Neurorrhaphy for Facial Reanimation with Interpositional Graft: Outcome in 23 Patients and the Impact of Timing on the Outcome

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OBJECTIVE: **Neurorrhaphy with interpositional graft is a practical technique to achieve facial reanimation when the continuity of the facial nerve is interrupted and a large gap between the proximal and distal stump exists. The aim of this study was to report long-term outcomes of neurorrhaphy for facial reanimation with interpositional graft. The roles of some variable factors in the outcome of neurorrhaphy with interpositional graft were also evaluated and compared.**

METHODS: **A retrospective case series from a single tertiary referral center comprised 23 patients with facial nerve interruptions who underwent neurorrhaphy with interpositional graft using either end-to-end anastomosis or end-to-side hypoglossal-facial technique. Preoperative data (age, sex, primary lesion, interval from paralysis to surgery, facial nerve function), intraoperative data (surgical approach, graft and type of neurorrhaphy), and postoperative data (facial nerve function) were collected and analyzed.**

RESULTS: **Mean follow-up time was 26.6 ± 11.9 months. Patients who underwent neurorrhaphy for facial reanimation within 1 year after onset of facial paralysis were more likely to achieve House-Brackmann grade ≤3 compared with patients who underwent neurorrhaphy >1 year after onset of facial paralysis (odds ratio = 23.85, $P = 0.04$). No other factors were associated with improved outcomes.**

CONCLUSIONS: **Early neurorrhaphy with interpositional graft (≤1 year) for facial reanimation resulted in better final facial nerve function outcomes compared with a delayed procedure.**

INTRODUCTION

Facial paralysis leads to a significant deterioration in quality of life because of its negative esthetic, physiologic, and psychological effects.[1] With the development of improved surgical technique and the routine use of nerve monitors, the incidence of facial paralysis has gradually declined in temporal bone and lateral skull base surgery. Although the morbidity of intraoperative facial nerve interruption has been minimized, during resection of facial nerve schwannoma and other lateral skull base lesions, such as vestibular nerve schwannoma and petrous apex cholesteatoma, sometimes injury or even sacrifice of the facial nerve is still inevitable.[2,3]

If the continuity of the facial nerve is interrupted, it is essential to reinnervate the facial muscles in a timely manner to restore the tone and movement of the paralyzed face. Numerous procedures have been developed for different conditions. When the proximal facial nerve stump is available, reinnervation is ideally achieved by restoring facial nerve integrity by either direct or cable graft repair in an end-to-end manner. When the proximal stump of the facial nerve is unavailable, alternative motor nerve axonal sources, such as hypoglossal, masseter, contralateral facial, and accessory nerves, should be used for a crossover repair to restore partial facial nerve function.[4-7] Of all the crossover repair procedures that have been developed, hypoglossal-facial anastomosis is currently the most popular and successful.[8]

Key words
- End-to-end anastomosis
- End-to-side hypoglossal-facial anastomosis
- Facial paralysis
- Interpositional graft
- Neurorrhaphy

