Original Investigation

Transposition of the Intratemporal Facial to Hypoglossal Nerve for Reanimation of the Paralyzed Face
The VII to XII TranspositionTechnique

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IMPORTANCE The hypoglossal nerve has long been an axonal source for reinnervation of the paralyzed face. In this study, we report our experience with transposition of the intratemporal facial nerve to the hypoglossal nerve for facial reanimation.

OBJECTIVES To determine the feasibility and outcomes of the transposition of the infratemeporal facial nerve for end-to-side coaptation to the hypoglossal nerve for facial reanimation.

DESIGN, SETTINGS, AND PARTICIPANTS A case series of 20 patients with facial paralysis who underwent mobilization and transposition of the intratemporal segment of the facial nerve for an end-to-side coaptation to the hypoglossal nerve (the VII to XII technique). Participants were treated between January 2007 and December 2014 at a tertiary care center.

MAIN OUTCOMES AND MEASURES Outcome measures include paralysis duration, facial tone, facial symmetry at rest, and with smile, oral commissure excursion, post-reanimation volitional smile, and synkinesis.

METHODS Demographic data, the effects of this technique on facial tone, symmetry, oral commissure excursion and smile recovery were evaluated. Preoperative and postoperative photography and videography were reviewed. Facial symmetry was assessed with a facial asymmetry index. Smile outcomes were evaluated with a visual smile recovery scale, and lip excursion was assessed with the MEEI-SMILE system.

RESULTS All 20 patients had adequate length of facial nerve mobilized for direct end-to-side coaptation to the hypoglossal nerve. The median duration of facial paralysis prior to treatment was 11.4 months. Median follow-up time was 29 months. Three patients were excluded from functional analysis due to lack of follow-up. Facial symmetry at rest and during animation improved in 16 of 17 patients. The median (range) time for return of facial muscle tone was 7.3 (2.0-12.0) months. A significant reduction in facial asymmetry index occurred at rest and with movement. The MEEI FACE-gram software detected a significant increase in horizontal, vertical, overall lip excursion and smile angle. No patient developed significant tongue atrophy, impaired tongue mobility, or speech or swallow dysfunction.

CONCLUSIONS AND RELEVENCE Mobilization of the intratemporal segment of the facial nerve provides adequate length for direct end-to-end coaptation to the hypoglossal nerve and is effective in restoring facial tone and symmetry after facial paralysis. The resulting smile is symmetric or nearly symmetric in the majority of patients with varying degree of dental show. The additional length provided by utilizing the intratemporal segment of the facial nerve reduces the deficits associated with complete hypoglossal division/splitting, and avoids the need for interposition grafts and multiple coaptation sites.

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Facial paralysis is a potentially devastating injury with negative aesthetic, physiologic, and psychological effects.[1,2] Clinical signs of facial paralysis are a reflection of lack of facial muscle tone, diminished or absent excursion, and sequelae of aberrant reinnervation. Impaired eyelid closure with associated corneal exposure can subsequently lead to keratitis, corneal ulceration, and eventual blindness.[3] The loss of function of the nasalis and dilator naris muscles combined with the weight of the unsupported midfacial tissues may cause nasal valve collapse and nasal obstruction.[4] In the lower face, oral commissure incompetence may result in speech deficits, sialorrhea, and oral phase dysphagia. The loss of facial expression can impair the ability to effectively communicate emotions and has been associated with isolation, embarrassment, and decreased quality of life measures.[5,6]

To restore tone and movement to the paralyzed face, timely reinnervation of the facial muscles is essential. Reinnervation is ideally achieved by restoring facial nerve continuity with the ipsilateral facial nucleus by either direct or cable graft repair. When the proximal facial nerve stump is not available, alternative motor nerve sources such as the hypoglossal, masseter, contralateral facial and accessory nerves may be used.[7] The hypoglossal nerve is a common donor motor nerve used for facial muscle reinnervation.[8] In the classical description, the hypoglossal nerve is completely sectioned in the neck and coapted to the main facial nerve branch. Coaptation of the entire hypoglossal nerve to the facial nerve in this manner is effective in reestablishing facial tone and some volitional movement but is also associated with severe tongue hemiatrophy and dysfunction leading to difficulties with speech, mastication, and swallowing.[8-10] In addition, severe synkinesis and mass facial contraction has been reported. To minimize these complications, partial neurotomy of the hypoglossal nerve has been suggested. May et al[11] proposed the use of an interpositional graft between a partially sectioned hypoglossal nerve and the main facial nerve branch. While this approach minimizes tongue atrophy, it requires a secondary nerve donor site and also subjects regenerating axons to mechanical barriers across 2 separate coaptation sites. Arai et al[12] introduced the technique of splitting the hypoglossal nerve along its length and transposing a split segment for end-to-end coaptation to the facial nerve. Though the hypoglossal splitting technique limits coaptation to a single site and avoids a secondary donor graft, it risks more injury to hypoglossal axons.[11] An effective technique that avoids the need for a secondary donor graft, maximally preserves hypoglossal integrity, and uses a single coaptation site is desirable.

