve stimulation identifies branches of the contralateral facial nerve that may be sacrificed without incurring functional deficits on the donor side. Usually, one or two nerve branches that cause elevation of the oral commissure and upper lip are chosen while protecting the branches that will preserve eyelid function. Next, the severed branches of the donor nerve are coapted in an end-to-end fashion with the free nerve graft, which is usually the sural nerve based on its caliber, length, and expendability. A subcutaneous tunnel is created across the upper lip, and the nerve graft is delivered to the contralateral side. If this procedure can be done shortly after the initial injury, the distal nerve graft may be coapted to the contralateral facial nerve branches at this time, but it is otherwise banked in the preauricular region in preparation for a free muscle transfer. Delayed repairs are discussed in a later section of this article.

Nerve Transfers and Partial Nerve Transfers

Facial nerve defects that are not amenable to repair using the ipsilateral or contralateral facial nerve must rely on innervation from an alternative source. Earlier techniques sacrificed an adjacent nerve, such as the hypoglossal, to provide regenerating axons for the distal facial nerve stump. However, donor morbidity is high when the entire donor nerve is used and includes swallowing and speech problems and tongue hemiatrophy. Additional morbidity arises from activation of the donor nerve's original target muscles to stimulate the reinnervated facial muscles. Following hypoglossal-facial nerve transfers, patients need to manipulate their tongues to activate the neurotized facial muscles and may develop synkinetic facial movements with speech, eating, and other tongue movements. Other donor nerves have also been used including the trigeminal[29,30] and spinal accessory nerves,[2,31,32] but their use has also resulted in gross, dyskinetic facial movements. However, with time, some patients with appropriate therapy and motor reeducation develop the ability to contract reinnervated facial muscles independently and spontaneously without consciously activating donor nerve function.[33]

To minimize donor morbidity, partial hypoglossal nerve transfer using up to 25% of the nerve has been described with adequate reinnervation of facial muscles and no appreciable loss of tongue function or bulk or speech deficits.[34–37] The ipsilateral hypoglossal nerve is exposed proximally where it has been shown to have a monofascicular pattern and then dissected distally where it develops a polyfascicular pattern.[38] An end-to-side neurorrhaphy is employed using an interposition nerve graft, usually the MABC, and a partial neurectomy in the hypoglossal nerve is performed to facilitate regeneration across the end-to-side repair. Care is taken to preserve fascicles of the hypoglossal nerve innervating the posterior aspect of the tongue.

Nerve transfers have also been used to provide temporary trophic support to the denervated neuromuscular junction if a prolonged period of denervation is anticipated such as in reconstructions using a cross-facial nerve graft and free muscle transfer.[39–42] Such "baby-sitter" procedures have been described utilizing both the hypoglossal and accessory nerves.[32] However, the efficacy of this technique has been questioned in the animal model, which suggests that recovery of muscle function is superior after a single prolonged period of denervation followed by a single reinnervation rather than repeated episodes of denervation followed by reinnervation.[43] As well, the patient is often reluctant to lose the result from the so-called baby-sitter procedure that is sacrificed in the hope of a better result.

SURGICAL MANAGEMENT OF ESTABLISHED FACIAL PALSY

Regional Muscle Transfers

When facial musculature has been denervated for more than a year, motor end plates are usually irreversibly lost, and surgical attempts at reinnervation are usually futile. A patient's resulting deficits, general medical condition, and expectations all play a role in determining the most appropriate surgical procedure at this point. If the patient does not wish to have multiple procedures or will not medically tolerate a prolonged anesthetic, a regional muscle transfer is a good choice for restoring voluntary facial movement. The temporalis and masseter muscles are most commonly chosen for regional transfer,[44] utilizing either a portion of the muscle or the entire muscle, or sometimes both muscles may be used if the natural vector of the patient's smile is in a more lateral direction.[45,46] We most commonly use a partial temporalis muscle transfer. The vector generated by the transferred muscle extends from the modiolus to the anterior zygomatic arch and resembles the vector created by contraction of the zygomaticus major muscle.

The temporalis muscle is mobilized through a preauricular incision extending cephalad over the temporalis. A superiorly based flap of deep temporal fascia $\sim$4 cm in width with its cephalic attachment to the muscle reinforced with suture is used to extend the reach of the transfer and provide a means of securing the muscle distally to the modiolus and orbicularis oris. The temporalis is mobilized to the superior border of the zygomatic arch, and insetting is the same as for a free muscle transfer using nonabsorbable clear sutures placed in the orbicularis oris muscle above (three sutures), below (one or two sutures), and at the modiolus (one suture). An intraoral splint is used to support the oral commissure on the affected side postoperatively for $\sim$6 weeks.

