Hypoglossal-Facial Nerve Anastomosis in Facial Reanimation: A Review

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Abstract

With the advancement in surgical techniques and instrumentation, especially after the introduction of operating microscopes and neuromonitoring, the incidence of iatrogenic facial nerve (FN) injury has decreased dramatically. However, the incidence of trauma and the traumatic injuries to the temporal bone/skull base have been increasing steadily, resulting in debilitating injury to the FN. Therefore, there has been a renewed interest among surgeons for various facial reanimation procedures. The backbone of these procedures is the hypoglossal-facial nerve anastomosis, which was introduced by Korte al [1]. However, this classical hypoglossal-facial nerve anastomosis leads to hemiglossal atrophy. To prevent hemiglossal atrophy and improve the quality of life, this classical procedure had undergone several modifications. In this review article, in addition to the description of classical hypoglossal-facial nerve anastomosis and its various modifications, we will discuss the management issues in patients with FN injuries.

Keywords
► facial nerve
► hypoglossal nerve
► anastomosis
► split
► reanimation

Introduction

Injury to the facial nerve (FN) results in facial paralysis. Facial paralysis is a debilitating condition associated with a variety of functional, psychological, and cosmetic problems that negatively affects all aspects of a patient's life. The surgical management of FN injuries is challenging and requires a multidisciplinary approach for its proper evaluation and treatment. In this review article, we will review various surgical approaches for facial reanimation.

The goals of facial reanimation in an established facial paralysis are facial symmetry at rest, symmetrical smile, oral competence, adequate eye closure (with protection of the cornea), absence or limitation of synkinesis/mass movement with voluntary, and coordinated, spontaneous facial movement.[1-4] However, this goal cannot be achieved in all the patients, as multiple factors often influence the final outcome after facial reanimation. Various factors that influence the surgical management and outcome include age of the patient, duration of facial paralysis, etiology of the paralysis, whether paralysis is complete, availability of proximal FN for anastomosis, availability of the motor donors that can be used for facial reanimation and, finally, compliance of patient to undergo long-lasting and complex rehabilitation.[1-4]

Etiology of Facial Paralysis

A variety of clinical conditions can cause FN paralysis. They can be broadly classified into the following three major categories:

1. **Intracranial causes** – Brain tumors (the most common being the cerebellopontine angle tumors like schwannomas), vascular abnormalities, developmental abnormalities, agenesis of the FN nuclei, trauma, and degenerative disease of the central nervous system (CNS).
2. **Intratemporal causes** – Developmental abnormalities, infections (bacterial or viral), tumors of the middle ear and mastoid region, trauma involving the fracture of temporal bone or skull base, and cholesteatoma
3. **Extratemporal causes** – Tumors of the parotid glands and skin (especially malignant) and iatrogenic.

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The most common cause of FN palsy in the literature review was found to be idiopathic/Bell palsy (70%) followed by trauma (10–23%), infections especially viral (4.5–7%) and neoplasms (2.2–5%).[4,5]

Approach to the Patient with FN Paralysis

A thorough detailed history and physical examination is essential. Detailed history about the onset of paralysis, initial degree of paralysis, duration, and associated symptoms. Physical examination includes careful observation and recording (especially video recording) of the facial asymmetries at rest, during voluntary, and reflex emotional movement. Degree of lid laxity, corneal opacities, oral competence, brow ptosis, and synkinesis should be noted, in addition to assessment of other cranial nerve deficits.

Diagnostic Tests

1. **Audiometry** – May be useful in identifying the etiology, secondary to retrocochlear lesion or mass lesion in the middle ear.
2. **Radiological investigations (CT and MRI)** – Evaluation of trauma to temporal bone or skull base as well as helpful in delineating various intracranial, intratemporal, and/or extratemporal tumors or pathologies.
3. **Electrodiagnostic tests** are used to estimate the severity of the nerve injury and are also helpful in explaining the prognosis to the patient.[3,4]

    a. **Electroneuronography (ENog)** – Most accurate and reproducible test; however, it is expensive and time-consuming. It provides an objective assessment of the FN function and measures the amplitude of evoked compound muscle action potentials (CMAPs). Surgery is required if there is a 90% decline in CMAP within the initial 14 days of the onset of facial paralysis.
    b. **Electromyography (EMG)** – Needle electrodes are placed within the facial musculature which measure spontaneous and voluntary electrical activity in the facial muscles. It is useful in assessment of muscle denervation and reinnervation with polyphasic action potentials indicating muscle reinnervation. It acts as an adjunct to electroneurography if surgical intervention is required

Procedures for Facial Reanimation

A variety of procedures have been proposed to address the issue of FN paralysis, which can be broadly divided into–

Dynamic procedures for FN paralysis – The primary aim of these procedures is to reanimate the face. They provide the best outcomes for facial paralysis in terms of function and cosmesis. Therefore, they should be offered to each and every patient with FN paralysis. These include procedures such as direct FN repair with or without grafting, nerve transfers, cross-facial nerve grafting, and various muscle transposition procedures.