The intratemporal segment of the facial nerve is often preserved in cases of skull base lesions resected proximal to the geniculate ganglion. Mobilizing the available intratemporal facial nerve in continuity with the intraparotid segment offers an opportunity for gaining adequate facial nerve length for a single site, direct coaptation to the hypoglossal nerve.[13,14] In this study, we use objective outcomes to describe our experience with the facial to hypoglossal technique (VII to XII transposition technique) using direct intratemporal facial to hypoglossal nerve transfer for facial reanimation.

Methods

This study is a retrospective review of the clinical experience of a single surgeon at a tertiary care medical center from 2005 to 2014. This study was approved by the Institutional Review Board at Johns Hopkins Hospital and written consent was obtained for procedures. During this period, 20 consecutive patients underwent facial reanimation with decompression and direct transposition of the intratemporal facial nerve to the hypoglossal nerve. Three patients were excluded from functional outcome analysis due to lack of follow-up. Demographic data, facial nerve status at the time of reanimation, and duration of facial nerve paralysis for the remaining 17 patients are shown in **Table 1**. All patients presented with complete facial paralysis (House-Brackman score VI of VI) or near-complete facial paralysis (House-Brackman score of V of VI).[15] Archived photographs and videos taken in a standardized fashion before and after surgery were analyzed.

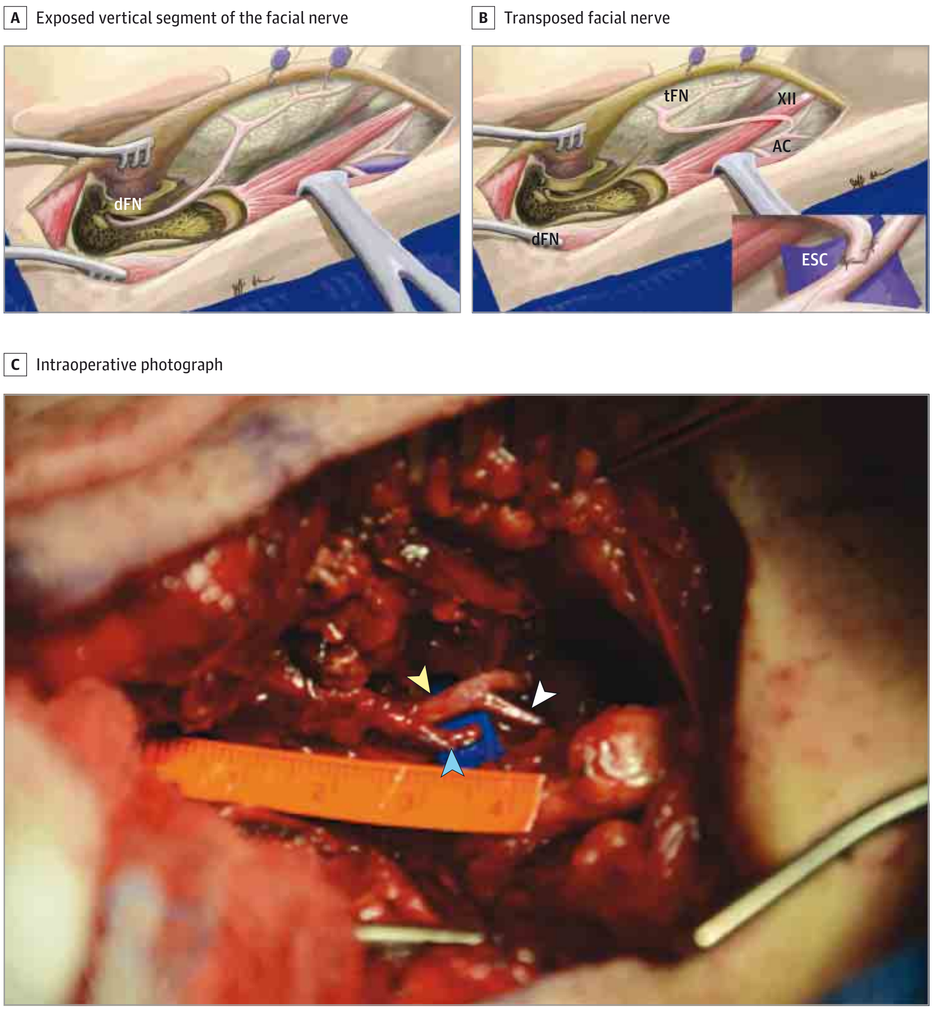
Surgical Technique

A cortical mastoidectomy is performed through a postauricular incision by a neuro-otologist. The vertical segment of the facial nerve is transposed from the second genu to the stylomastoid foramen (**Figure 1**). The facial nerve is divided as high as possible and carefully elevated out of the bony canal. The facial nerve is mobilized from the stylomastoid foramen extending into the parotid gland. The nerve branch to the digastric and the platysma muscles are clipped and divided. The incision is extended into the neck and the sternocleidomastoid muscle is exposed, the great auricular nerve is identified and preserved. The hypoglossal nerve is identified below the posterior belly of the digastric muscle and dissected distal and proximal to the takeoff point of the ansa cervicalis nerve. The mobilized facial nerve is tunneled through the parotid gland