Abbreviations and Acronyms
HB: House-Brackmann

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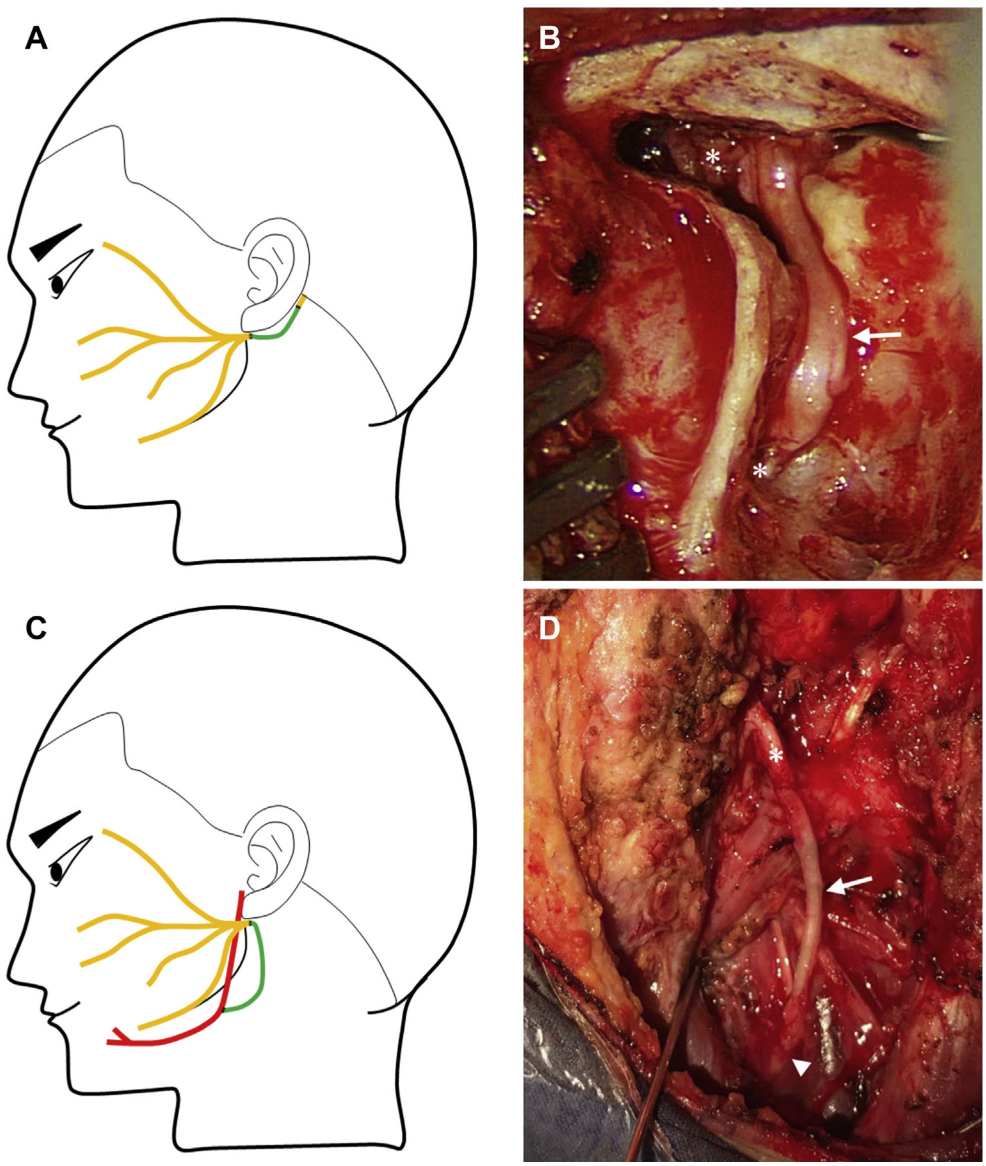

Figure 1. (**A**) Schematic diagram of end-to-end anastomosis of facial nerve with interpositional graft. The yellow line shows the interrupted facial nerve, and the green line shows the interpositional graft. (**B**) Intraoperative view of end-to-end anastomosis of facial nerve with interpositional graft. The *asterisk* shows the proximal and distal stumps of the facial nerve, and the *arrow* shows the interpositional graft. (**C**) Schematic diagram of end-to-side hypoglossal-facial anastomosis with interpositional graft. The yellow line shows the distal stump of the interrupted facial nerve, the green line shows the interpositional graft, and the red line shows the hypoglossal nerve. (**D**) Intraoperative view of end-to-side hypoglossal-facial anastomosis with interpositional graft. The asterisk shows the distal stumps of the facial nerve, the *arrow* shows the interpositional graft, and the *arrowhead* shows the hypoglossal nerve.

At the present time, there is still some disagreement regarding the effect of surgical facial nerve repair. In this study, we retrospectively studied patients with interrupted facial nerves who underwent neurorrhaphy using interpositional graft with different surgical techniques. The characteristics and facial nerve function outcomes of these patients and the roles of some variable factors, such as age, sex, type of neurorrhaphy, and interval from paralysis to surgery, in the outcome of neurorrhaphy with interpositional graft were evaluated and compared.

