Chapter 63: Rehabilitation of Facial Paralysis

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Complete unilateral paralysis of the face represents one of the most devastating emotional ordeals an individual can experience. The ability to restore symmetry and motion to patients afflicted with facial paralysis is one of the most rewarding skills of the well-trained reconstructive surgeon. This chapter concerns itself with rehabilitation of facial nerve injuries. Many of the diagnostic considerations and surgical techniques described are applicable to otogenic paralyses (intratemporal), as well as injuries and diseases that affect the parotid and facial portions of the facial nerve.

The facial nerve, once damaged, rarely attains full recovery of function. The slightest injury to one branch, even if the nerve is not divided, may produce permanent weakness or other dysfunction, such as spasm or synkinesis. Any patient sustaining facial nerve injuries or contemplating parotidectomy, and any preoperative patient with the slightest chance of sustaining surgical facial nerve injury should be told that his face will never regain *normal* movements. It is worthwhile for the surgeon to take an extra moment to confirm that the patient has understood this concept. Videotapes, photographs, or movies (of other patients) are oten necessary before the true meaning of the deformity of facial paralysis is conveyed to such a patient.

Many patients listen to the physician's words, yet are unable to fully understand the visual impact of facial paralysis and/or synkinesis. In this regard, it is unwise and unfair to describe hypoglossal-facial anastomosis or muscle transposition in such a way that the patient may believe that the facial nerve and movements will be restored. A realistic approach will yield the rewards of patient compliance, understanding, satisfaction, and acceptance of reality.

Causes of Facial Paralysis

The pathogenesis and eventual course of facial paralysis varies, depending on the causative injury or disease. Bell's palsy, for example, rarely if ever requires facial reanimation surgery. This chapter will focus on clinical situations requiring surgical reanimation.

Reanimation Modalities

In clinical situations requiring facial reanimation, the technique used will oten depend upon the availability of a viable proximal facial nerve. Tumor ablation with facial nere sacrifice (as in radical parotidectomy for parotid malignancy) dictates immediate facial nerve restitution, usually by cable grafting. When the nerve's continuity and viability are in question, however, as may be seen with cerebellopontine angle surgery, it is wise to wait 9 to 12 months before an extratemporal facial nerve operative procedure is undertaken. Hence, no one modality is unversally appropriate or all afflictions of facial nerve function. As a general rule, however, the order of preference is as follows:

1. Facial nerve regeneration
2. Facial nerve neurorrhaphy
3. Facial nerve cable graft
4. Nerve transposition
5. Muscle transposition.

Factors Determining Rehabilitation

A wide array of facial reanimation operations are available to the surgeon. Many of these procedures provide dramatic corrective results when appropriately applied, but their use may be injudicious on other patients.

Any single protocol is ill advised for the management of facial paralysis because patients' needs vary. The high school student with a parotid malignancy deserves the best long-term reanimation result possible. The ipsilateral nerve should be used in such instances. A nerve graft or substitution in an elderly person with a malignancy would be ill advised because the immediate result deriving from a fascia or muscle sling would be preferable. Cosmetic results are not as important for this type of patient, so the most expeditious procedure to restore function should be selected. All the factors determining the outcome of rehabilitation (listed later) should be considered before any facial reanimation procedure is undertaken. Many of these procedures relate to the status of the existing muscles and nerves; others are concerned with the patient's ability to achieve animation following the various procedures and depend on factors like age, radiation exposure, and preexisting disease such as diabetes, etc.

Needs of the patient

The patient's needs must be the paramount consideration in surgical planning for facial paralysis. Naturally, if the patient demands that normal function be restored, no operation will prove satisfactory because normal function is generally irretrievable.

Factors influencing the timing and performance of facial reanimation procedures are listed as follows:

1. Eye protection
2. Presence of partial regeneration
3. Donor consequences
4. Proximal and distal nere integrity
5. Viability of facial muscles

6. Status of donor nerves

7. Time elapsed since last injury

8. Age

9. Radiation injury

10. Diabetes and other metabolic and/or vascular disorders

11. Nutrition.

Eye protection

Evaluation and treatment of eyelid paralysis

Ocular symptoms in facial palsy arise from several mechanisms. The ability to prevent, diagnose, and treat paralytic eyelid sequelae before major complications occur is essential for treating any patient with facial paralysis. In most cases the outcome of the paralyzed eyelid is directly related to patient education and compliance. It is therefore the physician's responsibility to work closely with the patient to ensure that he understands the goals of eye care as well as the potential for serious ocular complications.

Paralysis of the orbicularis oculi results in drying and exposure of the cornea. Inability to protect the cornea occurs secondary to ectropion because the atonic lower lid and lacrimal punctum rest in poor apposition to the globe. This causes faulty eyelid closure and improper distribution of tears across the cornea.

Epiphora may result from failure of tears to enter the lacrimal punctum, secondary to the loss of the orbicularis oculi tear-pumping mechanism. The response to abnormal corneal sensation may be reflex hypersecretion, which further increases the epiphora.

Any facial paralysis patient with a poor Bell's phenomenon is at risk for developing exposure keratitis. Eye pain may herald the onset of keratitis. However in patients with diminished corneal sensation, exposure keratitis may progress to corneal ulceration without pain. Hence all patients with diminished orbicularis oculi function should have ophthalmologic consultation.

Nonsurgical methods of treatment

Initial efforts in eye care should be directed towards moisturizing the dry eye and preventing exposure. If the eyelid paralysis is temporary or partial, these local measures may be all that is necessary to protect the eye adequately. Artificial tears are commonly the first method used to keep the eye moist. Ointments may also be used, but they are less practical in the daytime because they tend to blur the vision.

Lacriserts, contact lenses, and occlusive bubbles are commonly used devices, although patient compliance may be problematic (Freeman et al, 1990) (Fig. 63-1). Patching or taping of the eyelids is frequently done. If incorrectly used, these methods may result in corneal injuries. Tape should not be placed vertically across the lashes, but instead should be applied horizontally above the eyelashes on the upper lid, and/or supporting the lateral canthal portions of the lower eyelid (Wesley and Jackson, 1988). When an eye patch is used, care must be taken that the eye cannot open because that will allow contact between the patch and the cornea to occur.

