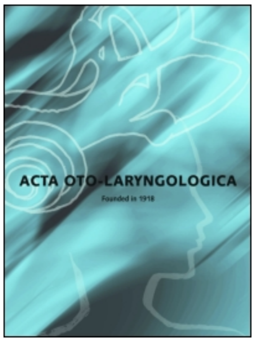

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RESEARCH ARTICLE

Facial reanimation using hypoglossal-facial nerve anastomosis after schwannoma removal

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ABSTRACT

Conclusion: In this series, the split type hypoglossal-facial nerve anastomosis resulted in more favorable outcomes in terms of both facial function and tongue atrophy.

Objective: This study compared surgical techniques for hypoglossal-facial nerve anastomosis after schwannoma removal and evaluated which technique achieves better facial outcomes and less tongue morbidity.

Method: This study included 14 patients who underwent hypoglossal-facial nerve anastomosis after schwannoma removal and were followed for more than 1 year. Three surgical techniques were performed: end-to-end, end-to-side, and split anastomoses. Facial palsy and tongue atrophy after anastomosis were evaluated using the scales suggested by House-Brackmann and Martins, respectively. Tumor volume and the time to surgery were also evaluated, and the effects on facial outcomes were analyzed.

Results: Overall, nine of 14 (64.3%) patients had favorable facial outcomes, and eight of 14 (57.1%) had favorable tongue outcomes. Regarding facial palsy, five of seven (71.4%) end-to-end, three of four (75%) split, and only one of three (33.3%) end-to-side patients had favorable facial function. Regarding tongue atrophy, all three (100%) end-to-side, three of four (75%) split, and two of seven (28.6%) end-to-end patients had favorable tongue outcomes. The effects of tumor volume and time to surgery on facial outcome were not significant.

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Facial palsy; hypoglossal-facial nerve anastomosis; tongue atrophy; schwannoma

Introduction

Preservation of facial nerve function is one of the primary goals in the comprehensive management of vestibular schwannoma. Most major centers now report higher anatomical preservation rates for the facial nerve [1]. Nevertheless, facial palsy may still occur with anatomic preservation of the nerve. Furthermore, resection of the facial nerve to achieve gross total tumor extirpation or facial nerve trauma during tumor management sometimes results in facial palsy. Depending on the degree of facial nerve injury, facial function may recover spontaneously. Unfortunately, some patients have permanent complete palsies. Managing facial palsy resulting from vestibular schwannoma removal requires a clear set of principles based on neuromuscular physiology and a systematic approach to patients to direct treatment options and allow predictable outcomes.

Several types of facial nerve anastomoses are used for facial reanimation, including primary end-to-end anastomosis [2], cable nerve graft interposition [3], and XII-VII nerve anastomosis [4,5]. Direct end-to-end anastomosis of the facial nerve or an interposition graft using the greater auricular nerve or sural nerve needs both the proximal and distal stumps of the facial nerve. These methods also have a time limitation after resection.

When the nerve is preserved anatomically during surgery, but post-operative facial palsy develops, direct end-to-end or interposition methods are inappropriate because the injured site is not obvious. Moreover, it is difficult to determine whether the palsy is permanent or reversible. In such cases, the correct strategy is to wait for spontaneous improvement. A nerve graft should be considered if there is no improvement after 6 months. When the damaged site is not obvious or more than 6 months have elapsed after the palsy developed, end-to-end anastomoses and interposition grafts are not effective and a nerve crossover, such as a XII-VII nerve anastomosis, is a good alternative option [6].

Generally, there are three XII-VII nerve anastomosis techniques. The first type is the traditional end-to-end anastomosis proposed by Körte [7] in 1903. In this technique, the hypoglossal nerve is transected and the entire cut edge of the proximal hypoglossal nerve is sutured directly to the distal facial nerve trunk. Ballance [8] suggested the end-to-side anastomosis in 1932; this technique does not transect the hypoglossal nerve and can preserve the continuity of the

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nerve and reduce tongue morbidity by making an epineural window, rather than resecting the hypoglossal nerve. However, facial recovery is doubtful. For better reanimation of the facial muscles and less tongue morbidity, the split anastomosis was designed [9]. The reported return of facial function is similar to that of the end-to-end anastomosis. However, no reports have directly compared all three types of anastomoses within a single institute. To compare the outcomes of the three types of anastomoses, we reviewed the long-term facial function and tongue atrophy in patients who underwent XII-VII nerve anastomosis after schwannoma removal. Other contributing factors were also analyzed.