MATERIALS AND METHODS

All neurorrhaphies for facial reanimation with interpositional graft performed either separately or concurrently with the removal of primary lesion from June 2014 to March 2018 were identified. These operations were performed through different approaches, and the facial nerve was reconstructed using end-to-end anastomosis or end-to-side hypoglossal-facial neurorrhaphy with the sural nerve or great auricular nerve as an interpositional graft. The clinical data of all patients, including age, sex, primary lesion, surgical approach, graft, type of neurorrhaphy, interval from paralysis to surgery, and preoperative and postoperative long-term facial function, were retrospectively acquired. Facial nerve function was assessed using the House-Brackmann (HB) grading system.[9] Postoperative facial nerve function of HB grade ≤ 3 was defined as a successful outcome, as patients with HB grade ≤ 3 have symmetry at rest and are able to completely close the eyes.

Grafting Technique

The great auricular nerve was harvested by a cervical extension of the original retroauricular incision, and the sural nerve was harvested through an incision along the posterior lateral aspect of the lower leg. Both ends of the graft were sharply cut with scissors. We do not pay any attention to the orientation of the graft, as this factor does not affect reinnervation as demonstrated by Nakatsuka et al.[10]

The proximal and distal stumps of the facial nerve were thoroughly checked under a microscope, and their healthies was ensured by fast frozen section. Close attention was paid to the stumps of the facial nerve, as a well-identified stump that was well vascularized and healthy would trigger good axonal regrowth. If both stumps of the facial nerve could be identified, the proximal and distal stumps of the facial nerve were anastomosed with a cable graft in an end-to-end fashion. If the proximal stump of the facial nerve was located too deep in the temporal bone to be reliably anastomosed with the interpositional graft, end-to-side hypoglossal-facial neurorrhaphy was performed. When performing end-to-side hypoglossal-facial neurorrhaphy, the hypoglossal nerve was identified along the posterior belly of the digastric muscle and dissected out first. It was then partially transected at the dorsal aspect to one fourth of its diameter. The interpositional graft was anastomosed with the distal end of the facial nerve and the hypoglossal nerve in an end-to-end and end-to-side pattern, respectively. Nylon sutures and surgical glue were used at each anastomosis site (Figure 1).

Statistical Analysis

Stata 12 (StataCorp LLC, College Station, Texas, USA) was used for statistical analysis. HB grades were dichotomized into ≤ 3 (i.e., success) or >3. Binary multivariate logistic regression analysis was used to estimate adjusted odds ratio of HB grade ≤ 3 at the last follow-up. Criterion for statistical significance was set at 2-tailed $P = 0.05$.

RESULTS

From June 2014 to March 2018, 23 patients were operated on in our skull base surgery department for facial nerve repair using an interpositional graft. In 19 patients, the neurorrhaphy was performed concurrently with removal of the primary lesion. In the other 4 patients, repair of the facial nerve was secondary to facial nerve injuries caused by middle ear surgery or temporal bone fracture. The average interval between injury and repair in secondary cases was 1.31 ± 0.99 months. The patients' characteristics are summarized in Table 1. Patients included 8 men (34.8%) and 15 women (65.2%) with a mean age of 43.3 years (range, 23.4–63.2 years). Patients were followed for a mean duration of 26.6 months (range, 8.9–54.7 months). The transmastoid approach was the most commonly used surgical approach (14 of 23), followed by translabyrinthine (5 of 23), subtemporal (2 of 23), combined translabyrinthine/middle fossa (1 of 23), and combined transmastoid/middle fossa (1 of 23). Most patients (18 of 23) underwent end-to-end facial neurorrhaphy with interpositional graft; the remaining patients (5 of 23) underwent end-to-side hypoglossal-facial neurorrhaphy with interpositional graft.

