Introduction

Facial function is often something taken for granted until it is compromised. The ability to express emotions such as joy, sadness, anger or confusion is something that makes humans unique from animals. A smile, a wink of an eye, and a raising of an eyebrow all convey messages without a single word being spoken. The popular game of poker realizes the wealth of information (and money!) that can be gained from the slightest facial expression; hence the term “poker face” was coined to describe a face that is unreadable...a face that is void of all emotion.

Needless to say, no one desires to live with a “poker face” the rest of their lives and it is important for otolaryngologists to understand the options available to patients with longstanding facial paralysis or sudden loss of facial function without likelihood of recovery. These two categories of patients are candidates for reanimation procedures. The expectations of the surgeon and the patient must be realistic and the primary goals of facial reanimation constantly emphasized: corneal protection, facial symmetry at rest, and symmetric smile restoration.

Facial nerve anatomy

Since the integrity of the facial nerve is critical to facial mimetics, it is prudent to have an understanding of the anatomy of the facial nerve prior to understanding facial reanimation. The nerve traverses intracranial, intratemporal and extratemporal territory. We will briefly review the segments as follows:

- Intracranial segment
  - Originates in pons
23-24mm segment within CPA to IAC

- Intratemporal
  - Meatal
    - From IAC to fundus
    - Anterior/superior portion of IAC (7-UP, Coke down)
    - 8-10mm
  - Labyrinthine
    - From fundus to geniculate ganglion (narrowest portion)
    - 3-5mm segment
    - Makes 1st genu prior to entering tympanic cavity
- Tympanic/horizontal segment
  - From geniculate ganglion to 2nd genu
  - 8-11mm
  - Superior to oval window/stapes
- Mastoid/vertical segment
  - 2nd genu to stylomastoid foramen
  - Anterior/caudal to lateral SCC
  - Lateral to sinus tympani and stapedius muscle
  - 10-14mm

- Extratemporal Segments - The extratemporal segments along with the muscles it innervates can be summarized as follows:
  - Postauricular Nerve
  - Nerve to stylohyoid
  - Nerve to posterior digastric

**Pes Anserinus**

- Temporal
  - Frontalis
  - Corrugator
  - Procerus
  - Upper orbicularis oculi

- Zygomatic
  - Lower orbicularis oculi
  - Anastomose with buccal b

- Buccal
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- Zygomaticus mm
- Levator anguli oris
- Buccinator
- Upper orbicularis oris

- Mandibular
  - Lower orbicularis oris
  - Depressor anguli oris
  - Depressor labii inferioris
  - Mentalis

- Cervical
  - Platysma

**Peripheral nerves and nerve injury**

A large portion of the facial reanimation techniques utilize the peripheral facial nerve (i.e. primary neurorraphy, anastomosis, etc). The peripheral portion of the facial nerve is basically like any other peripheral nerve in the body. Understanding the anatomy of peripheral nerves and how they respond to injury is important in developing a strategy to reanimate a patient’s paralyzed face. The peripheral nerve can be divided into 3 main components (listed from innermost to outermost): the endoneurium, the epineurium, and the perineurium. The endoneurium is the innermost portion that is adherent to the Schwann cell and crucial for regeneration of the nerve. Transection of this portion of the nerve results in poor prognosis for recovery and often results in aberrant regeneration, synkinesis or no regeneration at all. The perineurium is responsible for providing tensile strength to the nerve and provides a barrier of resistance to infection. Lastly, the epineurium (nerve sheath) is the outermost layer and responsible for nourishing the nerve via the vasa nervorum.