Static reconstruction procedures for FN paralysis – They do not provide facial reanimation, rather they act as adjunctive procedures in conjunction with dynamic techniques. However, they can be performed alone in the patients who are not fit for dynamic reanimation such as those with advanced age, physically debilitated, or those who presented after a significant time lag after the injury. The objectives include protection of the cornea, enhanced mastication and speech production via elevation of oral commissure and restoration of facial symmetry at rest (cosmetic improvement) either alone or in combination. Static procedures include the following:

1. Plication or shortening of facial musculature.
2. Lifting or recreation of nasolabial fold.
3. Facial sling suspension procedures using allograft (sutures) or autograft (strips of tensor fascia lata).
4. Shortening or thickening of upper lip and lower lip with commissure preservation.
5. For ophthalmic care, lower-lid shortening or tightening, gold weight implantation, tarsorrhaphy, canthopexy and canthoplasty
6. A variety of rejuvenation techniques such as brow lift, facelift and blepharoplasty
7. Use of implants or injections to restore/improve cosmosis.

Surgical Management of FN Paralysis According to the Timing of Onset of Facial Paralysis

1. Surgical treatment of acute FN paralysis (if recognized within 3 weeks)

    a. Primary FN repair or grafting

If the injury is recognized at the time of surgery – Primary FN repair or grafting should be done as it results in the best treatment outcomes. Intracranial FN injuries occur most commonly during the surgical resection of vestibular schwannomas. In such cases, immediate repair of the injury should be done for the best results, either by direct end-to-end anastomosis or by using an interposition graft (greater auricular nerve or sural nerve) with or without use of fibrin glue. Additional length of the FN can be obtained by rerouting the tympanic and mastoid segments of the FN. However, most of the time, a graft is required. Interposition graft can be placed from the intracranial nerve segment to the extracranial segment, thus bypassing the temporal bone, or it can be placed between the intracranial nerve segment to the temporal segment. Occasionally, this procedure is technically demanding as the proximal nerve near the brainstem is short and without epineural covering. Additionally, constant brainstem pulsation and constant flow of cerebrospinal fluid (CSF) makes the surgery difficult. No return of the FN function should be anticipated sooner than 4 months after the transection of the nerve. If no recovery is seen after a period of 8 months, reexploration and examination of the site of repair should be done.

If the injury is recognized in the immediate postoperative period (as infrequently seen with surgeries in the mastoid region)–Immediately remove the mastoid dressing and ear pack. Wait for a few hours for local anesthesia-induced weakness to wear off. If the paralysis persists and the surgeon is not sure about the integrity of the FN, reexploration should be done as early as possible. However, if the paralysis persists and the surgeon is sure about the integrity of the FN, the patient is started on high-dose prednisolone therapy. After 72-hour ENog was done, if it shows > 90% degeneration, reexploration is warranted. If ENog shows < 90% degeneration, close monitoring of the patient is advised, paralysis worsens with time, and reexploration should be done after proper counselling of the patient.

b. **FN decompression surgery** – Usually done in cases of traumatic injuries to the FN, however, definitive indications is a matter of debate in the literature. Chang et al proposed that all patients presenting with complete FN paralysis should undergo ENog.[6,7] Patients showing more than 95% degeneration criteria on ENog between 6 to 14 days of trauma should be offered FN decompression surgery after explaining the prognosis to the patient. If decompression surgery is to be performed, a total FN exploration from the meatal foramen to the stylomastoid foramen should be done and the nerve should be decompressed for 180 degree of its circumference.