Surgical methods

Tarsorraphy. The temporary lateral tarsorraphy is an expeditious and effective method for protecting the eye in patients with mild lagophthalmos and mild corneal exposure. A horizontal mattress suture of 7-0 silk or nylon is placed laterally so as to approximate the gray line (muco-cutaneous junction) of the upper and lower lids. Tarsorraphy sutures will remain effective longer if they are placed through bolsters made of portions of rubber catheters.

For longer-lasting protection, the lid adhesion tarsorraphy is preferred. The lid margin (gray line) of each lid is trimmed 4 to 6 mm from the lateral canthus, and a similar suture technique is used to approximate the denuded muco-cutaneous junctions of upper and lower lids (Fig. 63-2). Like the temporary lateral tarsorraphy, this procedure can be reversed in case function returns.

Wedge resection and canthoplasty. Wedge resection and canthoplasty are highly effective methods in the repair of paralytic ectropion. Wedge resection of all layers of the lower lid is simple and expeditious, but when lower lid laxity is moderate to severe, lateral canthoplasty is more reliable.

In cases of severe ectropion the lower lid punctum may be everted. In these instances a medial canthoplasty is used to restore the physiologic relationship of the punctum to the globe (Jelks et al, 1979; Kazanjian and Converse, 1974).

Weights, springs, and slings. Eyelid closure in patients exhibiting lagophthalmos can be obtained in several ways. Perhaps the most popular technique currently involves gold weight insertion into the upper lid. Preoperative assessment determines the amount of weight to be used by taping weights to the upper eyelid until the distance between the eyelids is 1 mm otr less. An additional 0.2 g is added to the gold weight to counteract the strengthened levator muscle function that usually develops.

Under local anesthesia an incision is made extending equally between the medial third and middle third of the supratarsal crease and the skin is elevated to the superior border of the tarsus. A pocket is formed immediately superficial to the tarsus to accommodate the dimensions of the weight. The weight is placed such that its inferior border is parallel to and 3 mm from the lash line with the weight's fenestrations positioned superiorly. It is secured with sutures to the tarsus and the orbicularis-levator complex is reapproximated. The skin is closed and the position of the weight evaluated for proper size and orientation (Freeman et al, 1990).

Gold weight have some noteworthy disadvantages: a small incidence of extrusion is associated with their use. In addition, weights depend on gravity and therefore do not protect the cornea when the patient is supine, so a nighttime ointment is often required. Finally, the gold weight can occasionally be noticed by the casual observer as a bump in the eyelid.

Palpebral springs and silastic slings as described by Morel-Fatio and Arion respectively have been used under similar circumstances (Arion, 1972; Morel-Fatin and Lalardrie, 1964). The palpebral spring technique has undergone several modifications since it was originally described, yet remains the procedure of choice in some surgeons' hands for severe lagophthalmos. Silastic slings are used less frequently and are complicated by lateral ectropion (Levine, 1986). Both procedures share the disadvantages of extrusion as well as of being more difficult to place than lid weights.

Presence of partial regeneration

Partial regeneration is often overlooked, and yet is extremely important in understanding which operation should be performed. If the facial nerve has undergone enough regeneration to permit a few axons to reach the facial muscles, this partial innervation may be sufficient to preserve the muscles for many years, even though they may be totally paralyzed. This situation will optimize results from hypoglossal-facial anastomosis and is preerable to a muscle transfer.

Donor consequences

Many surgical procedures designed for facial reanimation borrow neural elements or signals from other systems, that is, the hypoglossal and trigeminal systems. The consequences of sacrificing the donor nerve ("donor deficit") are most important in planning for the overall needs of the patient. Certainly, the surgeon must assess the donor nerve preoperatively in all cases. The hypoglossal nerve must be tested for strength and vitality before it is transected and anastomosed to the distal facial nerve. Similarly, the trigeminal nerve must be vital when its muscles, either masseter or temporalis, are considered for transposition into the facial muscle system.

The donor effects of facial reanimation surgery may be quite detrimental to the patient's welfare. For example, a patient who has sustained a prior hypoglossal nerve injury on the opposite side could become an "oral cripple" if the remaining hypoglossal nerve were transected for use in a XII-VII anastomosis. Similarly, the trigeminal nerve must be intact if the ipsilateral masseter or temporalis muscle is to be considered for muscle transfer in facial reanimation.

The ideal reanimation procedure would be one with the following characteristics:

1. No donor deficit
2. Immediate restitution of facial movement
3. Appropriate involuntary emotional response
4. Normal voluntary motion
5. Facial symmetry.

No operative procedure currently available satisfies all these parameters. In fact, even a bacteriologically sterile and precise sharp surgical transection and immediate microsurgical repair of the facial nerve will not allow this normal a result. Hence, the surgeon must clearly understand all operations available as well as their potential results and sequelae.

Status of the proximal facial nerve

As a general rule, the most desired neural source for rejuvenation of the paralyzed face is the ipsilateral facial nerve. Anastomosis or grafting to the ipsilateral nerve has no donor consequence (other than the minor hypesthesia or anesthesia from harvesting of a nerve graft) and allows at least some degree of voluntary and involuntary control of facial movement. Exceptions to this general rule, as noted above, are those situations in which the patient needs prompt relief from corneal exposure or drooling, and a tissue transfer/sling technique may be preferred because its effects are immediate.

For these reasons, the integrity of the proximal facial nerve is most important. As with other motor nerves, no reliable electrical tests exist to confirm the viability of the proximal nerve when it is discontinuous with its distal portion. The following list shows which factors affect proximal nerve viability, thereby enabling the clinician to make a qualified assessment (Ducker et al, 1969).

1. Nature of nerve injury, clean transection, crush, and so on.

2. Location of injury (proximal versus distal).

3. Age (younger nerves tending to regenerate more quickly and fully).

4. Nutritional status (directly affects nerve regeneration).

5. History of radiation (impedes neural regeneration).

Status of the distal nerve

The facial nerve distal to the injury is the conduit for neural regeneration to the facial muscles following neurorraphy, grafting, or hypoglossal-facial anastomosis. Accordingly, the anatomic integrity and continuity of the distal nerve to the facial muscles is most important.