Table 1. Demographic Data and Paralysis Durations

Patient No./Sex/Age	Facial Nerve Intact	Time to Facial Reanimation Surgery, mo	Time Until Onset of Recovery, mo	Total Paralysis Duration, mo
1/M/46	Yes	15	6	21
2/F/50	No	11	4	15
3/M/47	Yes	13	12	25
4/F/20	No	6	2	8
5/M/38	Yes	17	12	29
6/F/35	No	2	5	7
7/F/24	No	16	11	27
8/F/51	No	4	12	16
9/F/48	Yes	28	12	40
10/F/55	No	1	5	6
11/M/22	No	8	5	13
12/M/38	No	6	7	13
13/M/46	Yes	13	6.5	19.5
14/M/67	Yes	12	6	18
15/F/68	No	12	6	18
16/M/3	No	28	7	35
17/F/52	No	2	5.5	7.5

Figure 1. The VII to XII Technique



A, The vertical segment of the facial nerve decompression is exposed after mastoidectomy. B, The transposed facial nerve is coapted to the hypoglossal nerve anastamosis. The inset illustrates coaption with 30% to 40% neurotomy, distal to the ansa cervicalis take-off. Although the geometric configuration of the facial nerve to the hypoglossal nerve is end-to-side, the axons are oriented end-to-end. C, Intraoperative photograph showing the mobilized and transposed facial nerve (yellow arrowhead, hypoglossal nerve; white arrowhead, ansa cervicalis; blue arrowhead, transposed facial nerve). Approximately 4 cm of facial nerve length is gained with this approach for a tension-free coaptation. AC indicates ansa cervicalis; dFN, decompressed facial nerve; ESC, end-to-side coaptation; tFN, transposed facial nerve; XII, hypoglossal nerve.

to the hypoglossal nerve. Under operative microscope magnification, the hypoglossal nerve distal to the ansa cervicalis is prepared for coaptation. Adventitia is cleaned off a small segment of the hypoglossal nerve and the width of the nerve is ascertained. A 7-0 prolene suture is passed through the hypoglossal nerve to mark 30% to 40% of its width. A partial neurotomy is made to the prolene suture marker, which is then removed. The facial nerve is then coapted to the proximal exposed end of the hypoglossal axonal bundles using 9-0 or 10-0 nylon epineural sutures. The configuration of the facial nerve and hypoglossal nerve is now end-to-side but the axons make end-to-end contact (Figure 1B and C). The coaptation is reinforced with fibrin glue. In cases where tension-free coaptation could not be performed distal to the ansa cervicalis branch point, nerve coaptation is performed proximally to the cephalic aspect of the hypoglossal nerve to limit recruiting axons destined for the infrahyoid muscles.

Restoration of Facial Symmetry

Facial asymmetry was assessed with the facial asymmetry index (FAI) that was generated using the Mirror medical imaging software.[16] First, the length from the medial canthus to the ipsilateral oral commissure was measured on the affected and nonaffected sides. The difference between these 2 values, which provides an objective quantitative measure of asymmetry, is termed the facial asymmetry index (mm). A lower FAI corresponds to a lesser difference (closer symmetry) between the affected and nonaffected sides of the face (**Figure 2**). The medial canthus was chosen as a reliable reference point because it is a fixed point that rarely alters by dynamic facial movement or common periorbital procedures. The oral commissure was selected as reference point for the lower facial symmetry. Facial asymmetry index was compared for preoperative and postoperative photographs at rest and with an attempted smile.

Smile Quantification

Preoperative and postoperative photographss were quantified for smile and oral commissure excursion using the smile and oral Facegram software version 1.0 (Sir Charles Bell Society).[17]

Smile Recovery Score

A visual smile recovery scale was used to evaluate postoperative smile as seen by a casual observer in day-to-day social in-

Figure 2. Example of FAI Measurement

A, FAI = 2.6; B, FAI = 6.5; C, FAI = 0.1; D, FAI = 0.1 (at 28 months follow-up). A typical Mona Lisa smile is represented here with improved tone and contraction of the left lower eyelid, definition of the nasaolabial fold, and symmetric elevation of the oral commissure relative to the nonparalyzed right side. FAI indicates facial asymmetry index.

teractions. Recovered smiles were rated from 1 to 5 (1, poor; 2, adequate; 3, good; 4, very good; 5, excellent).[16] The smile recovery was reproducibly and objectively scored based on dental show counting the number of exposed upper teeth on each side of midline.