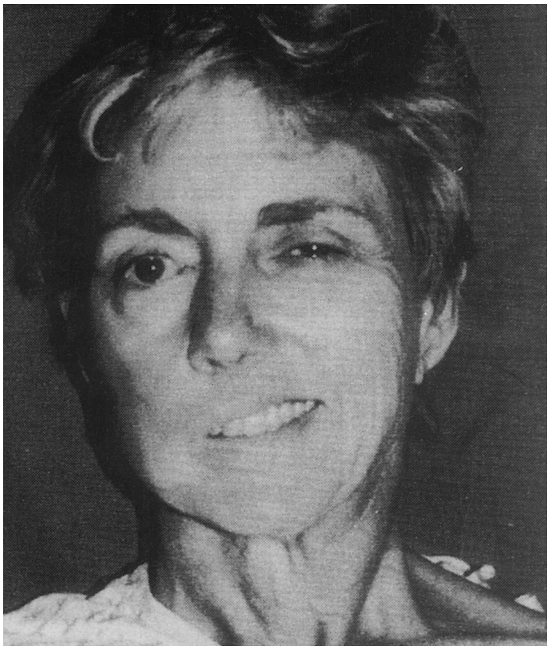
The senior author has found the temporalis muscle transfer to be a very reliable alternative to microsurgical reconstruction in restoring facial function after prolonged denervation (Fig. 1). The success of the procedure depends on the patient's ability to contract the temporalis independently on the affected side to match the degree of facial muscle contraction on the normal side. Although involuntary facial contractions are rarely symmetric, our experience has demonstrated that appropriate patients do extremely well with postoperative therapy and motor reeducation.

Free Tissue Transfers

Regional muscle transfers, like nerve transfers, mandate an element of synkinesis to activate the transferred muscle. Free tissue transfers may avoid these problems if the patient is medically and psychologically tolerant of longer and multiple procedures.[1] Ipsilateral nerves and free cross-facial nerve grafts may provide innervation for free muscle transfers. Alternatively, some free tissue transfers have a neural pedicle with sufficient length to reach the contralateral facial nerve. Donor muscles for free tissue transfer have included the gracilis,[47] latissimus dorsi,[14] pectoralis minor,[11] and rectus abdominis.[48]

Free tissue transfers may require either one or two stages. Use of cross-facial nerve grafts, due to the extensive amount of time required for axonal elongation across the graft, has conventionally required two stages. First, a cross-facial nerve graft is coapted to the donor nerve and tunneled to an area near its intended target. A period of 6 to 8 months is required for axons to regenerate across the nerve graft, at which point a free tissue transfer is performed. The neural pedicle of the transferred muscle is coapted to the distal end of the axon-rich cross-facial nerve graft. Our current preference is to perform a cross-facial nerve graft procedure followed by a vascularized free gracilis muscle transfer $\sim$8 months later (Fig. 2). The gracilis muscle is preferred because of its expendability, ease of harvest, parallel fiber orientation, and reasonable length of excursion with contraction. The latissimus dorsi muscle with its longer neurovascular pedicle is useful in facial palsy reconstruction when a long pedicle is preferred, for example, with associated facial trauma. The gracilis muscle is trimmed for appropriate tension, anchored proximally to the zygomatic arch and overlying fascia, and inset distally to the orbicularis oris at the oral commissure as described previously for the temporalis muscle transfer.