Materials and methods

Patient population

From June 2011 to October 2015, 21 patients with complete facial palsy after schwannoma removal underwent XII-VII nerve anastomosis performed by the same surgeon. Of these, 14 patients were followed for more than 1 year. Three types of surgical techniques were performed for XII-VII nerve anastomosis: end-to-end in seven patients; end-to-side in three; and split in four patients.

Grading unilateral facial palsy

Facial nerve function was evaluated pre- and post-operatively using the facial nerve grading system of House and Brackmann [10]. The assessment includes gross facial appearance at rest, with movement, and during motion of the forehead and around the eyes and mouth. Facial nerve function was graded from I–VI and the patients were divided into favorable (grades II and III) and unfavorable (grades IV and V) groups.

Grading tongue atrophy

The degree of tongue atrophy was evaluated and graded from I–IV according to the scale proposed by Martins et al. [11]. A normal tongue was graded I, and discrete hemi-atrophy without deviation was graded II. Patients with mild hemi-atrophy and tongue deviation less than 30° were graded III, and those with severe hemi-atrophy and deviation over 30° were graded IV. After grading, the patients were divided into favorable (grades I and II) and unfavorable (grades III and IV) groups.

Hypoglossal–facial nerve anastomosis method

Common surgical procedure was performed to identify hypoglossal and facial nerve. A retroauricular incision was made and extended toward the neck. The facial nerve was identified between the stylomastoid foramen and the posterior margin of the parotid gland. The hypoglossal nerve was identified along the posterior belly of the digastric muscles, and then dissected free just before it passed deep to the mylohyoid muscle. Then, three XII-VII nerve anastomosis techniques were performed (Figure 1).

The end-to-end is the classical anastomosis and transects the hypoglossal nerve. To ensure sufficient proximal hypoglossal nerve stump, the nerve was transected as far distally as possible. The facial nerve was dissected and prepared so that it can be connected without stretching. Then, the transected proximal hypoglossal nerve stump was sutured to the distal stump of the facial nerve (Figures 2(A–C)). The end-to-side anastomosis did not transect the hypoglossal nerve, but made an epineurial window instead using microdissection scissors. The facial nerve stump should be able to reach the hypoglossal nerve. Without interrupting the continuity of the hypoglossal nerve, the facial nerve stump was connected to the hypoglossal nerve through a small epineurial window (Figures 2(D–F)) [12]. The split anastomosis constructed a longitudinal branch of the hypoglossal nerve by making a linear incision to parallel the direction of the hypoglossal nerve fibers using an 11-blade edge [6,9]. Then, half of the divided hypoglossal nerve was transected distally, and the distal end was translocated superiorly. The facial nerve was dissected and the distal stump of the facial nerve was translocated to inferior to meet the split branch of the hypoglossal nerve without stretching. The divided half of the hypoglossal nerve was connected to the distal facial nerve stump, while the remaining half of the hypoglossal nerve maintained its continuity (Figures 2(G–I)).

Factors considered

We evaluated the tumor volume of each patient using a three-dimensional volume measurement program (Aquaria iNtuition^{TM}; TeraRecon, Foster City, CA). Tumor images were reconstructed and the volume was determined automatically in cubic centimeters. Based on the tumor volume, the patients were categorized into large or small–medium tumor volume groups. The time from schwannoma removal to XII-VII nerve anastomosis was categorized as immediate or delayed. The patients who underwent XII-VII nerve anastomosis right after schwannoma removal in the same procedure were classified as immediate. If there was more than 6 months between XII-VII nerve anastomosis and schwannoma removal, the patients belonged to the delayed group. Demographic analysis of correlation of facial and tongue outcomes with sex or age was performed.