Nerve injury, according to Sunderland, can be classified into five main categories. These categories are based on histological studies displaying damage to various portions of the nerve:

- **First degree (Neurapraxia)**
  - Nerve compression/ischemia
  - Nerve continuity preserved/no Wallerian degeneration
  - Short period of dysfunction; rapid and complete recovery.
    - Partial loss of function (i.e. paresis instead of paralysis)
    - No muscle wasting
    - No signs of muscular fibrillation or degeneration

- **Second degree (Axonotmesis)**
  - Axon severed but endoneurium of Schwann cell intact.
Degeneration distal to injury site
- Loss of motor, sensory and sympathetic function at injury site.
- Muscle denervation distal to injury
- Fibrillation present as well as atrophy
- Recovery time dictated by injury severity (months)
- Complete functional restoration

- Third degree (Neurotmesis)
  - Intrafascicular injury with disruption of endoneurium
    - Wallerian degeneration/axonal decomposition
  - Delayed axonal regeneration
    - Recovery often incomplete
    - Aberrant regeneration
  - Motor and sensory function lost in field of injured nerve
    - Longer recovery period than 1st and 2nd degree injuries
    - Despite eventual re-innervation, muscle recovery may be incomplete at best

- Fourth degree (Neurotmesis)
  - Undisturbed nerve trunk but site of injury contains ruptured fasciculi, damaged Schwann cells and regenerating axons
    - Wallerian degeneration
    - Possible neuroma formation
  - Complete loss of motor, sensory and sympathetic function
    - Some degree of spontaneous recovery possible but is nonfunctional
    - Synkinesis; aberrant regeneration between fascicles

- Fifth degree (Neurotmesis)
  - Loss of nerve continuity; disruption of all structures in the area of injury.
  - Few viable neurons; severely disturbed retrograde neuronal function
  - Synkinesis/incomplete return of function
  - Axons may regenerate but fail to re-innervate the correct fasciculi

**Functional Anatomy of Facial Mimetics**

Functionally speaking, there are 18 paired muscles that participate in facial expression. When it comes to clinical assessment of facial function, however, there are certain muscles which play a larger role than others: the frontalis, orbicularis oculi, zygomaticus major, orbicularis oris, and the lip depressors. Functional elements that are scrutinized include the nasolabial fold (NLF) and the dynamics of the smile.
The nasolabial fold is comprised of dense fibrous tissue, the upper lip levators, and the striated muscles originating in the fascia of the nasolabial fold. At its superior limit, the fold begins at the convergence of the ala nasi, cheek, and upper lip. The fold then descends in a lateral course to end at the oral commissure. The nasolabial fold can assume varying shapes and depths and is unique to each individual. The nasolabial fold can appear straight, concave, or convex.

The smile, a facial expression people perform everyday without a second thought, occurs in two stages. First, the upper lip levators contract along with the nasolabial fold musculature to elevate the nasolabial fold against resistance from the cheek. Next, the levator superior, zygomaticus major, and caninus muscles raise the lip and NLF upward.

The smile comes in 3 main varieties: the zygomaticus major smile, the caninus smile and the full denture smile. The 3 smiles can be summarized as below:

- **Zygomaticus major smile**
  - Most common type (67%)
  - Dominated by zygomaticus major and buccinator muscle
  - Corners of the mouth elevate first

- **Canine smile**
  - 2nd most common (31%)
  - Mainly controlled by levator labii superioris contracting prior to zygomaticus major and buccinator
  - Dominant upward elevation of lip followed by elevation of corners of the mouth

- **Full-denture smile**
  - Least common (2%)
  - Due to contraction of elevator and depressors of the lips and angles of the mouth
  - Maxillary and mandibular teeth displayed

**Establishing candidacy and overall goals of reanimation**

Whenever a physician entertains the idea of surgery as a treatment option, candidacy for that surgical procedure must be established through careful evaluation of each individual patient. Facial reanimation is no exception to this rule. Those who are candidates for facial reanimation procedures are those with nerve transection injury, facial paralysis of 1 year or more, facial paralysis without physical or electrical signs of recovery, congenital facial dysfunction or those with hyperkinetic syndromes (hemifacial spasm, blepharospasm). Also, the goals of facial reanimation must always be kept in the forefront of both the surgeon and the patient’s mind: corneal protection, symmetry of the face at rest, and restoration of a symmetric smile. General principles to bear in mind are that reinnervation of facial muscles should occur as early as possible and the upper and lower face should be reanimated separately in order to avoid mass
movement. In addition, the surgeon should realize that both static and dynamic procedures can be employed to yield a satisfactory result. Lastly, each procedure should be tailored to the patient’s unique needs.