HB grade outcomes before and after neurorrhaphy are shown in Table 1. The average duration of facial paralysis until the surgery was 35.2 months (range, 0–396 months). Of patients, 15 had surgery ≤ 12 months after the onset of paralysis (mean 2.4 ± 3.1 months; range, 0–12 months), and 8 had surgery >12 months after the onset of paralysis (mean 96.8 ± 125.0 months; range, 18–396 months). Of the 15 patients with facial paralysis for ≤ 1 year, 13 underwent end-to-end anastomosis with interpositional graft, and 2 underwent end-to-side hypoglossal-facial anastomosis with interpositional graft. Of patients with facial paralysis for >1 year, 5 underwent end-to-end anastomosis with interpositional graft, and 3 underwent end-to-side hypoglossal-facial anastomosis with interpositional graft. The final outcome of facial nerve function was HB grade 2 or 3 in 9 patients and HB grade >3 (unfavorable outcome) in 14 patients at last postoperative follow-up (Table 2). Clinically detectable synkinesis with no significant mass movement is a common manifestation in patients who recovered animation. Tongue movement was normal in all patients with hypoglossal-facial neurorrhaphy. Multivariate logistic regression analysis results are shown in Table 3. Except for the interval from paralysis to surgery, no other factors were associated with improved outcomes. When adjusted for patient age, sex, and surgical technique, neurorrhaphy performed ≤ 12 months after the onset of facial paralysis was associated with 23.85-fold greater odds of achieving HB grade ≤ 3 (95% confidence interval 1.15–493.43, $P = 0.04$).

DISCUSSION

Despite the improvement of surgical techniques and the use of intraoperative nerve monitoring, the facial nerve is still at risk of injury and sometimes has to be sacrificed for the radical removal of primary lesions in modern neuro-otologic procedures. When the continuity of the facial nerve has been interrupted, surgical repair of the facial nerve is needed to restore its motor function. Various facial nerve reanimation techniques have been developed to repair the facial nerve and partially restore its function, including end-to-end facial nerve anastomosis with or without interpositional graft, cross-face facial nerve anastomosis,

Table 1. Characteristics and Outcomes of Patients Who Underwent Neurorrhaphy for Facial Reanimation with Interpositional Graft

Characteristics and Outcomes	Value
Sex	
Male	8 (34.78%)
Female	15 (65.22%)
Age, years, mean (range)	43.3 (23.4—63.2)
Primary lesion	
Facial nerve schwannoma	10
Vestibular nerve schwannoma	3
Temporal bone chondrosarcoma	1
Petrous apex cholesteatoma	2
Middle ear cholesteatoma	1
Endolymphatic sac tumor	1
Temporal bone myxoma	1
Temporal bone fracture	1
Trauma	1
Iatrogenic injury	2
Approach	
Transmastoid	14
Translabyrinthine	5
Translabyrinthine + middle fossa	1
Subtemporal	2
Transmastoid + middle fossa	1
Type of neurorrhaphy	
End-to-end	18
End-to-side hypoglossal-facial	5
Graft	
Great auricular nerve	20
Sural nerve	3
Interval (paralysis to surgery)	
≤1 year	15
>1 year	8
Preoperative HB grade	
1	2
3	1
4	5
5	12
6	3

Continues

Table 1. Continued

Characteristics and Outcomes	Value
Postoperative HB grade	
2	1
3	8
4	10
5	4
Follow-up time, months, mean (range)	26.6 (8.9—54.7)

HB, House-Brackmann.

hypoglossal-facial neurorrhaphy, and masseteric-facial neurorrhaphy.[11,12] If a large gap between the proximal and distal stump exists, primary repair of the nerve is impossible, and a cable graft usually needs to be harvested from other donor sites for a tension-free neurorrhaphy. In our study, when the proximal stump of the facial nerve was accessible, an end-to-end anastomosis with interpositional graft was the first choice; and when the proximal stump of facial nerve was unavailable, the end-to-side hypoglossal-facial neurorrhaphy with interpositional graft was used.