Statistical analysis

The data were analyzed using SPSS 18.0 (SPSS, Chicago, IL), and $p < 0.05$ was considered statistically significant. Non-parametric tests were used because the results were not normally distributed. To compare the three anastomosis groups, the Kruskal–Wallis test was used and Dunn's test was performed as a *post-hoc* sub-group analysis. The Mann–Whitney U-test was used to evaluate tumor volume and time to surgery. Logistic regression test was performed for demographic analysis.

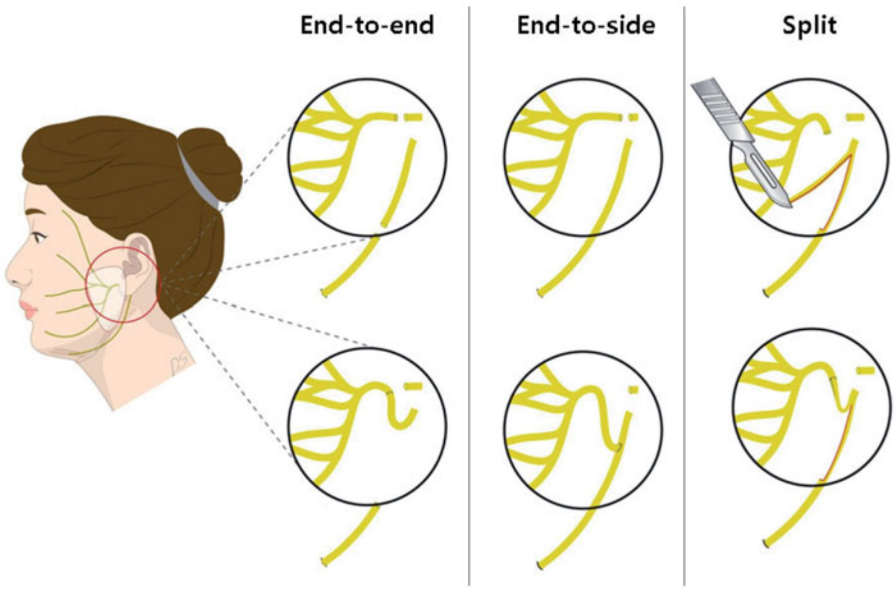

Figure 1. Schematic drawings of the end-to-end, end-to-side, and split anastomosis types. Preparation of the hypoglossal and facial nerves is depicted in the upper circles and post XII-VII anastomosis in the lower circles.