Several groups have reported one-stage free muscle transfers. Using muscles such as the rectus femoris or latissimus dorsi, which have a long nerve pedicle, the muscle transfer and nerve coaptation to the contralateral facial nerve can be done at the same time.[49,50] Although the distance across which regenerating axons must travel is equal to that in the standard two-stage cross-facial nerve graft, groups performing one-stage operations report no problems with muscle reinnervation either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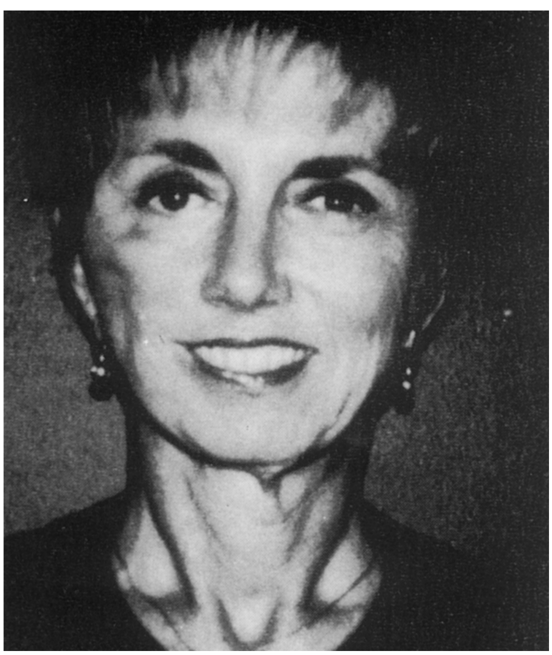
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Figure 1 Middle-aged woman with established right facial palsy. (A) Preoperative photograph demonstrating smile. (B) Intraoperative photograph of temporalis muscle transfer. (C) Two-year follow-up demonstrating smile.

clinically or by electromyographic data.[51] Muscular recovery has been reported as early as 6 months following one-stage operations. Harii et al proposed two possible mechanisms by which one-stage procedures equal or surpass the results of two-stage procedures.[47] First, blood may flow in a retrograde manner from the transferred muscle into the neural pedicle, effectively creating a vascularized nerve graft. Next, one-stage procedures require only one neurorrhaphy, whereas the use of two suture lines with a nerve graft limits axonal regeneration and degree of muscle reinnervation. Using this technique, branches of the normal facial nerve to be diverted to the free muscle are exposed through an incision made on the unaffected cheek at the anterior border of the parotid gland or near the nasolabial fold,[47] or a preauricular incision may also be used.[49,51–53] Although questions remain about the long-term outcome and the integrity of the neuromuscular junction in one-stage procedures, the shorter recovery period and reduced operative times remain distinct advantages with this increasingly popular technique.

Muscles with dual innervation provide an additional option for single-stage procedures. A single donor muscle can be used to reanimate multiple sites with multiple donor nerves, allowing selective activation of a single transferred muscle. The long femoral nerve