When the surgeon is dealing with acute injuries (less than 72 hours old), the electrical stimulator may be used to identify the distal nerve, and also the muscular innervation of distal branches. After this "golden period" however, the surgeon must rely on visual identification of the divisions and branches of the distal nerve because the ability to be stimulated electrically is generally lost after approximately 72 hours. For this reason, transected nerve branches in trauma or tumor cases should be tagged for identification by placing a small colored suture around or adjacent to each nerve branch. Any anatomic or surgical landmarks should be dictated precisely in the operative note.

If no suture markers are available, and the "golden period" has elapsed, careful surgical searching (preferably with loupes or an operating microscope) may reveal each of the divisions or branches of the facial nerve. A topographic map is essential, however, in guiding the dissection. A review describes the variability with which these branches are placed (Bernstein, 1984). The following landmarks are helpful (Fig. 63-3).

1. The pes anserinus can be found 1.5 cm deep to a point 1 cm anterior and 2 cm inferior to the tragal cartilage.

2. The superior division courses rom the pes to the lateral corner of the eyebrow, convex posterosuperiorly (Fig. 63-3). Bernstein (1984) stressed that these temporal and frontal branches may be multiple, and as far posterior as the superficial temporal vessels.

3. The buccal branch courses superiorly and then anteriorly distally and medially, passing 1 cm inferior to the inferior border of the zygomatic arch (Fig. 63-3).

4. The marginal mandibular branch passes from the pes directly over the angle of the mandible and then under the inferior border of the mandible for approximately 3 cm after which it crosses above the mandible at the level of the facial vessels.

Several anatomic variations may exist, requiring ingenuity in nerve grafting. When the facial nerve trunk and pes anserinus are intact, a cable grat (or hypoglossal nerve) should be sutured to that portion of the main nerve trunk. However, certain injuries and surgical procedures may sacrifice important individual portions of the nerve, requiring selective routine of reinnervation to specific divisions. The order of priority for facial nerve branches is as follows:

Buccal and zygomatic branches (equal)

Marginal mandibular

Frontal

Cervical (the latter may be disregarded and/or excluded).

As an example, when a parotid tumor operation has resulted in excision of the pes anserinus and the proximal facial branches, a branched nerve graft may be placed so as to reinnervate the zygomatic and the buccal branches, excluding the less important branches.

When nerve grafts are sutured to the entire facial nerve trunk, the relatively unimportant cervical branch appears to be the most easily innervated, and may steal reinnervation axons needed for more important facial muscles. Fisch (1977) has advised clipping of this branch to route innervation to the more important portions of the face, although we know of no data to confirm the efficacy of this technique.

If no nerve branches can be found, and electromyography (EMG) has shown that denervated facial muscles are present, the nerve graft may be sutured directly to the muscles that the surgeon wishes to reinnervate. This technique is known as *muscular neurotization.*

In these instances, the most important muscles are those of the midface (zygomaticus major and minor, levator labii superioris), and orbicularis oculi muscles. Reinnervation will not be as complete as in routine nerve grating, as the regenerating axons must form new connections to the old motor endplates, or create their own (Aitken, 1950).

Viability of facial muscles

Several variables affect the facial muscles and the results of nerve grating and transfer procedures. The variables that may limit the results of the most precisely performed operation are:

1. Scar tissue

2. Congenital absence

3. Denervation atrophy

4. Subclinical innervation.

Electromyography is an indispensable tool in determining whether denervation atrophy or subclinical innervation exists. EMG is in fact the single most important test in determining the type of operative procedure to be performed. It is important that the surgeon know and work well with the electromyographer so that the facial muscles can be well mapped, and nerve grafting or transfer carried out in appropriate situations. If communication is poor between surgeon and electromyographer, the data from EMG may result in the wrong operative procedure being performed, for example, hypoglossal-facial anastomosis may be inappropriately performed on a patient with severe denervation atrophy of the facial muscles.

Four types of information are generally available from EMG. *Normal voluntary action potentials* mean that functioning motor axons have connections with and are stimulating motor units of facial muscle. *Polyphasic potentials* are seen during reinnervation and may precede visible evidence of reinnervation. *Denervation* or *fibrillation potentials* indicate that otherwise normal denervated muscle exists. *Electrical silence,* with no potentials seen, indicates atrophy or congenital absence of muscle, provided that the electromyographer has positioned the electrode correctly (Smith et al, 1981).

Preexisting innervation *prevents* reinnervation by another neural source. Frequently, facial paralysis is associated with complete denervation of all facial muscles. However, in certain instances (otologic procedures, "failed" nerve grafts, acoustic neuroma surgery), a small number of axons may regenerate to the facial muscles and innervate motor end-plates. If this axon population fails to reach a "critical mass", the innervation may not be sufficient to invoke facial movement. However, most or all of the motor endplates may be secured by this subclinical innervation. In these instances, it is foolhardy to attempt reinnervation by neurotization procedures (introduction of nerve, innervated muscle, or neuromuscular pedicles into the paralyzed muscle) because innervated motor endplates reject new innervation. Usually this is not a problem because in performing cable grafts or nerve substitution procedures the distal facial nerve containing the subclinical innervation will be transected in preparation for the suture anastomosis of the graft or transposed hypoglossal nerve.

Status of donor nerves

The hypoglossal is the most frequently used nerve source for transfer. Several reflex and physiologic similarities between the hypoglossal and the facial have been described by Stennart (1979). However, the integrity of the hypoglossal nerve must be determined before it is transfered for reinnervation. Irradiation of the brain stem, lesions of the skull base and hypoglossal canal, and surgical procedures of the upper neck may affect the strength and vitality of this nerve. The surgeon should ask the patient preoperatively to protrude the tongue and wiggle it back and forth in protrusion; then the surgeon should push against the ipsilateral half of the tongue to determine that its musculature is vital.