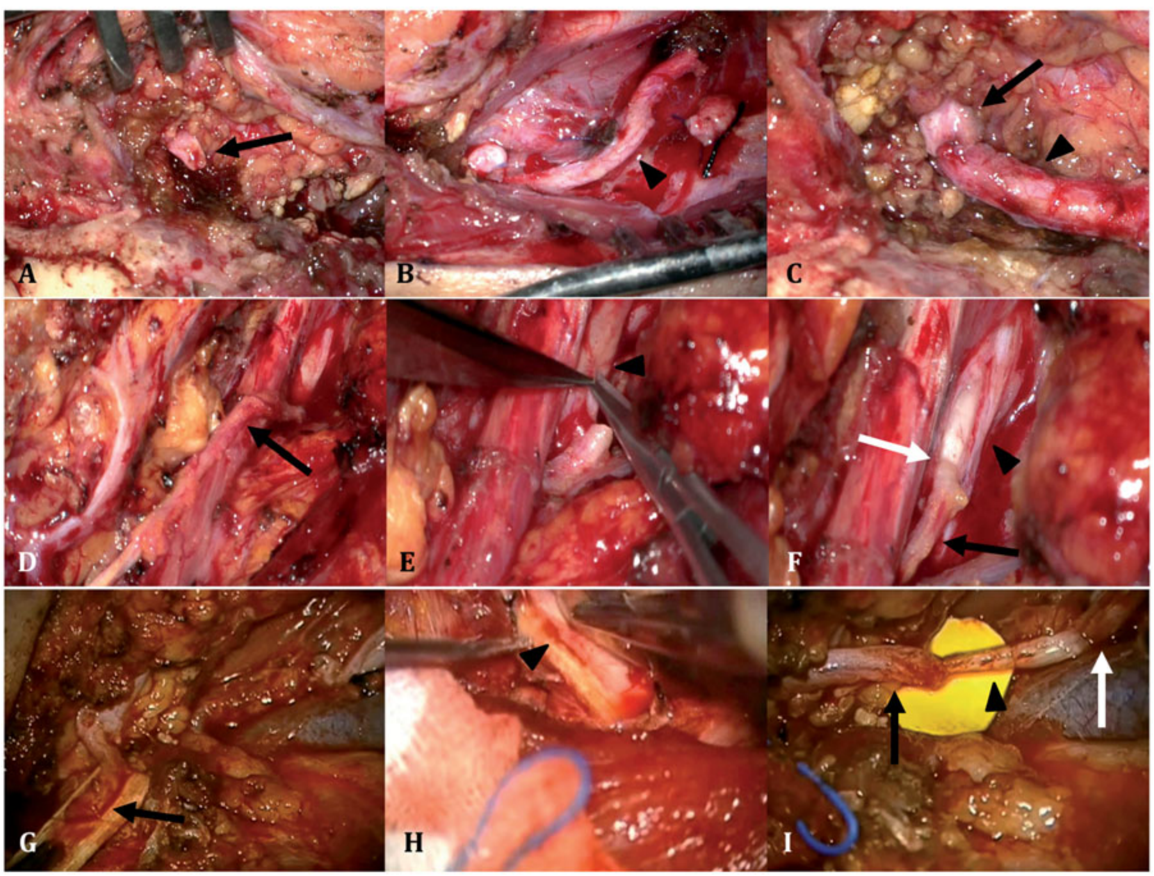

Figure 2. Intra-operative findings of each type. (A–C) End-to-end type: the distal facial nerve stump was identified within a parotid gland (black arrow); the hypoglossal nerve was identified (arrowhead); and end-to-end anastomosis was performed. (D–F) End-to-side type: the facial nerve stump was dissected and drawn into the upper neck (black arrow); an epineurial window was opened on the hypoglossal nerve (arrowhead); and the facial nerve stump was connected to the epineurial window of the hypoglossal nerve (white arrow), and end-to-side anastomosis was performed. (G–I) Split type: the facial nerve stump was prepared (black arrow); the hypoglossal nerve was divided, and a longitudinal branch was designed (arrowhead); a split anastomosis was performed with the descending portion of the hypoglossal nerve maintaining continuity (white arrow).

Results

Fourteen patients underwent XII-VII nerve anastomosis after schwannoma removal and were followed for more than 1 year. There were seven end-to-end, three end-to-side, and four split type anastomoses (Table 1). Regardless of the anastomosis type, nine of 14 (64.3%) patients had favorable facial outcomes, and eight of 14 (57.1%) had favorable tongue outcomes (Figure 3(A)). The facial outcome was favorable in five of seven (71.4%) end-to-end, three of four (75%) split, but only one of three (33.3%) end-to-side patients (Figure 3(B)). The degree of tongue atrophy was favorable in all three (100%) end-to-side, three of four (75%) split, but only two of seven (28.6%) end-to-end patients (Figure 3(C)). Actual facial and tongue outcomes of each type are shown in Figure 4. There were no statistical differences in facial ($p = 0.474$) or tongue ($p = 0.094$) outcomes among the three anastomosis groups. Time to surgery was not a factor in the facial ($p = 0.491$) or tongue ($p = 0.755$) outcomes; tumor volume was also not a factor in the facial ($p = 0.635$) and tongue ($p = 0.539$) outcomes (Figure 5). Patient age and sex had no significant relationship with facial and tongue outcomes, regardless of anastomosis type.

Discussion

A XII-VII nerve anastomosis is a good option for patients with facial palsy, although the best surgical technique remains controversial. To evaluate which technique is more effective, this study compared three anastomosis techniques and evaluated the facial outcomes and accompanying tongue morbidity. It is widely believed that the end-to-end type is good for facial restoration. This procedure re-establishes facial tone, reduces asymmetry, and allows some movement, but may be associated with significant late tongue morbidity [5]. Although good facial outcomes are expected, complete resection of the hypoglossal nerve can result in unilateral tongue atrophy, swallowing difficulty, and speech problems [13]. The interpositional jump graft technique, not introduced in this study, was proposed to decrease the glossal dysfunction [3]. However, there were some concerns about this technique regarding a delay in reanimation, since there are two anastomosis lines and a long neural graft [14]. The end-to-side type was developed to prevent tongue muscle atrophy and it does not interrupt the continuity of the hypoglossal nerve. Therefore, in terms of tongue morbidity, the end-to-side type is better. Some authors have reported good facial outcomes with no or fewer tongue muscle complications [12,15].