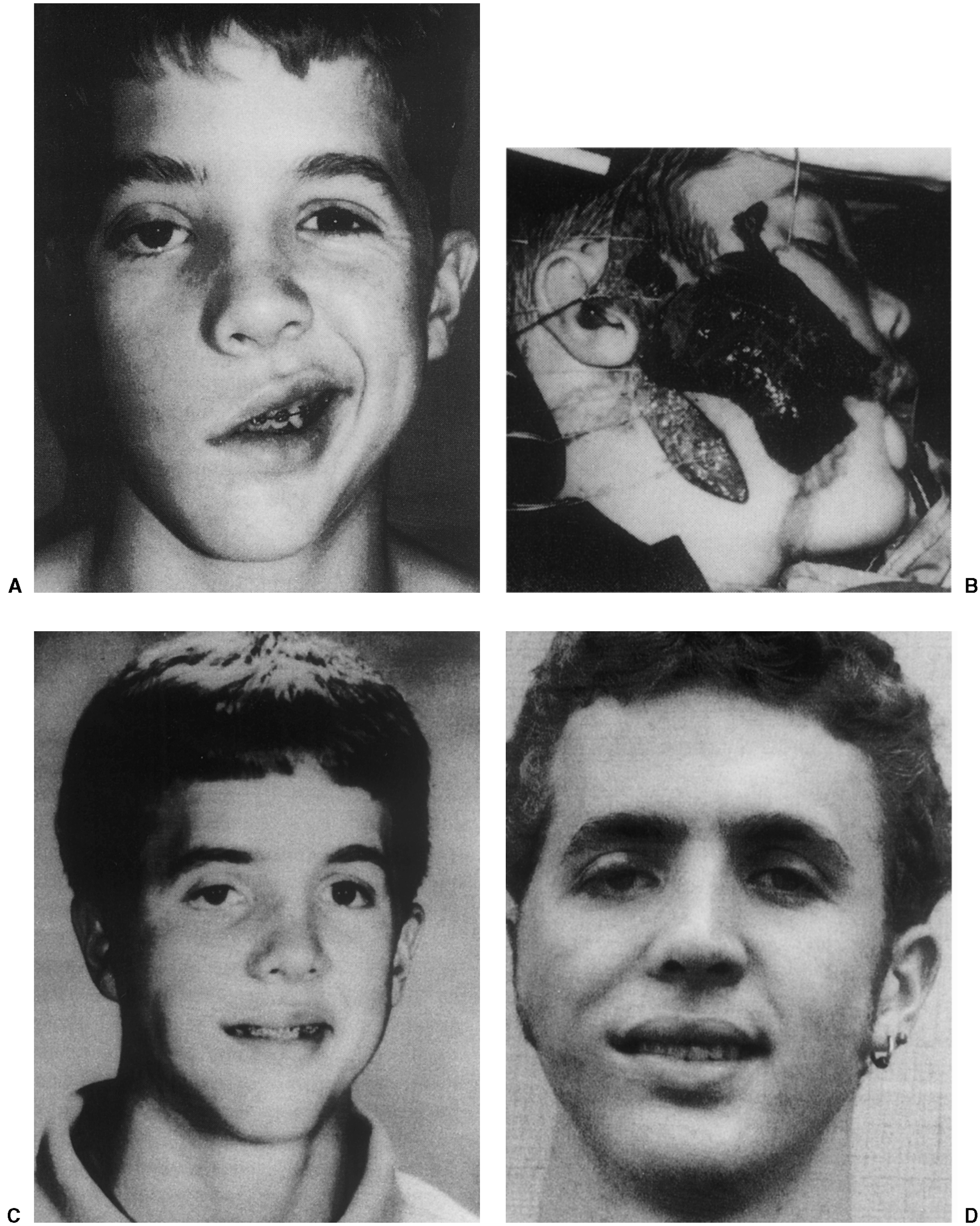

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Figure 2 Teenage male with established right facial palsy. (A) Preoperative photograph demonstrating smile. (B) Intraoperative photograph showing transfer of free vascularized gracilis muscle 8 months following cross-facial nerve graft procedure. (C) Two-year and (D) 7-year follow-up demonstrating smile.

innervating the rectus femoris may be coapted to the contralateral facial nerve to elicit lip elevation, while the inferior segment of the same muscle may be used for lip depression via a short motor nerve coapted to the ipsilateral masseteric nerve.[50]

STATIC PROCEDURES

While muscle and nerve transfers may be used to reanimate the paralyzed face, static procedures, such as eyelid weighting and sling procedures, also improve both functional and aesthetic results.

Lagophthalmos, or inability to close the eyelids, is a significant functional deficit following facial nerve injury, and exposure keratitis and tearing are common sequelae. The use of gold weights is the most commonly used technique to correct this problem.[54,55] Gold weights ranging from 0.8 to 1.6 g are placed immediately superficial to the tarsal plate and centered over the pupil with the patient in centric gaze. Although this procedure reliably achieves eyelid closure, several complications can occur. Excessively heavy weights are commonly chosen, although this may be subsequently corrected.[56] Implant visibility, extrusion, downward migration, and ocular irritation are also common complications.[57] Reanimation of the eye is discussed in detail in another article in this issue.

Restoring facial symmetry poses a significant challenge following facial paralysis. Gore-tex or tensor fascia lata slings may be used to provide traction on the perioral musculature to return the paralyzed modiolus to a more natural position.[58] Conversely, limiting the function of the nonparalyzed side by denervation with botulinum toxin may also help to restore facial symmetry.[59,60] Usually, secondary procedures are performed $\sim$18 to 24 months after major reconstruction to allow wound healing and scar remodeling and to allow patients to identify which aspects of their facial aesthetics and function they wish to change. Other ancillary procedures may include debulking procedures, tightening or repositioning procedures, or selective denervations to maximize symmetry. Contour deformities may be further improved with fat grafts,[61] dermal fat grafts,[62] fascia lata grafts,[63] or other alloplastic alternatives.[64]

CONCLUSIONS

Treatment of facial nerve injuries requires a detailed understanding of the facial nerve anatomy, accurate clinical examination, and timely and appropriate diagnostic studies. Options for reconstruction depend on the extent of the injury, availability of the proximal nerve stump, the time since the injury, and the patient's ability to tolerate lengthy surgical procedures. Although no option is perfect, these techniques may help to achieve facial symmetry, prevent drooling, and restore the patient's ability to express emotion with the facial musculature. New techniques including single-stage free tissue transfer, bioengineered nerve grafts, and further research on the characteristics of the facial musculature will inevitably contribute to the future surgical management of facial nerve injuries.

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