The hypoglossal nerve is the most favorable axonal source for facial nerve rehabilitation owing to its adjacent anatomic location to the facial nerve, ideal caliber, and neuronal brain plasticity.[13,14] As sacrifice of hypoglossal nerve for an end-to-end neurorrhaphy always causes deterioration of tongue function, the end-to-side hypoglossal-facial neurorrhaphy has been developed aiming at partial hypoglossal nerve sparing. Currently, there are 3 modifications of this technique: hypoglossal-facial interpositional graft technique, split hypoglossal-facial anastomosis, and direct end-to-side hypoglossal-facial neurorrhaphy after mobilization of the intertemporal part of facial nerve.[15-17] In some of our cases, after radical removal of the primary lesion, the trunk of the distal facial nerve was too short to achieve a tension-free anastomosis using the split or intertemporal mobilization technique, so we performed hypoglossal-facial neurorrhaphy with interpositional

Table 2. Interval Between Surgery and Paralysis and Preoperative and Postoperative Facial Nerve Function

	Preoperative		Postoperative	
Interval Between Surgery and Paralysis	HB Grade ≤3	HB Grade >3	HB Grade ≤3	HB Grade >3
≤1 year	3	12	8	7
>1 year	0	8	1	7
Total	3	20	9	14

HB, House-Brackmann.

Table 3. Binary Multivariate Logistic Regression Analysis of Postoperative Facial Nerve Outcomes Adjusted for Patient Age, Sex, Surgical Technique, and Interval from Paralysis to Surgery

Covariates	OR of HB Grade ≤3 (95% CI)	*P* Value
Male sex	0.15 (0.02—1.47)	0.10
Age	0.94 (0.85—1.05)	0.29
Surgical technique (end-to-end)	0.78 (0.07—8.75)	0.85
Interval (≤1 year)	23.85 (1.15—493.43)	0.04*

OR, odds ratio; HB, House-Brackmann; CI, confidence interval.
**P* value <0.05 is considered significant.

graft to connect the hypoglossal and facial nerve in the end-to-side manner.

When using an interpositional graft in facial nerve repair, because the sprouting axon has to overcome 2 coaptation sites, the reinnervation quality is poorer compared with primary repair.[18] There are some other factors that also contribute to the long-term outcome of neurorrhaphy, such as the time interval from onset to repair, the type of primary lesion, and the condition of the nerve. Of all the factors contributing to optimal reanimation, timing of repair is the most important one. Because muscle tissue will gradually undergo fatty replacement and fibrosis after denervation, the very first criterion of neurorrhaphy for facial reanimation is to achieve motor axons reaching facial muscle endplate before muscle fibrosis and atrophy. Theoretically, the total duration of facial paralysis reflects how long the facial muscles are denervated; thus, neurorrhaphy performed within a short interval after facial paralysis could likely result in less denervated muscle atrophy and faster recovery. Cumulative data of previous studies have demonstrated that neurorrhaphy for facial reanimation in ≤1 year is very important for good outcome, and early anastomosis permits a better recovery.[19-22] In this study, our results show that patients who underwent neurorrhaphy for facial reanimation within 1 year after the onset of facial paralysis had a 23.85-fold odds of having HB grade ≤3 compared with patients treated in a delayed manner ($P = 0.04$). No other factors were associated with improved outcomes. This result demonstrated again that a short interval between the onset of facial paralysis (≤1 year) and surgical repair could bring better final outcomes than a long interval.

This study has several limitations. Most of the limitations are inherent owing to the retrospective nature of the study, such as being unable to confirm the accuracy of data and the lack of electromyographic data for these patients. Additionally, in this study, most patients underwent neurorrhaphy concurrently with tumor resection. Such an approach can significantly shorten the treatment period and reduce the total cost and is currently preferred and routinely adopted by the authors. However, as a potential treatment bias, simultaneous neurorrhaphy cannot totally rule out the possibility of tumor recurrence, which may lead to a poor prognosis of neurorrhaphy.

CONCLUSIONS

Neurorrhaphy with interpositional graft is an effective way to achieve facial reanimation when primary repair of the facial nerve is impossible. Patients may benefit from early neurorrhaphy with interpositional graft (≤1 year) for facial reanimation. However, owing to the sparse data on this subject, further investigation is needed to confirm this conclusion.