Table 1. Patient populations and surgical outcomes. There were seven end-to-end, three end-to-side, and four split type cases. Facial outcomes were graded using the House-Brackmann scale (I–VI) and tongue outcomes using Martins' scale (I–IV).

Case no.	Gender/age	Side	Anastomosis type	Surgical time	Facial outcomes	Tongue outcomes
1	F/32	Left	End-to-End	Immediate	III	III
2	M/35	Right	End-to-End	Immediate	III	III
3	M/26	Left	End-to-End	Immediate	IV	II
4	F/18	Left	End-to-End	Immediate	II	III
5	M/45	Left	End-to-End	Delayed	III	III
6	F/50	Right	End-to-End	Delayed	III	III
7	F/60	Right	End-to-End	Delayed	IV	II
8	F/29	Right	End-to-Side	Immediate	IV	I
9	F/42	Left	End-to-Side	Immediate	III	I
10	F/14	Right	End-to-Side	Delayed	IV	I
11	M/50	Right	Split-to -End	Immediate	III	II
12	F/56	Left	Split-to -End	Immediate	III	II
13	M/23	Left	Split-to -End	Delayed	III	III
14	F/21	Left	Split-to -End	Delayed	IV	II

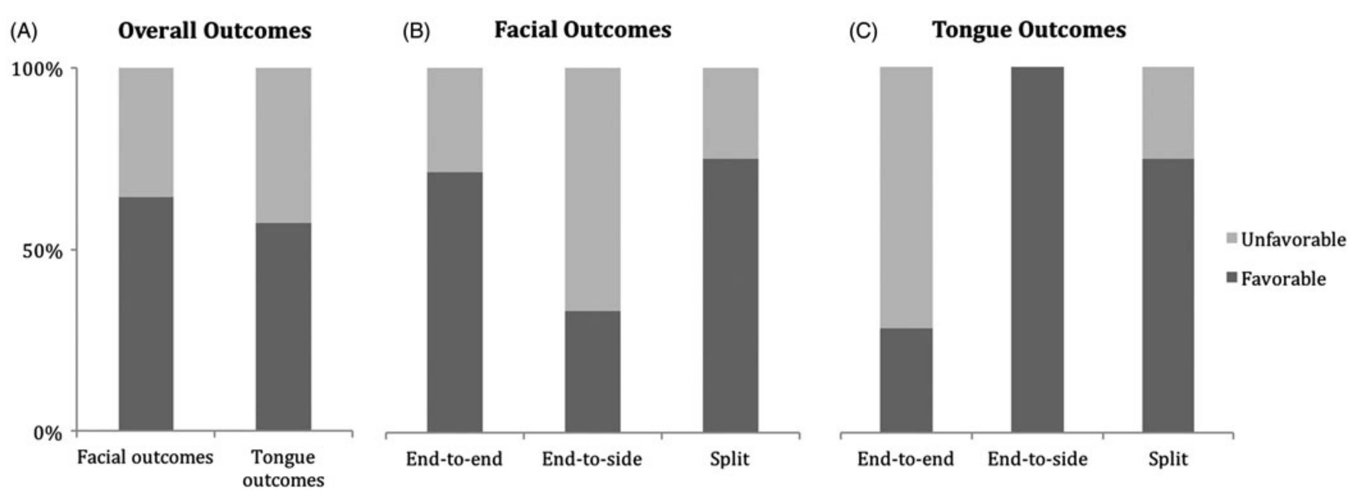

Figure 3. (A) Overall, nine of 14 (64.3%) patients had favorable facial outcomes and eight of 14 (57.1%) patients had favorable tongue outcomes. (B) Facial function was favorable in five of seven (71.4%) end-to-end, one of three (33.3%) end-to-side, and three of four (75%) split patients. (C) Tongue outcome was favorable in two of seven (28.6%), three of three (100%), and three of four (75%) patients, respectively.