Historically, the trigeminal nerve has been used or facial reanimation in many ways. Currently the methods used most often involve masseter or temporalis muscle transfer. Obviously, if either of these procedures is contemplated, the motor portions of the trigeminal nerves must be intact. Palpation of the muscle during jaw clenching will easily confirm whether the muscle is functional. The cross-face nerve graft procedure (facio-facial anastomosis) was initially thought to be the most appropriate and ingenious facial reanimation procedure (Scaramella, 1971; Smith, 1971). The procedure is unique in borrowing appropriate neural input from the contralateral normal side and routing it to the paralyzed side. It is discussed later in this chapter. Obviously, for purposes of this discussion, it would require a strong donor (contralateral) facial nerve if cross-face reinnervation were to be attempted.

Time since transection

A chronic longstanding paralysis with complete muscle degeneration creates several problems regarding eventual reinnervation surgery. The facial muscles may undergo *denervation atrophy.* Severe atrophy would render the muscles incapable of reinnervation and contraction. Such severe atrophy may occur after 18 months of complete denervation, although in some clinical instances muscles have inexplicably been known to persist for many years without incurring such atrophy (Gutman and Young, 1944). Electromyography is the most helpful method for assessing facial muscle atrophy and hence is a preoperative prerequisite for all candidates for reanimation if the paralysis is of more than 12 months' duration. The presence of "nascent", polyphasic, or normal voluntary action potentials seen in a patient with facial paralysis indicates that reinnervation is present but is incapable of producing facial movement. If over 12 months have elapsed since the facial nerve injury, the situation can be assumed to be stable and an operative procedure may be warranted. However, in the first 12 months, these potentials may all means that reinnervation is occurring and that facial movements may return in the next few months. Reanimation surgery should be postponed. Fibrillation or denervation potentials mean that the EMG electrode is positioned in denervated muscle. This is an optimal situation for cable nerve grafting, or, when no viable proximal facial nerve is available, for hypoglossal-facial anastomosis.

One of the most significant EMG findings is electrical silence. This absence of all electrical EMG potentials usually means that the muscles of facial expression have undergone denervation atrophy. The surgical implication is that nerve grafting or transfer is futile and hence contraindicated. If the facial muscles are absent or atrophied, muscle transfers are indicated.

Other effects of time include endoneural scarring in the distal nerve segment. It is not known whether this acts as an impediment to nerve regeneration, but when associated with muscular atrophy, it probably further precludes nerve grafting or transfer.

Age

The proximal neuron's ability to regenerate declines with time elapsed from denervation, as well as with advancing age of the patient. This is most probably because of the diminishing regenerative vitality of the perikaryon (cell body), although peripheral scarring may play a role. The clinical implication is that facial reanimation surgery should always be performed as soon as possible, provided that the operative procedure does not interfere with or injury existing innervation or ongoing reinnervation (Ducker et al, 1969).

Radiation therapy

Radiotherapy, a necessary component of treatment of certain salivary gland malignancies, appears to have a deleterious effect on reinnervation via facial nerve grafts. McGuirt and McCabe (1977) demonstrated satisfactory muscle reinnervation from grafting despite irradiation in animals. Conley and Miehlke (1977) have published reports indicating that facial nerve grafts function well even though irradiated, stating that nerves are among the radioresistant tissues of the human body. Pillsbury and Fisch (1979) found that radiotherapy reduced the average outcome from 75% to 25% in a review of 42 grafted patients. Irradiation probably affects the neovascularization of the nerve graft by decreasing vascularity of the tissue bed, and probably injures the proximal and distal segments of the nerve as well. The most sensitive portion of the nerve to radiation, the pontine nucleus, is usually spared high doses because most salivary gland tumors do not require irradiation of the brain stem.

Diabetes and nutritional factors

Diabetic patients are notoriously poor at regenerating injured nerves. This may be because of cellular biochemical processes that result in a lack of neuronal vitality in the regenerative effort. The microangiopathy is an additional factor that may affect the grafted segment. These factors would not preclude performing a nerve graft procedure in a diabetic patient, but when combined with radiation, advancing age, and other factors, might cause the surgeon to consider muscle transfer or a suspensory operation rather than a neural anastomosis. Nerve grafting may be followed by delayed reinnervation and poorer results.

Congenital Paralysis

Of 95 cases of neonatal paralysis, Smith et al (1981) found 74 to be secondary to intrauterine injury or birth trauma whereas 21 were thought to be congenital. These infants should be studied with nerve excitability and EMG tests early in life so that the status of nerves and muscles can be ascertained. Most cases of injury-related neonatal paralysis recover rapidly whereas those associated with other congenital anomalies (such as Mobius syndrome) are permanent. Nerve exploration or transfer is generally futile in the latter cases.

Surgical Reanimation

Preoperative assessment

A. History

1. Type of injury

2. Time since injury

3. Age

4. Radiation

5. Nutritional factors

6. Prior operative report

B. Physical examination

1. Prior incisions and scars

2. Integrity of trigeminal and hypoglossal nerves

3. Facial motion (Is entire face paralyzed?)

4. Status of eye (lagophthalmost, ectropion?)

C. Electromyography (perform on all patients who have had paralysis for over 1 year), CT scan, temporal bone (if there is any question about the cause of paralysis).

D. CT scan of temporal bone and MR scan of parotid gland (if there is any question about the cause of paralysis).

Facial Nerve Grafting

So-called cable or interposition nerve grafts are frequently the desired approach to facial muscle reinnervation. Probably the most common setting for this procedure is in combination with radical parotidectomy and facial nerve sacrifice. The clinical uses of interposition grafts are shown in the following list:

1. Radical parotidectomy with nerve sacrifice
2. Temporal bone resection
3. Traumatic avulsions
4. Cerebellopontine angle tumor resection
5. Any other situation in which viable proximal nerve can be sutured and distal elements of facial nerve can be identified.

When performed on acute cases such as for parotid malignancy, the surgeon customarily identifies the distal facial nerve trunk divisions or branches for the distal anastomosis. Nerve restitution should be performed at this time unless extenuating circumstances rule out immediate grafting (anesthetic complications, intraoperative emergencies, etc). In the event that grafting is not undertaken at the time of nerve sacrifice, it should be completed within 72 hours thereafter so that the facial nerve stimulator may be used to identify the distal branches. When this is not done, the distal branch becomes nonstimulable and hence is much more difficult to locate and identify.