2. Surgical treatment of FN paralysis between 3 weeks to 2 years
   a. **Nerve transfers** – commonly used are hypoglossal, masseteric branches of the trigeminal nerve, spinal accessory and motor branches of the cervical plexus. The most commonly used procedure is the hypoglossal-facial nerve transfer and its various modifications.
   b. **Cross-facial nerve grafting** – Appropriate segmental branches of the healthy FN serve as a donor and sural nerve as a cable graft. It salvages the target facial muscles until the cross-facial nerve fibers arrive at the paralyzed side (usually 9–12 months after the procedure). This is followed by coaptation of the distal ends of the cross-facial nerve grafts with the peripheral branches of the involved FN in the second surgery.[8,9]
3. **Surgical treatment of FN paralysis > 2 years (chronic FN paralysis)** – Such long durations of FN paralysis usually cause atrophy of the native facial musculature, therefore, use of alternative muscles for facial reanimation is mandatory. This includes the following:
   a. **Regional muscle transfers** – The most commonly used muscle is the temporalis muscle, wherein a 1.5 to 2 cm wide strip of muscle is elevated from the cranium and rotated inferiorly to reach the oral commissure. Also, masseter muscle transfer can be used for smile reanimation.
   b. **Free muscle transfers** – using the techniques of microvascular free flap transfer, various muscles can be freely transferred for facial reanimation, such as gracilis, pectoralis minor, serratus anterior, latissimus dorsi, and others.

Hypoglossal-facial Anastomosis

It is the most widely accepted technique for FN neurotization. It was described by Korte in 1903 when he performed direct end-to-end neurorrhaphy between the hypoglossal nerve (HGN) and the FN with good results.[10] Before providing a detailed description of this procedure, it is important to understand the course and anatomy of the FN and HGN.

Anatomy of the Facial Nerve

FN surpasses all other cranial nerves in the human body in terms of its intraosseous length and tortuosity. The peripheral FN can be divided into 6 portions (from proximal to distal): cisternal, meatal (8–10 mm)– within internal acoustic meatus, labyrinthine (3–4 mm)– fundus of internal acoustic meatus to geniculate ganglion, tympanic (8–11 mm)– geniculate ganglion to the pyramid, mastoid (10–17 mm)– pyramid to the stylomastoid foramen, and extracranial. The extracranial portion can be divided into prebifurcation portion (between the stylomastoid foramen and its bifurcation into temporo- and cervicofacial divisions) and postbifurcation portion (from its bifurcation to five major facial branches in the parotid gland, i.e., temporal branch, zygomatic branch, buccal branch, marginal mandibular branch, and cervical branch). The FN supplies secretomotor fibers to the lacrimal, submandibular and sublingual glands, carries taste sensations from the anterior ⅔rd of the tongue and, most importantly, supplies the muscles of facial expression.[11]

Anatomy of the Hypoglossal Nerve

HGN is a pure motor nerve that arises from the hypoglossal nucleus in the medulla and leaves the brainstem through the anterolateral sulcus of medulla oblongata. It leaves the cranium by passing through the hypoglossal canal. Once out of the canal, it has a forward and downward oblique course in the neck. In the neck, it first runs posterior to the internal jugular vein, then lies medial to it, and at the level of digastric intermediate tendon it turns anteriorly toward the tongue. It supplies all the intrinsic as well as extrinsic muscles of the tongue except the palatoglossal muscle.[12,13]

Technique of Classical Hypoglossal-facial Anastomosis

Because of the close proximity of the HGN and the FN in the neck along with close connections of the FNs and HGNs in the brainstem as well as in the motor cortex(thereby increasing brain plasticity), HGN is the most favored nerve for anastomosis [14-16]

Timing of the surgery – To obtain the best results following neurotization, HGN–FN anastomosis should be performed within 1 year after the injury, as suggested by the majority of the authors in the literature review.[5,17] Longer intervals are associated with poor results as facial mimetic muscles undergo significant atrophy with time and they are histologically replaced by the fatty tissues.

Operative Steps – The patient is positioned supine with his head turned toward the contralateral side of facial paralysis, with shoulder roll under the ipsilateral scapula, so that the sagittal suture is almost parallel to the floor. The skin incision (preauricular type) begins in front of the tragus, goes around the ear lobe, and then follows the anterior border of the sternocleidomastoid muscle (SCM), terminating at the level of angle of mandible (►**Fig. 1A**). Dissection in the superficial plane will expose the parotid gland, SCM muscle, and superficial nerves and vessels (preserving greater auricular nerve). This is followed by search for the FN branches within the parotid gland at the posterior border. Once identified, they are followed proximally to identify the bifurcation of the FN. Another method of identification of the FN is by "auditory-mastoid polygon," as described by Campero et al in 2007 (►**Fig. 1B**).[18] This is followed by dissection in the deeper plane to identify the digastric muscle, HGN, and further exposure of the FN. Average distance from the digastric muscle posterior border origin to the exit point of HGN under the digastric muscle posterior border is usually 35.8 mm (range 30.1–41.5 mm). The posterior border of digastric muscle is then retracted posteriorly and inferiorly to expose the HGN behind the internal jugular vein at the level of axis vertebrae. The average distance between the bifurcation of the FN and the point where the HGN turns and becomes horizontal is 31.56 mm (range 27.6–35.8 mm). Therefore, to perform a tensionless anastomosis, approximately 18 to 20 mm of proximal HGN stump is required before it turns and becomes horizontal. This also requires sectioning of ansa hypoglossi to perform a major nerve transposition. After adequate mobilization, tensionless end-to-end anastomosis is performed using 10/0 nylon sutures.