REFERENCES

1. Melvin TA, Limb CJ. Overview of facial paralysis: current concepts. *Facial Plast Surg*. 2008;24:155-163.
2. Matthies C, Samii M. Management of 1000 vestibular schwannomas (acoustic neuromas): clinical presentation. *Neurosurgery*. 1997;40:1-9.
3. McRackan TR, Rivas A, Wanna GB, et al. Facial nerve outcomes in facial nerve schwannomas. *Otol Neurotol*. 2012;33:78-82.
4. Shiobara R, Ohira T, Kanzaki J, Toya S. A modified extended middle cranial fossa approach for acoustic nerve tumors. Results of 125 operations. *J Neurosurg*. 1988;68:358-365.
5. Scaramella LF. Cross-face facial nerve anastomosis: historical notes. *Ear Nose Throat J*. 1996;75, 343, 347-352, 354.
6. Conley J, Baker DC. Hypoglossal-facial nerve anastomosis for reinnervation of the paralyzed face. *Plast Reconstr Surg*. 1979;63:63-72.
7. Coombs CJ, Ek EW, Wu T, Cleland H, Leung MK. Masseteric-facial nerve coaptation—an alternative technique for facial nerve reinnervation. *J Plast Reconstr Aesthet Surg*. 2009;62:1580-1588.
8. Yetiser S, Karapinar U. Hypoglossal-facial nerve anastomosis: a meta-analytic study. *Ann Otol Rhinol Laryngol*. 2007;116:542-549.
9. House JW, Brackmann DE. Facial nerve grading system. *Otolaryngol Head Neck Surg*. 1985;93:146-147.
10. Nakatsuka H, Takamatsu K, Koshimune M, Imai Y, Enomoto M, Yamano Y. Experimental study of polarity in reversing cable nerve grafts. *J Reconstr Microsurg*. 2002;18:509-515.
11. Garcia RM, Hadlock TA, Klebuc MJ, Simpson RL, Zenn MR, Marcus JR. Contemporary solutions for the treatment of facial nerve paralysis. *Plast Reconstr Surg*. 2015;135:1025e-1046e.
12. Bianchi B, Ferri A, Sesenna E. Facial reanimation after nerve sacrifice in the treatment of head and neck cancer. *Curr Opin Otolaryngol Head Neck Surg*. 2012;20:114-119.
13. Cusimano MD, Sekhar L. Partial hypoglossal to facial nerve anastomosis for reinnervation of the paralyzed face in patients with lower cranial nerve palsies: technical note. *Neurosurgery*. 1994;35:532-533.
14. Asaoka K, Sawamura Y, Nagashima M, Fukushima T. Surgical anatomy for direct hypoglossal-facial nerve side-to-end "anastomosis.". *J Neurosurg*. 1999;91:268-275.
15. May M, Sobol SM, Mester SJ. Hypoglossal-facial nerve interpositional-jump graft for facial reanimation without tongue atrophy. *Otolaryngol Head Neck Surg*. 1991;104:818-825.
16. Arai H, Sato K, Yanai A. Hemihypoglossal-facial nerve anastomosis in treating unilateral facial palsy after acoustic neurinoma resection. *J Neurosurg*. 1995;82:51-54.
17. Atlas MD, Lowinger DS. A new technique for hypoglossal-facial nerve repair. *Laryngoscope*. 1997;107:984-991.
18. Mark M, Barry MS. *Facial Paralysis: Rehabilitation Techniques*. New York: Thieme; 2003.
19. Guntinas-Lichius O, Streppel M, Stennert E. Postoperative functional evaluation of different

reanimation techniques for facial nerve repair. *Am J Surg*. 2006;191:61-67.

20. Samii M, Matthies C. Indication, technique and results of facial nerve reconstruction. *Acta Neurochir (Wien)*. 1994;130:125-139.

21. Kunihiro T, Kanzaki J, Yoshihara S, Satoh Y, Satoh A. Hypoglossal-facial nerve anastomosis after acoustic neuroma resection: influence of the time anastomosis on recovery of facial movement. *ORL J Otorhinolaryngol Relat Spec*. 1996;58:32-35.

22. Yawn RJ, Wright HV, Francis DO, Stephan S, Bennett ML. Facial nerve repair after operative injury: impact of timing on hypoglossal-facial nerve graft outcomes. *Am J Otolaryngol*. 2016;37:493-496.

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