Surgical planning

In planning the procedure, the surgeon frequently finds the proximal site in the intraparotid portion proximal to the pes anserinus. This may present technical difficulties in that there may not be a sufficient proximal stump for technical ease in suturing. In other instances, the nerve may be transected at the stylomastoid foramen. Under these circumstances, a mastoidectomy should be performed and the facial nerve should be located in its midmastoid portion. Distal to this portion, the nerve's sheath merges with periosteum of the stylomastoid foramen and temporal bone, making this portion difficult to dissect free for suture. This difficult region exists roughly from 1 cm above to 1 cm below the stylomastoid foramen. Use of the mastoid portion of the facial nerve may require use of the longer sural nerve rather than the greater auricular nerve as a cable graft; this procedure will be discussed later.

Distally, several situations may be encountered that may require some ingenuity in effecting reanimation. When the distal anastomotic site is at the proximal to the pes anserinus, a simple nerve-to-nerve suture will suffice. More frequently, however, after resection for parotid malignancy several branches and/or divisions may present or anastomosis. In these cases, priority must be given to the zygomatic and buccal branches, sometimes to the exclusion of other less important facial nerve branches, because of the branching pattern of the nerve graft. Frequently, a two-branch graft can be prepared from the greater auricular or the sural nerve. This lends itself to suturing of one branch of the nerve graft to the buccal branch and the other graft branch to the zygomatic branch or superior division. This technique will direct innervation to the important orbicularis oculi muscle and the muscles of the buccal-smile complex (Fig. 63-4).

In the rare instance in which time has elapsed and distal nerve branches cannot be found, it is acceptable to route the necessarily longer nerve grafts directly to the important muscles cited, usually the orbicularis oculi and the zygomaticus major. Attachment of the graft into a denuded portion of muscle will allow some neurotization to occur.

Choosing a donor nerve

The two most commonly used donor nerves are the greater auricular nerve and the sural nerve. When harvesting the greater auricular nerve, tumor considerations mandate that the ipsilateral nerve not be used. Consequently the opposite neck should always be prepped and draped for harvesting the contralateral nerve in parotid tumor cases. Surgically the landmarks are well defined: a line drawn from the mastoid tip to the angle of the mandible is then bisected by a perpendicular line that crosses the sternocleidomastoid muscle from inferoposterior to anterosuperior, passing toward the parotid gland. The greater auricular nerve is directly beneath this line. By dissecting the nerve superiorly into the parotid, a two- and sometimes three-branch graft can be harvested. It is usually necessary to ligate branches of the posterior facial vein in this process.

Many surgeons prefer the sural nerve for facial nerve grafting. There are three main reasons why this graft is preferred:

1. Longer grafts (up to 35 cm) may be harvested.

2. The nerve has been shown to have a greater neural-to-connective tissue ratio and a larger diameter than most other nerves available for grafting, including the greater auricular (Sunderland, 1952).

3. A second operating team can harvest the nerve graft while tumor extirpation or grafting preparations are being performed in the parotid fossa.

The sural nerve is formed by the junction of the medial sural cutaneous nerve and the peroneal nerve between the two heads of the gastrocnemius muscle. The nerve lies immediately deep to and behind the lesser saphenous vein. A pneumatic tourniquet should be applied to the thigh and a transverse incision made immediately behind the lateral malleolus. As many "stair-step" horizontal incisions as necessary should be used coursing over the length of the nerve during the harvesting procedure. It is important to avoid tugging or other trauma on the nerve while harvesting. The nerve should be placed in lactated Ringer's solution after debriding away any small pieces of fat or other soft tissue that might interfere with vascularization of the graft.

Surgical technique

For neurorrhaphy, interrupted sutures of 9-0 or 10-0 monofilament nylon are preferred. A 75- or 100-micron needle is appropriate. A straight and a curved pair of jeweler's forceps as well as a Castroviejo needle holder are satisfactory instruments for performing the anastomosis. Both ends of the nerve graft and the proximal and distal stumps should be transected cleanly with a fresh sterile razor blade (McCabe, 1970). Some oozing of axoplasm will usually be seen at the proximal stump following preparation, but this generally can be ignored. For nerve trunk anastomosis, four simple epineural sutures will usually coapt the nerve ends accurately. However, obvious discrepancies in size or other epineural gaps should be closed with additional sutures. The needle should pass through epineurium only so as to avoid injury to the fascicular neural contents. The nerve graft should lie in the healthiest possible bed of supporting tissue, with approximately 8 to 10 mm of extra length for each anastomosis. Thus, the graft should lie in a somewhat "lazy S" configuration (Fig. 63-4), which appears to preclude tension during healing. Hemovac and other suction drainage systems should be placed well away from any portions of the nerve graft. When adequate nerve stump exist, securing them with a special microneural nerve clamp proves helpful. This facilitates the anastomosis in a manner similar to a microvascular anastomosis.

When one division may have been excised or injured and other portions of the nerve remain intact, it may be desirable to graft from a fascicle with the pes anserinus to a distal branch. It is possible to dissect the nerves and divisions proximally into the pes anserinus and perform fascicular dissection at this point. Curved jeweler's forceps used for dissecting in the plane and direction parallel to the nerve fascicles will allow this dissection (Fig. 63-5). The distal buccal branch often has several small filaments so it may be necessary to select the larger of these for distal anastomosis.

Approximation of the nerve ends using an acrylic glue has been described (Histacryl) or cyano-butyl-acrylate) (Miehlke, 1968). Subsequent investigators have shown that neural anastomosis with this tissue adhesive yields results similar to nerve suture. The technique is most helpful in tight temporal bone anatomic surgical situations rather than distal facial anastomosis (Siedentop and Loewy, 1979).

Following temporal bone resection, the nerve may be routed from the tympanic or the labyrinthine portions directly to the face through a bony window near the posterior root of the zygomatic arch. This will shorten the necessary length of the nerve graft. However, when using this technique it is important to ensure the nerve graft's protection from trauma at the temporomandibular joint if the joint is preserved. Conley and Baker have reported excellent results using similar techniques (Conley and Baker, 1979, 1983).