Demerits/Pitfalls of classical HFN–FN anastomosis – With time and appropriate rehabilitation, most of the patients reported a good functional outcome following end-to-end HGN–FN anastomosis. Pitty et al reported positive results in 65% of his patients, poor results in 22%, and complete lack of innervation in 13% of the patients.[15] With time, eyelid and mouth closure, facial symmetry and voluntary function of the compromised face recovers significantly. However, the following are the major concerns:

1. Hemiglossal atrophy, leading to speech and swallowing problems (major concern).
2. Synkinesis.
3. No recovery of reflex gestures such as emotions.
4. Poor mobility of individual facial muscles.
5. Facial hypertonicity in some patients.

Anastomosis of a descending hypoglossal branch to the FN or anastomosis of a descending HGN branch to the distal stump of the HGN after classical HFN–FN anastomoses were also reported in the literature to reduce the above mentioned complications, but the operative results were inconsistent.

Fig. 1 Preoperative pictures of the patient showing (**A**) Preauricular skin incision. (**B**) Auditory-mastoid polygon for the localization of the FN. This polygon is formed by anterior vertical line–running by the anterior border of EAM cartilage, posterior vertical line–running by the tip of the mastoid process, superior horizontal line–obliquely placed, representing the lower end of the EAM cartilage and the tip of the mastoid process, and inferior horizontal line–2 cm below the inferior border of the EAM cartilage. EAM, external auditory meatus; FN, facial nerve.

Technical Variants of the Classical End-to-end HGN-FN Anastomosis

Various technical modifications have been proposed in the literature with the basic aim of minimizing disruption of HGN and achieving good facial reanimation (►**Fig. 2**).

1. **Split HGN for anastomosis** – was introduced by Arai et al, and later, a few modifications were done by Cusimano and Sekhar et al.[18,19] However, the histopathological evidence for usefulness of longitudinal splitting of HGN in anastomosis was provided by Asaoka et al.[20] Asaoka et al in 1999 performed a histomorphological analysis of the FNS and HGNs using 24 cadavers along with three severed FN specimens obtained during surgery.[20] The results were as follows:

    a. Number of axons in normal HGN cadaveric specimens (9778 ± 1516) > number of axons in normal FN cadaveric specimens (7228 ± 950) > number of axons in the injured FN specimens obtained intraoperatively.
    b. Cross-sectional areas of normal HGN cadaveric specimens (1.541 mm^2) > cross-sectional areas of normal FN cadaveric specimens (0.948 mm^2) > cross-sectional areas of injured FN specimens obtained intraoperatively (0.66 mm^2).

Therefore, the size of the cut end of the injured FN approximately matched with the size of the half-cut end of the HGN.

Operative Steps – After preauricular skin incision or modified Blair incision was used for parotidectomy (inverted L-shaped preauricular skin incision + cervical limb extending into the neck), FN is identified and sectioned as proximally as possible. This is followed by exposure and dissection of HGN till it passes deep into the mylohyoid muscle. Then longitudinal splitting of HGN to the level of facial artery has to be done. Each half of the HGN is then electrically stimulated to observe the contractions of the tongue muscles. The longitudinal half that showed the least response is selected for the anastomosis. This