Synkinesis

The presence of synkinesis was recorded clinically and the type and response to intervention noted.

Statistical Analysis

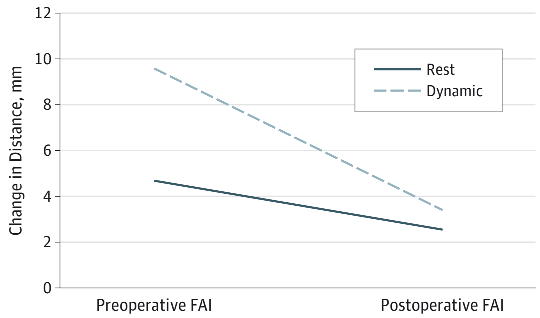
Statistical analysis for smile quantification and facial symmetry was performed using the Wilcoxon signed rank test. Data were considered statistically different for P values less than .05.

Results

The most common cause of paralysis was vestibular schwannoma (n = 10), followed by facial nerve schwannoma (n = 3). Other causes include Bell palsy, fourth ventricle cavernous angioma, geniculate ganglion hemangioma, and meningioma. Eleven patients underwent facial nerve transection with removal of a tumor in the cerebellopontine angle (CPA) or brainstem. The remaining 6 patients had anatomically intact facial nerves following CPA tumor resection but failed to spontaneously recover after at least 6 months of observation. All 20 patients had adequate facial nerve mobilized for direct coaptation to the hypoglossal nerve. The facial nerve was coapted distal to the ansa cervicalis branching point in 11 patients and proximally in 9 patients. Complete data with at least 1 year of follow-up was available for 17 patients. The median (range) duration of facial paralysis prior to treatment was 11.4 (1.0-28.0) months. The mean (range) reinnervation time (earliest clinical evidence of reinnervation) was 7.3 (2.0-12.0) months. Median (range) follow-up time was 34.0 (12.0-96.0) months.

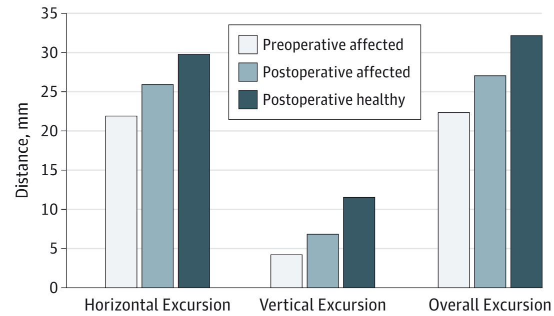
At rest, the preoperative mean facial asymmetry index was 4.67 mm. This was significantly reduced to 2.55 mm postoperatively (Δ = 2.12mm; P = .003). Preoperative mean facial asymmetry score with smile was 9.57 mm and was reduced to

Figure 3. Correction of the FAI Following the VII to XII Procedure



The FAI measures the difference in slope between the 2 lines, each measured from the medial canthus to the oral commissure on the affected and nonaffected sides of the face. Data are presented for mean FAI scores preoperatively and postoperatively at rest (solid line) and with dynamic movement or smile (dashed line). FAI indicates facial asymmetry index.

Figure 4. Mean Oral Commissure Excursion



Improvement in horizontal, vertical, and overall excursion from preoperative to postoperative measurements is compared with the nonparalyzed side. The mean oral commisure excursion was evaluated using the MEEI Face-Gram software.[17]

Table 2. Facial Asymmetry Index Scores, Preoperative and Postoperative Oral Commissure, and Smile Angle Measurements Using FACE-Gram