Millesi (1977) introduced interfascicular nerve repair reasoning that the exact microsurgical approximation of nerve fascicles or fascicle groups might minimize synkinesis and/or mass movement. It is well known that this type of repair is preferred in nerve injuries in the extremities; however, such repairs have not been universally accepted for use in the facial nerve. Several reasons exist for this limited acceptance. The tympanic, and in many cases, the mastoid portions of the nerve have only one or two fascicles and the intraneural topography is questionable. There are very few, if any, sensory fibers in the facial nerve in its extratemporal portion, so performing sensory-to-sensory fascicular repair is not of value.

We, as well as May and Miehlke (in independent reports), have reported that discrete spatially oriented fascicles are present in the nerve near the stylomastoid foramen (Crumley, 1980; May, 1973; Miehlke, 1958). Other authors, notably Sir Sidney Sunderland (1977) and Tomander et al (1980), have reported conflicting data demonstrating that various portions of the face are represented in a random fashion in the proximal nerve. At the present time, it is probably best to perform fascicular repair when the injury obviously lends itself to the technique, (ie, clean lacerations through the pes anserinus, branch nerve grafts that require fascicular dissection in the pes, etc) while waiting for basi research to reveal the exact neural topography of the more proximal portions of the nerve.

Cross-face nerve grafting

The creative and physiologic method of cross-face nerve grafting provides the possibility for facial nerve control of previously paralyzed facial muscles. It is the only procedure that has the theoretic ability of specific divisional control of facial muscle groups, for example, the buccal branch controlling the buccal branch distribution, the zygomatic branch innervating the orbicularis oculi, etc. Originally described by Scaramella and Smith in independent reports in 1971, the technique has not proven as advantageous as it was first thought to be. Anderl's work has shown the potential for this unique technique, following up the pioneering authors with his large series reported in several manuscripts. Anderl (1973) described his own results as good in 9 of 23 patients, while Samii (1979) reported only 1 of 10 cases had good movement as a result of this technique. A more recent update by Ferreira (1984) indicates that those patients operated on in the first 6 months of the paralysis did better than those operated on later; however, some of these cases may have undergone partial spontaneous reinnervation as they appeared to have had lesions without total palsy and the traditional waiting period of 1 year was not allowed to elapse.

The cross-face technique appears to suffer from a lack of sufficient axon population and neural excitatory vitality. It must be classified as of marginal value at the time of this writing, although its great potential may be realized in the future. Conley has discussed the shortcomings and unproven status of the procedure (Conley and Baker, 1983; Conley, 1979).

Surgical technique

The operative technique consists of transection of several fascicles, usually of the buccal branch, on the nonparalyzed side through a nasolabial fold incision. One to three sural nerve grats are approximated to these normal contralateral branches. The nerve grafts are then passed through subcutaneous tunnels, usually in the upper lip. Cross-face grafts for the eye region are often passed above the eyebrow.

The anastomosis with the paralyzed facial nerve branches is done by most surgeons at a second stage, 6 to 12 months after the first. As described by most authors, the first stage is performed in the first 6 months of paralysis. This is not advisable unless the paralysis is of known permanence; for example, if ipsilateral facial nerve regeneration may induce reanimation, the surgeon should wait. Tinel's sign may often be elicited on the paralyzed side after several months because of sensory fibers accompanying the motor fibers through the cross-face graft. At this time, the cross-face graft is explored and sutured to the appropriate branches on the paralyzed side. This is approached through a parotidectomy/rhytidectomy approach, and is usually performed within the parotid portion of the paralyzed side.

Currently the technique is only used in conjunction with free muscle transfers. Reinnervation of paralyzed facial muscles is not sufficient to justify the procedure without muscle transfer.

Nerve Transposition

Reinnervation by connecting an intact proximal facial nerve to the distal ipsilateral facial nerve is generally the preferred method for facial paralysis rehabilitation. It is only when a proximal facial nerve stump is not viable or available that attention should be turned to other systems, for example, muscle or nerve transfer.

Hypoglossal transfer

Of the various nerves available for anastomosis with the facial nerve, the hypoglossal nerve is preferred. The reason is that both an anatomic and a functional relationship exists between the facial and hypoglossal nerves. They both arise from a similar collection of neurons in the brainstem, and they also share similar reflex responses following trigeminal nerve stimulation (Stennart, 1979). In addition, the hypoglossal is in close anatomic proximity, and is readily available during other operations on the facial nerve. Hypoglossal nerve transection results in much lesser donor disability than does sacrifice of the spinal accessory or the phrenic, other regional nerves that have been used for facial reanimation. The most common criticism of hypoglossal transfer has been that of lack of voluntary emotional control. Although this is true, it is also usually true of ipsilateral facial nerve anastomosis in that mass movements and spasms usually preclude any voluntary control of eye closure, smiling, or other emotional movements.

Surgical technique

A parotidectomy incision with an extension inferiorly towards the hyoid bone is usually used. The procedure may also be performed with somewhat more difficulty through a modified rhytidoplasty incision, which passes behind the ear rather than anteriorly. The parotid gland is dissected forward from the sternocleidomastoid muscle and the facial nerve is identified in its trunk-pes anserinus region. The posterior belly of the digastric muscle is then identified and the hypoglossal nerve is dissected free immediately medial to the tendon of the latter muscle. The ansa hypoglossi should be identified and dissected free, so that if desired it may be sutured to the distal hypoglossal stump for reinnervation of the tongue musculature. The hypoglossal should be transected as far distally as possible to provide extra length for the anastomosis. It is advisable to then dissect the nerve and pass it superiorly deep to the posterior belly of the digastric muscle to facilitate anastomosis. Four to eight epineural sutures of 10-0 monofilament nylon complete the anastomosis, after the nerve ends are prepared carefully under high power using a blade breaker knife.

Results

In the largest series to date, 137 patients, approximately 95%, regained satisfactory tone in response, with some mass facial movement (Conley and Baker, 1979). Of these cases 15% demonstrated hypertonia and excessive movement in the middle one third of the face; however, none of these patients requested that the transferred nerve be reoperated. This excessive movement was found to decrease gradually over 10 to 20 years. Seventy-eight percent of the patients had moderate to severe atrophy whereas 22% showed minimal atrophy; this wide variability in response of the tongue to hypoglossal nerve transection has been confirmed by other series (Miehlke et al, 1979) (Fig. 63-6).