**Assessment and Planning**

Assessment of a patient with facial paralysis begins by looking at the situation as a whole; not merely determining which facial muscles are functional from those that are not. In addition to the functional deficit, the cause of facial paralysis should be ascertained, the duration of paralysis, the likelihood of recovery, the presence of other cranial nerve deficits, the life expectancy of the patient and lastly the patient’s individual needs and expectations.

In terms of the physical exam of the patient with a paralyzed face, the House-Brackmann scale is used to convey the extent of the injury:

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**Concept of Dynamic Reanimation**

When deciding on which surgical options are best suited for a particular situation, it may be beneficial to conceptualize the animated face as a continuity of 2 systems: a proximal system (facial nerve nucleus/proximal facial nerve) and a distal system (facial musculature and distal branches of facial nerve). Based on the integrity of these systems, various surgical options can be employed.

The first example using this 2-systems concept could be of a 33 year old patient who sustained iatrogenic facial nerve injury during a mastoidectomy. In this scenario, both the distal and proximal systems are still intact as this is an acute injury. Reinnervation options include primary neurorraphy or a nerve graft. In primary nerve repair, end-to-end anastomosis is preferred as long as it is tension free and ideally performed within 72 hours of injury. This method of repair can be performed with defects ≤ 17mm. The most common methods include group fascicular repair and epineural repair. During the process of primary nerve repair, it is important to remove all debris and devitalized tissue from the ends of the nerve to be reapproximated. Nonabsorbable suture in the form of 9-0 nylon is used taking care to use small bites of epineurium during the repair.
In situations where the defect is >17mm, then interposition grafting will be the method of choice. The most common cable grafts used include the great auricular nerve, the sural nerve and the medial antebrachial cutaneous nerve (MACN). When using cable grafts, recovery is noticeable in 6 months, but the patient as well as the surgeon should not expect a full recovery until 12-18months later. Most patients can expect to reach a House-Brackmann III. *(For details regarding the anatomy, methods of harvest for these cable grafts, please see the power point presentation (slides 24-32) that accompanies this text.)*

The second hypothetical scenario to utilize this two-system concept involves a 59 year old male who sustained loss of facial function following resection of an acoustic neuroma. In this scenario, it is feasible that the patient’s proximal system is no longer intact, while the distal system is unaffected. The most likely options to be used in this case would be nerve crossover techniques. Crossover techniques are most often used in scenarios where there is irreversible facial nerve injury, intact facial musculature/distal facial nerve function, intact motor endplates, or intact proximal donor nerves are available. Ideally, this type of repair is performed within a year of the onset of facial paralysis so as to avoid distal muscle atrophy. Advantages to crossover techniques include low level of difficulty, the time interval until movement (4-6 months), avoidance of multiple sites of anastomosis, and the achievement of mimetic-like function with practice. Disadvantages involve donor site morbidity and some degree of synkinesis. The most common techniques used in crossover grafting are the hypoglossal-to-facial (most popular), spinal accessory-to-facial (largely abandoned due to donor site morbidity), and facial-to-facial crossover utilizing the sural nerve. *The hypoglossal-to-facial technique is described in detail in the accompanied PowerPoint slides (slides 35-39) as well as a video demonstration of a “masseter-to-facial” crossover (not performed at our institution).*

A third example will be of a patient with Mobius syndrome; congenital facial paralysis. In this case, both the proximal and distal facial nerve as well as the facial musculature are not intact. Situations such as this will require the use muscle transposition or free muscle transfer for dynamic reanimation. Muscle transpositions, otherwise referred to as “dynamic slings”, are used when: a) the facial neuromuscular system is absent, b) neural techniques described earlier are unsuitable, c) facial nerve interruption of at least 3 years with loss of motor endplates and d) Crossover techniques are not possible due to donor nerve sacrifice. The most reliable muscle transfers presently being used include the temporalis and masseter transfers. It is important to note that although both of these techniques have been shown to yield satisfactory results, extensive biofeedback/physical therapy is needed due to the unnatural movements that are needed to perform facial expression. For example, with the temporalis muscle transfer, patients must learn to smile by clenching the jaws.