Patient No.	Smile Score	FACE-Gram Measurements, mm								Facial Asymmetry Index Measurements, mm			
		HE		VE		OE		SA		Rest		Smile	
		Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop
1	3	28.98	28.28	8.96	1.20	30.34	28.30	72.82	92.42	10.5	2.6	15.76	2.1
2	3	18.96	30.10	5.95	7.77	19.87	31.9	72.59	104.47	2.6	1.9	12.1	2.4
3	3	24.41	30.77	4.36	6.37	24.80	31.42	79.86	101.69	11	4.5	12	0.7
4	4	21.30	23.84	3.88	9.05	21.66	25.50	100.31	110.78	2.2	0.8	4.6	2.4
5	2	19.47	18.30	3.05	5.45	19.71	19.09	98.91	106.60	6.2	3.1	10	3.2
6	4	15.10	26.65	3.94	11.20	15.61	28.91	104.62	112.78	2.9	0.1	6.5	0.1
7	4	21.96	25.30	4.63	10.34	22.44	27.34	101.90	112.22	4	2.1	6.4	1.5
8	3	23.17	28.44	3.33	10.35	23.41	30.27	98.20	110.00	1.7	1.7	10.9	0.7
9	4	24.55	27.27	4.08	3.96	24.89	27.55	80.56	98.26	6.5	4.4	9.8	2.4
10	4	24.77	24.08	0.54	2.57	24.78	24.22	88.74	96.09	0.5	1	6.4	3.4
11	3	15.96	27.77	8.78	11.32	18.21	29.99	118.83	112.18	4.3	1.9	10.3	3.5
12	3	20.73	27.82	0.58	11.57	20.74	30.14	91.61	112.59	5.1	4.6	9.4	5.5
13	4	27.62	34.28	5.84	5.70	28.23	34.75	101.93	99.44	6.4	1.6	9.2	1.8
14	1	19.46	18.05	2.15	1.85	19.59	18.15	96.32	84.16	4.3	6.3	12.2	16.3
15	4	24.33	23.53	5.72	10.02	24.99	25.58	103.24	113.10	1.9	1.6	8.0	5.2
Mean		22.05	26.30	4.39	7.25	22.62	27.49	94.03	104.45	4.67	2.55	9.57	3.41
Mean change, mm		NA	4.25	NA	2.86	NA	4.87	NA	10.42	NA	2.12	NA	6.16
P value		NA	.005	NA	.012	NA	.004	NA	.004	NA	.003	NA	<.001

Abbreviations: HE, horizontal excursion; OE, overall excursion; Preop, preoperative; Postop, postoperative; SA, smile angle; VE, vertical excursion.

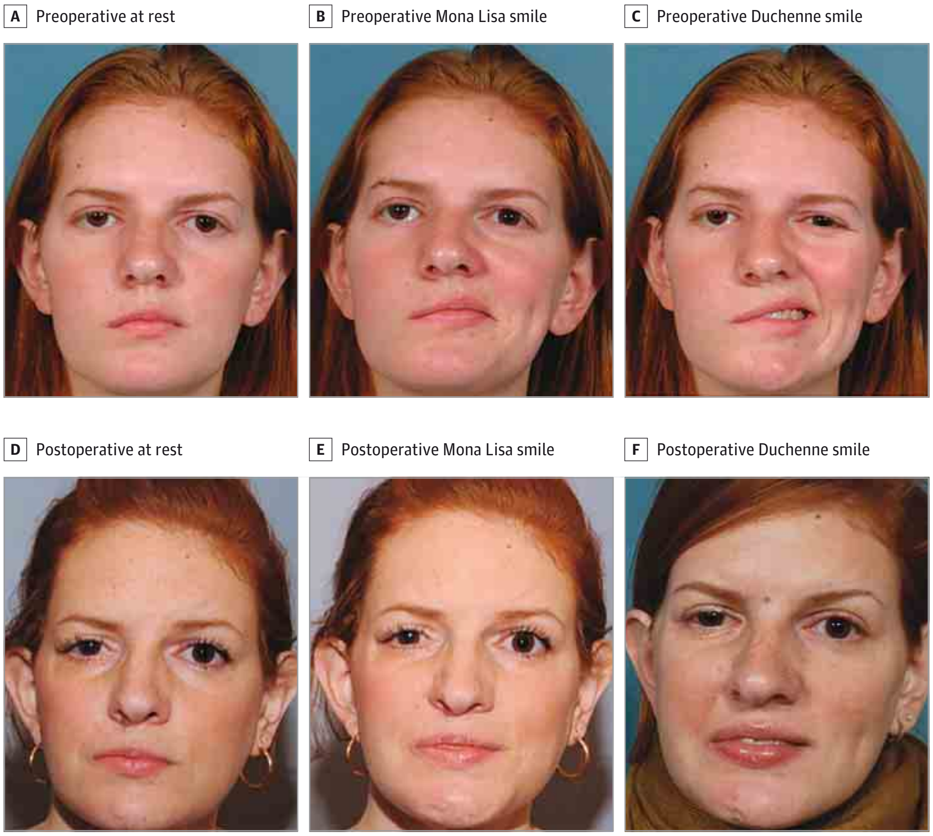
3.41 mm following reinnervation (Δ = 6.16 mm; $P < .001$) (**Figure 3**). Oral commissure excursion for all patients using the FACE-gram program is presented in **Table 2**. A statistically significant mean increase was found in horizontal (Δ = 4.24 mm; $P = .005$), vertical (Δ = 2.86 mm; $P = .01$) and overall excursion (Δ = 4.87 mm; $P = .004$) (Table 2 and **Figure 4**). Mean change in smile angle (Δ = 10.424 degrees) also significantly differed between the preoperative and postoperative photos for the affected side ($P = .004$) (Figure 3D). Using the visual smile recovery score, 7 patients had very good smile outcomes, 8 had good scores, 1 patient had adequate smile recovery, and 1 had poor smile recovery. No patient in this series had a clinically detectible restoration of dynamic brow elevation with tongue thrust.