When desirable, the hypoglossal may be used to reanimate only one portion of the paralyzed face. Stennart (1979) used the hypoglossal nerve to reanimate the lower face while existing elements of the ipsilateral facial nerve were routed to the upper division for eye and forehead rejuvenation. Sachs and Conley (1983) describe a combination of the hypoglossal nerve with masseter transfer in a similar combined program. The author has used hypoglossal transfer for reanimation of the upper or lower division selectively by performing fascicular dissection in the pes anserinus to identify the specific fascicles that required reinnervation (Fig. 63-5).

Other nerve transfers

The spinal accessory nerve was used before the hypoglossal. Drobnik apparently performed the first XI-VII anastomosis in 1879 (Stennart, 1979). The phrenic nerve has been similarly used, but this technique causes paralysis of the diaphragm and induces undesirable involuntary inspiratory movements in the facial muscles (Hardy et al, 1957). The technique is now obsolete.

The neuromuscular pedicle technique described by Tucker transfers a branch of the ansa hypoglossi nerve and a small muscle block directly to paralyzed facial muscles. According to Tucker (1978) this procedure is of value only for the perioral muscles, depressor anguli oris, and the zygomaticus muscle. The procedure is described as transferring innervated motor endplates to the denervated facial muscles without the usual delay period seen with free nerve grafts and nerve transfers. The technique allows very limited reanimated strength because of the small number of axons present in the donor nerve. In addition, sound electrophysiologic confirmation that the technique actually produces reinnervation in somewhat lacking, despite a report by Anonsen et al (1985). Until physiologic data and confirmation by other surgeons are presented the procedure must remain in the category of potential but unproven.

Muscle Transfers

Free muscle grafts (nonvascularized)

Hakelius (1979) described 107 free muscle transplants in 89 patients. He reported transfer of the extensor digitorum brevis muscle of the second toe to the paralyzed eyelid. The muscle graft is placed through a bony tunnel in the nasal pyramid such that a portion of the muscle contacts the normal contralateral orbicularis muscle. For the buccal-smile complex of muscles, the palmaris longus or extensor digitorum brevis muscle is used. Similar techniques have been described by Thompson (1971) in England. The tendon of the palmaris longus is attached to the zygomatic arch on the paralyzed side. The muscle belly is then sutured to the oral commissure and allowed to interact with raw surfaces of the orbicularis oris muscle. Reinnervation of the graft occurs from the orbicularis oris muscle fibers on the nonparalyzed side. These procedures are largely of historical interest because refinements in microneurovascular transfer have made it possible to provide functional muscle replacement for atrophic paralyzed facial muscles.

Microneurovascular transfer

Microneurovascular muscle transer was popularized in the 1970s and has been combined with cross-face nerve grafting to restore some facial movement (Harii et al, 1976). Because facial movements are highly complex and interrelated, enthusiasm for free muscle transfer was stimulated by the potential to use muscles that might provide isolated or independent segmental contractions, such as for superior elevation of the oral commissure. In patients with absence of facial musculature (such as those with congenital paralysis as in Möbius syndrome) this approach seems to have strong potential. Various muscles including the gracilis, latissimus dorsi, serratus anterior, rectus abdominis, pectoralis minor, and extensor digitorum brevis have been used (Buncke et al, 1984; Delon and MacKinnon, 1985;

Harrison, 1985; O'Brien et al, 1980; Terzis, 1989). Length, width, and cross-sectional area of the donor muscle have proved to be important factors in achieving significant facial reanimation. Other considerations, such as fiber length to produce a range of excursion similar to the contralateral face and a segmental nerve supply facilitating independently functioning motor units and thinning of the donor muscle, are necessary (McKee and Kuzon, 1989). The gracilis is often selected for free-flap facial reanimation. Donor morbidity is minimal and a two-team approach can be used. Recently the extensor carpi radialis brevis was reported to be a nearly ideal single muscle to replicate a normal smile (Rubin, 1974; Wells and Manktelow, 1990).

Despite profound advances in microvascular technology, the proponents of free muscle transfer have clearly not demonstrated that it is the method of choice in facial reanimation. Problems of undesirable bulk, scarring, and asymmetric movement are seen with this as well as with other techniques. As a rule, facial movements on the reconstructed side are not as great as on the normal side. Delineation of the exact role of free muscle transfer must await further refinements in technique and improved results (Harii, 1979).

Masseter transfer

Although masseter and temporalis muscle transfer techniques are effective, they generally should be used only if ipsilateral cable nerve grafting is not possible. For most patients with viable facial muscles, a nerve transfer such as hypoglossal facial anastomosis, is also preferable to muscle transposition. However, when the proximal facial nerve and the hypoglossal nerve are unavailable, or when acial muscles are surgically absent or atrophied, new contractile muscle must be delivered into the face. A large group of patients who fit into this category are those whose complete paralysis has laster 2 years or longer. These cases are usually characterized by severe denervation atrophy, as noted upon electromyography. In these situations, muscle transfer is the preferred technique of reanimation.

Since the masseter was first used for facial reanimation in 1908, many modifications have been described (Lexer and Eden, 1911). Many authors, notably Conley, prefer the masseter muscle for rehabilitation of the lower and mid face (Conley and Baker, 1978).

The masseter transfer procedure is generally performed for rehabilitation of the sagging paralyzed oral commissure, and the buccal-smile complex of muscles. The masseter's upper origin from the zygomatic arch allows a predominantly posteriorward pull on the lower midface. Transfer of the muscle can be accomplished externally by way of a rhytidectomy/parotidectomy incision, or intraorally using a mucosal incision in the gingivobuccal sulcus lateral to the ascending ramus of the mandible (Fig. 63-7). The masseter's blood supply is medial and deep, and its nerve supply passes through the sigmoid notch between the condylar and coronoid processes of the mandible to reach the upper deep surface of the muscle. The nerve supply then ramifies and courses distally and inferiorly, terminating near the periosteal attachments on the lateral aspect of the mandibular angle and body. In general, the external approach is preferred, insofar as the intraoral approach is associated with somewhat limited access, poorer muscle mobilization, and less vascular control. The troublesome facial artery branches may be difficult to secure when using this limited exposure, hence the external approach is preferred.