Indications for free muscle flaps/microneurovascular transfer are the same as those for muscle transfers previously discussed. This technique requires viable muscle as well as innervation and is traditionally performed in 2 stages. The first stage involves performing a cross-face nerve graft from the nonparalyzed side of the face to the paralyzed side using a sural nerve graft. After approximately 1 year, long enough to allow for neural ingrowth of the graft, the free muscle transfer is performed. The “workhorse” flap for free muscle transfer is the gracilis. However, other flaps such as the latissimus dorsi, extensor digitorum brevis, and
serratus anterior are also being utilized. Please see the power point slides that accompany this text in order to view illustrations regarding anatomy and surgical technique for the temporalis and masseter transfer (slides 43-48) as well as the gracilis flap (slide 51).

Paralytic Eyelids

The paralyzed eyelid can result in serious morbidity for the patient. Consequences of orbicularis oculi paresis include delayed blinking and lagophthalmos, impairment of the nasolacrimal system, xerophthalmia, risk of exposure keratitis, corneal ulceration and blindness. The goals of surgery when addressing paralytic eyelids is to maintain normal corneal epithelium. Depending on the specific situation, numerous techniques exist to address the eyelid: lateral tarsorrhaphy, lateral tarsal strip, gold weight/spring implants, and open v. endoscopic brow lifts for significant brow ptosis. All patients who are going to have eyelid procedures should have an evaluation by ophthalmology to assess visual acuity, lower lid laxity (snap test), tear production (Schirmer test), lacrimal system integrity (Jones test), and the measurement of the distance between the upper and lower eyelids upon closure (margin gap). (Slides 54-55 of the “facial reanimation” power point file display a technique for performing gold weight implantation as well as a video demonstrating the lateral tarsal strip procedure (actual video not obtained at our institution).

Static Procedures

Static procedures are indicated for a selected group of patients and situations: 1) Debilitated individuals with a poor prognosis, 2) those without nerve or muscle available for dynamic procedures 3) for use as an adjunct procedure with dynamic techniques to provide immediate benefit. The major advantages of static procedures include immediate restoration of facial symmetry at rest, less complaints regarding oral commissure ptosis (i.e. drooling, disarticulation, mastication difficulties), and relief of nasal obstruction caused by alar collapse. Today, a variety of materials can be utilized to create static slings. Materials such as Gor-Tex (PTFE), alloderm, and fascia lata have all proven successful. Gor-Tex and alloderm avoid donor site morbidity; however, a higher risk of infection has been reported compared to fascia lata. A technique for performing static facial slings is described on slide 58 of this power point file.

Summary Outline

(The outline below is reconfigured in algorithm format in the PowerPoint file -- slide 59)

Facial Paralysis

A. Acute (< 3 wks)
   1. Nerve exploration/decompression
   2. Nerve repair
      a. Primary anastomosis
      b. Cable grafting
i. Great auricular nerve
ii. Sural nerve
iii. Medial antebrachial cutaneous nerve (MACN)

B. Intermediate (3 wks- 2 yrs)
   1. Nerve transfer
      a. Hypoglossal-facial
      b. Spinal accessory-facial
      c. Masseteric-facial
   2. Cross face nerve grafting using sural nerve

C. Chronic (>2 yrs)
   1. Muscle transfers
      a. Temporalis
      b. Masseter
      c. Digastrics
   2. Free muscle flaps/microneurovascular transfer
      a. Gracilis
      b. Latissimus dorsi
      c. Serratus anterior
      d. Pectoralis minor

D. Static procedures/ancillary procedures (can be performed at any time period listed above)
   1. Gold weight/spring implants
   2. Slings
   3. Lid procedures

Discussion by Dr. Susan McCammon:

I should caution you not to use the greater auricular nerve in a situation in which you’re looking at a malignancy where you may have to do the neck, obviously, and there’s a potential for perineural invasion
References

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Lee, K.J. Essential Otolaryngology, 8th ed.

Lee, K.J., Elizabeth Toh. Otolaryngology: A Surgical Notebook


Canalis and Lambert. The Ear: Comprehensive Otology