The youngest patient in this series had hypoglossal nerve transfer following schwanomma resection at age 3 years and has been followed for 8 years. He regained near perfect symmetry, excellent commissure excursion, symmetric dental show, and symmetric initiation of commissure movement with attempted smile. However, in unguarded social settings (on a video review) when he laughed, his smile remained partially asymmetric.

Synkinesis

All patients who recovered animation had some degree of clinically detectible synkinesis. No patient developed significant mass movement defined as disfiguring abnormal movement of several muscles.

Figure 5. Preoperative and 66-Month Postoperative Photographs After VII to XII Procedure



A-C, Preoperative photographs. D-F, Postoperative photographs. Note that the paralyzed right upper lip has nearly symmetric bulk and tone relative to the nonparalyzed left side.

All patients were treated with selective botulinum toxin injections and facial retraining exercises, and the symptoms improved. No patient required secondary selective neurectomy. Two representative case illustrations are shown in Figure 2 and **Figure 5**.

Complications

No patient developed clinically evident tongue atrophy, impaired tongue mobility, speech, or swallow dysfunction. One patient developed a postoperative wound infection at their post auricular incision site that was treated with local wound care. One patient who had the nerve coaptation proximal to the ansa cervicalis branching point developed mild facial movement with swallowing that resolved over time. There were no complications related to the cortical mastoidectomy and facial nerve mobilization such as cerebrospinal fluid leak, hearing loss, vascular injury, mastoiditis, or a displaced auricle.

Discussion

The hypoglossal nerve is a common axonal source for dynamic facial nerve rehabilitation when the proximal stump of the facial nerve is not available. In its classic form, this procedure is associated with tongue hemiatrophy, speech and swallow dysfunction, facial movement and hyper-contracture. Modifications to the classic procedure have been proposed to improve facial function while minimizing functional deficits to the tongue.[11,12,18-25] Several authors have reported using split hypoglossal-facial nerve techniques to reanimate the paralyzed face.[12,18] As described by Arai et al,[12] the distal hypoglossal nerve is partially divided and split longitudinally along its length to gain length for direct coaptation to the main facial nerve branch. Initial results with the split technique were disappointing, but more recent studies have shown satisfactory results with mild to moderate hypoglossal hemiatrophy. Shipchandler et al,[18] using the May classification score, reported good to excellent results in 12 of 13 patients. Tongue morbidity from the hypoglossal splitting technique has been attributed to the trauma to axonal bundles associated with separating fascicles in a polyfascicular nerve.[11] As axons in the hypoglossal nerve thread their way through neural tubules in a random, interweaving fashion, splitting the nerve along its distal portion proves harmful and appears to cause hemiatrophy of the tongue because there is transection of axons at multiple points.[11]

To minimize tongue morbidity from complete hypoglossal sectioning or splitting, May et al[11] described the interposition graft technique. He reported improved tone and symmetry in all patients and a 10% recovery of mimetic movement. Preservation of tongue function has been consistently reported with this technique but restoration of tone, symmetry, and excursion has been variable.[26] One explanation is that the 2 neurorrhaphies necessary for interpositional grafting may inhibit axonal sprouting and migration through the donor graft compared with growth across 1.[22] Another disadvantage is donor site morbidity from harvesting the great auricular nerve, sural nerve, or other sensory donor grafts.

The mastoid segment of the facial nerve measures between 15 to 20 mm. This segment is often preserved following resection of facial nerve lesions at or proximal to the geniculate ganglion. Mobilizing the mastoid segment of the facial nerve in continuity with the intraparotid segment allows for direct coaptation to the hypoglossal nerve without the need for an interposition graft or nerve splitting. Several anatomic and clinical studies have presented data on this approach[13,14,19,25,27-29] Atlas and Lowinger[13] reported 3 cases of intratemporal facial nerve transposition using a similar technique, with functional recovery in all cases and a dramatic reduction in hemiglossal weakness. Recently, Slattery et al[25] described 19 patients who underwent a similar technique with 36.8% attaining House-Brackmann grade III, 47.4% a grade IV, and 15.8% a grade V result. Our experience with 20 patients using the VII to XII transposition technique shows a reliably high restoration of dynamic and static facial symmetry and excursion with minimal tongue morbidity.