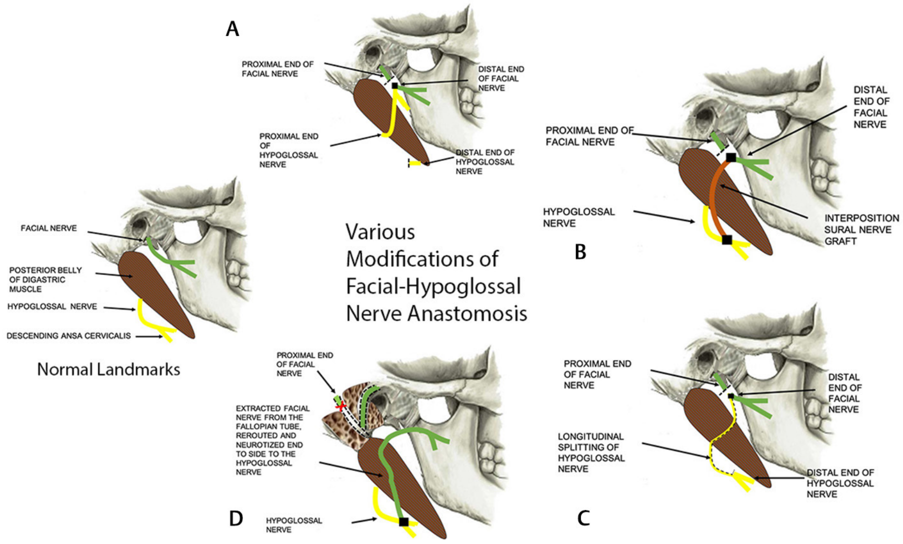

Fig. 2 Schematic diagram showing classical facial-hypoglossal nerve anastomosis and its variants (**A–D**).

half is divided as distally as possible. Then, the distal half end of HGN was anastomosed to the distal stump of the FN without tension.

Demerits/Pitfalls – As it involves the longitudinal splitting of HGN, there are high chances of trauma to the axonal bundles, which traverses the nerve in random and interweaving fashion, leading to unsatisfactory results after anastomosis in most of the case series in the literature.

2. **Interpositional jump graft technique** –
   The most commonly used is the sural nerve graft. The distal stump of FN is anastomosed with the HGN either in end-to-end fashion or in end-to-side fashion directly or after a small longitudinal incision in the HGN.[14,21] To avoid the problem of graft retraction after harvesting, the length of jump graft should be 25% longer than the distance between the stumps of FNs and HGNs. This technique was popularized by May et al, and it leads to improved tone and symmetry of facial musculature in most of the patients with preservation of the tongue function.[22] Additionally, the chances of "over-innervation" complications are reduced, as the axons have to cross two suture lines for facial reanimation.

Demerits/Pitfalls

1. Since the axons have to travel through two anastomotic sites before reaching their final destination, therefore the quality of reanimation and the time taken for the same is variable.
2. Donor nerve site morbidities such as numbness along the course of greater auricular nerve and sural nerve.
3. Release of extra length of FN for anastomosis

To perform a tensionless anastomosis between the FN and the HGN, an extra length of FN can be obtained by drilling the temporal bone and further mobilization of the FN, since the length of the FN from stylomastoid foramen to its bifurcation is approximately equal to 18.93 mm and the distance between the FN and the HGN is approximately equal to 31.56 mm. An extra length of 12.63 mm of the FN is required for a tensionless anastomosis, as the approximate length of the mastoid FN is 16.35 mm. Therefore, drilling of the mastoid bone and mobilization of the FN can be done as suggested by Sawamura and Abe et al.[23] This is the most preferred technique, as results are encouraging both in terms of facial reanimation and preservation of tongue function.[23,24]

Steps – After a lazy S-shaped incision (craniocervical) along the anterior border of SCM, approximately 8 cm in length, exposure of anterior ⅓rd of the mastoid process is done by partially detaching the SCM. This is followed by the exposure of the FN in the cranial base and further dissection within the parotid gland to aid easy mobilization. Then, partial resection of the mastoid process to open the stylomastoid foramen is done. Fracture of the styloid process and anterior retraction along with its attached muscles is followed by further exposure of the facial canal up to the external genu of the descending portion of the FN, using a diamond drill and copious irrigation. It is followed by the sectioning of the chorda tympani nerve and further mobilization of the FN as proximally as possible, so that adequate length of the FN is available for tensionless anastomosis. The HGN behind the internal jugular vein is then exposed. Approximately ½ to ⅖th of the HGN is transected proximally at the level between C1–C2 to the most proximal branch of descending part of HGN. Because of the large diameter of HGN at this level, less than ½ of the HGN is suitable for end-to-side anastomosis with the atrophic FN. This is followed by tensionless end-to-end anastomosis, which is performed using 10/0 nylon sutures.

Advantages

1. Single anastomosis.
2. End-to-end alignment of the axonal bundles.

3. Maintain the anatomic continuity of the HGN.
4. No requirement of donor graft.
5. Better preservation of the glossal function and restoration of the facial movements.

Demerits/Pitfalls – Involves drilling of the mastoid and the temporal bone, therefore long operative time.

Conclusion

Management of FN injuries is complex and challenging. For best results, it requires a thorough assessment of the patient injuries and a multidisciplinary team approach. Depending on the patient's clinical condition, both static and dynamic surgical interventions should be offered to the patients. Results of various reanimation procedures are encouraging; however, patients should be properly counselled about the results and the need for long-term follow-up and rehabilitation.

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Conflict of Interest
None declared.

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