A generous parotidectomy incision is made and extended inferiorly below the mastoid tip. The parotid gland and masseteric fascia is exposed. The posterior border of the muscle is freed from the mandible's ascending ramus, and the inferior attachments at the lower border of the mandible are also detached with electrosurgical cutting current. The nerve supply courses along the deep surface approximately midway between the anterior and the posterior border of the muscle (Fig. 63-7). Hence it is advisable to transfer the entire A-P diameter of the muscle, and preserve the deep fascial layer when dissecting the muscle free from the mandible. Mobilization of the periosteal attachments along the inferior border will allow secure tissue for anchoring sutures and promote more length of the transposed muscle.

Continued dissection is then carried forward to the nasolabial fold in the subcutaneous plane using large Metzenbaum or rhytidectomy scissors. The external incisions are made at or just medial to the nasolabial fold, the lateral oral commissure, and at the vermilion cutaneous junction of the lower lip. Each of these incisions is connected to the cheek tunnel, allowing transfer of slips of the masseter muscle. The muscle may be divided into three slips for attachment at these three sites, or the entire periosteal end of the muscle may be used to suture to the remnants of the obribularis oris muscle from the lateral upper lip to the commissure and just below. These muscle slips are sutured to the dermis and the orbicularis oris muscle using 4-0 clear nylon sutures. Recently, May (1984) proposed that suturing to the mucocutaneous line deep to the orbicularis muscle promotes a more normal aesthetic appearance and nasolabial fold as compared to suturing to the dermis. The best results depend upon:

1. Gross overcorrection. No matter how this procedure is performed, gravity and natural laxity of the tissues will allow for sagging of the oral commissure, so that the intraoperative result should be a contorted hyperelevation of the oral commissure.

2. Preservation of masseteric nerve supply.

3. Placement of many sutures in the transposed muscle. The surgical assistant should hold the oral commissure at the exaggerated overcorrected level during attachment of the muscle.

4. Following skin closure (the commissure should continue to be held upward), the skin of the perioral and cheek region should be painted with benzoin or Mastisol, and a tape dressing left in place for 7 days so as to retain overcorrection.

Perioperative antibiotics are recommended. The patient should not be given anything by mouth; nasogastric feedings should be administered for the first 5 days to minimize masseter movement.

Results from the masseteric procedure are quite gratifying and usually yield a high degree of facial symmetry. However, the masseter's arc of rotation will not allow or rehabilitation around the orbit. For this reason, the temporalis may be combined with masseter transfer, or used alone to rehabilitate the lower midface and the orbital region's paralysis.

Temporalis transfer

Although Gillies (1934) is usually given credit for introducing the temporalis procedure, Rubin (1977) deserves much credit for refining the goals of the procedure and the operative technique in the USA.

Like the masseter, the temporalis transfer procedure requires an intact ipsilateral trigeminal nerve. The nerve supply to the temporalis lies along the deep surface of the muscle. The upper origin of the temporalis muscle is fan-shaped and arises from the periosteum of the entire temporal fossa. The muscle belly converges on a short tendinous portion deep to the zygomatic arch and inserts on the coronoid process and a portion of the ascending ramus of the mandible. The muscle is best exposed through an incision that passes first above the ear, next slightly posteriorly, and then in an anteromedial arc. This will expose the entire upper portion of the muscle (Fig. 63-8). A convenient aponeurotic dissection plane exists lateral to the temporalis fascia.

In Rubin's technique, the muscle is dissected free from the periosteum and attached to fascial strips, which are turned down inferiorly to reach the oral commissure and eyelid area. If these fascial strips are omitted, the transposed muscle's length is insufficient to reach the lateral oral commissure.

We prefer to use the technique described by Baker and Conley (1979), who describe retaining the integrity of the upper muscle and its overlying fascia. The latter is dissected free, then turned inferiorly for suturing to the oral commissure.

A tunnel at least 1 to 1.5 in wide must be made over the zygomatic arch to allow the muscle to turn inferiorly and to eliminate an insightly bulge. The attachment of the strip should be just medial to the nasolabial fold so that the natural crease is reproduced by the muscle pull. As with the masseteric operation, a marked overcorrection is necessary on the operating table.

A soft silicone block may be used to fill the depression in the donor defect; hairstyling may obviate the necessity for this step.

The anterior one third of the temporalis muscle can be turned laterally into the eyelids (see Fig. 63-8). Subcutaneous tunnel dissection between the paralyzed orbicularis oculi and the eyelid skin allows passage of the fascial strips medially through both lids to the medial canthus, where they are sutured. As with any reconstructive procedure, adjustments and suture revisions should be checked carefully on the operating table so that the proper eyelid contour results from the procedure.

With both masseter and temporalis transfer, facial muscle activation originates from the trigeminal nerve. Patients need to be taught by videotape, biofeedback, or similar methods the proper way to contract the muscles by chewing or biting. Some younger patients may actually learn how to incorporate these movements into their own facial expressions; eg, smiles, grimaces, etc. However, patients should be told preoperatively that muscle transfer procedures will not allow any emotional or involuntary reanimation. In the best hands, these techniques will allow symmetry and tone in repose, with some learned and induced movements upon attempted chewing.

The surgeon must not forget the importance of corneal protection while planning and executing any of the above reanimation surgical procedures. To allow corneal desiccation and loss of the eye would be a tragic accompaniment to an otherwise successful reanimation result. Simple suture tarsorraphy will provide lid closure during the healing period before eyelid function returns, following temporalis transposition, XII-VII anastomosis, facial nerve neurorraphy, or grafting.

Summary

In summary, a variety of techniques is available for facial nerve rehabilitation following paralysis. The surgeon needs to know the advantages and disadvantages of the various techniques in order to apply them properly in each clinical situation. Thorough knowledge of neuromuscular pathophysiology is also important in understanding how time affects the choice of rehabilitative procedures. When properly informed regarding the limitations of these operative procedures, most patients can be rehabilitated and many of their symptoms can be alleviated.