Fundamental to the VII to XII transposition technique is the mobilization of adequate facial nerve for single-site coaptation to the hypoglossal nerve. We found that this feasible in all cases. Ideally, the facial nerve should be coapted distal to the branching point of the ansa cervicalis to avoid including axons destined for the infrahyoid muscles. In our series, the majority of patients had nerve coaptation distal to the to the ansa cervical branch point. Coaptation proximal to the ansa cervicalis resulted in transient facial twitching with swallowing in only 1 patient. Limiting the neurotomy to the cephalic aspect of the hypoglossal nerve when coaptation is performed proximal to the ansa cervicalis may explain the low recruitment of ansa cervical axons. Hayashi et al[30] attempted to determine if there was a difference in tongue atrophy when the facial nerve was coapted to a segment of the hypoglossal nerve that produced the least tongue contraction following intraoperative nerve stimulation. They found no difference in outcome using this technique and abandoned this selection approach.

Asaoka et al[31] established that the mean (SD) number of axons in a normal hypoglossal nerve is 9778 (1516) compared with 7228 (950) axons in a normal facial nerve. Partial neurotomy through 30% to 40% of the hypoglossal nerve exposes between 2900 to 3900 axons, which is approximately 40% of the motor axons in the facial nerve. Our results show that 30% to 40% hypoglossal neurotomy adequately reinnervates the paralyzed face. To ensure adequate neurotomy, we first clean the targeted segment of the hypoglossal nerve of its adventitia. Under high microscopic magnification, we pass a 7-0 nylon suture through the nerve to isolate 30% to 40% percent of its width. A sharp neurotomy is then performed to the guiding nylon suture. Preserving at least 50% of intact axonal continuity in the hypoglossal nerve may be necessary to maintain tongue function and preserve atrophy.

Abe and Sawaumura[14] hypothesized that the decreased tongue morbidity with VII to XII procedures was owing to partially sectioning the hypoglossal nerve proximal to the descending ansa hypoglossal branch. In this series, we performed partial neurotomy of the hypoglossal nerve both proximal and distal to the descending branch of the hypoglossal nerve. With either coapation site, we recorded no tongue morbidity. We theorize that the extent of neurotomy rather than the proximity to the ansa cervicalis underlies the degree of tongue dysfunction. The extent of neurotomy used in this series may also explain the absence of mass movement and severe hypercontracture recorded.

Among the various techniques described for recruiting hypoglossal axons for facial muscle reinnervation, the hypoglossal split technique is best suited for comparison with the VII to XII transposition technique described herein. Both techniques involve a single nerve coaptation site with end-to end alignment of axons, maintain anatomic continuity of the hypoglossal, and do not require a secondary donor nerve graft. Comparing and contrasting these 2 techniques is helpful to the clinician. The VII to XII transposition technique requires a cortical mastoidectomy and exposure of the vertical segment of the facial nerve to mobilize adequate nerve length for a single site coaptation. While most trained otolaryngologists are familiar with mastoidectomies, an otologist may be needed to perform this aspect of the procedure more efficiently. The split hypoglossal technique gains adequate length by separating hypoglossal fascicles along a longitudinal segment of the nerve. This approach risks injury to nerve axons that do not end up in the facial nerve but are wasted as they escape or sprout out into surrounding tissue. Compared with the isolated 30% to 40% neurotomy in the VII to XII technique, axons from the proximal neurotomy site that do not end up in the facial nerve still have an increased chance of tracking through the distal segment of the hypoglossal nerve. These technical differences may explain the much lower tongue morbidity recorded in our series when compared with series using the split nerve technique. Hayashi et al[30] proposed measures that they believe minimize collateral axonal injury when splitting the hypoglossal nerve. These include dissection under high microscopic magnification, and careful longitudinal splitting of the nerve fascicles with the finest possible technique against a lead background, which they believe minimizes spiraling of the nerve.

Unlike hand muscles where functional outcome following reinnervation surgery can be measured by assessing pinch, grip, and flexion and extension strength, objective measurement of facial muscle function after reinnervation remains a challenge. It is challenging to isolate single facial muscle action for measurement or composite action of all the muscles of facial expression given the voluntary and involuntary aspects that are often at play. Previous studies using the VII to XII facial reanimation techniques have heavily relied on the House-Brackmann grading scale to report outcomes, although this scale was not originally designed for this purpose. Therefore, the House-Brackmann scale was not used as an outcome measure in this study. A recent study introducing the eFACE scoring system[32] attempts to provide an electronic facial assessment application that reliably tracks facial recovery after reanimation procedures. For this study, we isolated the lower face from the periocular region for objective outcome analysis of both static and dynamic changes using photos and videos. Periocular effects of the VII to XII procedure were not analyzed because patients had undergone different types of static procedures.

Facial asymmetry, particularly of the lower face, triggers significant negative feedback from the observer and adversely affects patients with facial paralysis.[33-35] Restoring facial symmetry both at rest and with animation is a desired goal in facial reanimation surgery. In a previous study,[36] oral commissure asymmetry—as little as 3 mm—could be perceived by the casual observer. Oral commissure asymmetry was reported as unacceptable by 60% of casual observers viewing images for just 2 seconds when the difference was 6 mm or more.[35,36] In this study, the average preoperative asymmetry index at rest was 4.87 mm and 9.68 mm when a smile was attempted. Following the VII to XII procedure, the facial asymmetry index at rest and when smiling were significantly reduced (2.61 mm and 3.28 mm, respectively) below the 2-second, 6-mm observer threshold. The posttreatment mean asymmetry index was below the 3-mm perceptible threshold when at rest and slightly higher when smiling. The reduction in the facial asymmetry index following the VII to XII procedure is a reflection of improved tone on the paralyzed side and decreased hypercontraction on the nonparalyzed side.

Horizontal, vertical, and overall excursion of the lip, in addition to smile angles following the VII to XII procedures were objectively measured with the MEEI Face-gram.[17] In this series, the mean commissure excursion was noted to be 5.16 mm, a statistically significant improvement in excursion, but still less than the excursion of the nonparalyzed side.

Beyond the quantitative measurements of commissure excursion, we sought to analyze smile outcomes as they will be seen by a casual observer. Such a measure does not rely on measurements of length of contraction or angles but rather visual cues seen in day-to-day social interaction by the casual observer (eg, perceived symmetry and dental show). Using a visual smile recovery scale, we evaluated smile outcome based on oral commissure symmetry and upper dental show as a measure of the degree of upper lip elevation. The most desirable smile recovery outcome is characterized by spontaneity, symmetric lip excursion, and contraction of the orbicularis oculi muscle with wrinkling of the crow feet area and cheek elevation. This type of smile reflects light off the face and evokes positive emotional experience and feedback.[37] This smile type was not realized in any patient using the VII to XII procedure. However, the majority of patients were able to produce a symmetric Mona Lisa type smile (score of 3 on the smile recovery scale) with 6 patients developing very good smiles (score of 4) with nearly symmetric dental show. All patients who recovered showed signs of orbicularis contraction, malar elevation, and contraction of the zygomaticus muscle but no spontaneous animation without deliberate tongue action. Adaptation of the recovered smile in social settings requires facial retraining therapy directed by mirror and video feedback. In uncontrolled settings, spontaneous emotional expression, such as laughing, is poor with this technique. This is typical with all nerve substitution procedures relying on cranial nerves not driven by the facial nucleus. The youngest patient in this series with the highest potential for neural plasticity was 3 years old at the time of his reanimation procedure following complete resection of the facial nerve for a geniculate schwanomma. After 8 years of continuous physical therapy he is able to independently isolate eyelid closure and generate a nearly symmetric smile with symmetric dental show. His smile, with conscious effort, is quick in initiation but not completely spontaneous.

Restoring blink efficiency is a desirable but challenging goal in facial reanimation surgery with few dynamic solutions. In the VII to XII technique, regenerating axons can reach the orbicularis oculi muscle since the coaptation is done to the main facial nerve branch. Although not objectively measured, it is our experience that reinnervation of the orbicularis oculi leads to long-lasting improvement in lower eyelid tone. One can test improved tone to the orbicularis oculi muscle by asking the patient to voluntarily squint with the aid of tongue trust. Though we show successful reinnervation using the VII to XII technique in this cohort, the hypoglossal nerve, as a donor in facial reanimation should be used with caution, or avoided, in patients with disease processes that have affected 1 hypoglossal nerve or may progress to do so. Also, patients with preexisting dysphagia may have their condition worsened with the use of the hypoglossal nerve. In such cases, alternative donor nerves such as the masseter nerve should be considered. Familiarity with the unique strengths of the hypoglossal, masseteric, and alternative nerves allows the appropriate selection and design of reanimation procedures using each donor nerve in isolation or in combination. One limitation of this study is the use of instruments that assesses facial reanimation outcomes in controlled clinical settings. Given that patients spend more of their lives in unguarded social settings, it will be interesting to know how these reanimation techniques will fair when tested in real-world settings. The visual smile recovery scale used in this study attempts to study smile recovery from the perspective of a casual observer but requires further refinement and validation.

Conclusions

Transposing the intratemproal facial nerve to the hypoglossal nerve is an effective technique for dynamic rehabilitation of facial paralysis with minimal morbidity. The VII to XII technique reliably and significantly improves facial tone, symmetry, and oral commissure excursion. Smile recovery with this technique can achieve near symmetric oral commissure excursion, upper dental show, but true spontaneous movement may be difficult to attain. While interexaminer variability and subjective clinical evaluations make it difficult to compare different study cohorts for outcomes in facial reanimation surgery, this study objectively measures oral commissure excursion, smile outcomes, and facial symmetry following facial to hypoglossal transfer and lends support to its incorporation as an effective option for facial reanimation.

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