Figure 4. Actual facial outcomes. (A, B) Post-operative facial expression after end-to-end anastomosis. (C) Post-operative tongue movement after end-to-end anastomosis. (D–F) The same expressions after end-to-side anastomosis and (G–I) split anastomosis.

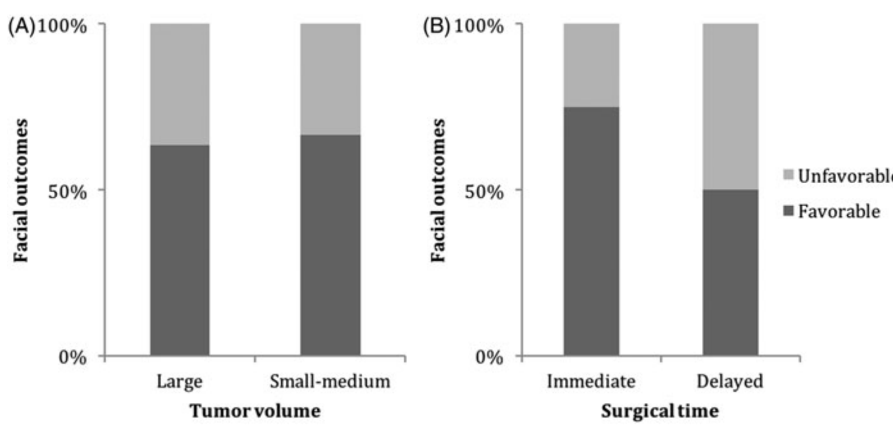

Figure 5. (A) Tumor volume factor. There were favorable outcomes in two of three (66.7%) patients in the large tumor group and six of 10 (60%) in the small–medium group. (B) Surgical timing factor. The immediate and delayed groups had favorable outcomes in six of eight (75%) and three of six (50%) patients, respectively.

In our study, this procedure resulted in no tongue morbidity, but facial recovery was in doubt. The split type is designed so that one-half of the hypoglossal nerve is connected to the distal stump of the facial nerve, while the other half maintains continuity. This modified surgical technique was developed as a potential solution to reduce significant tongue morbidity while preserving favorable facial recovery [9,16].

The overall outcome in our study was acceptable. Good facial function with more tongue morbidity occurred with the end-to-end type, as expected. The facial outcomes of the end-to-side type were in doubt and unsatisfactory, while the facial outcomes of the split type were better than we expected and similar to those of the end-to-end type. The studies with satisfactory outcomes of end-to-side technique have been reported [12,17]. However, there is lack of data out there on direct comparison of end-to-end, end-to-side, and split techniques with one surgeon in a single institute. Achieving consistency of surgical skills, nevertheless the limitations of relatively small sample size, our results showed that the split type of XII-VII nerve anastomosis was a more acceptable technique. To ensure good facial outcomes while considering the tongue muscles, according to our study, we recommend the split technique for XII-VII nerve anastomosis. The split technique achieved greater preservation of the tongue muscles. Moreover, the facial outcomes of the split type in our study were more favorable than with the end-to-end type.

A split XII-VII nerve anastomosis involves splitting the hypoglossal nerve equally. Then, one split bundle is rotated superiorly to anastomose with the facial nerve trunk. The most significant clinical benefit of this approach is reduced morbidity in the ipsilateral tongue and stable favorable facial recovery. This technique is also not fettered by the length of remnant facial nerve. Although some minor deficits may persist, they are markedly reduced when compared with total hypoglossal nerve sacrifice, allowing patient compensation to play a significant role in improved function.

Studies have reported that the axon paths through the hypoglossal nerve are interwoven and the axons do not travel in strict linear paths through the epineurium [18]. Sequential neuronal cross-sectional studies have shown variable and often twisting axon paths through the nerve. Therefore, when the nerve is split, many axons are likely transected. The ideal 50/50 distribution may ultimately become a 30/30/40 distribution, where 40% of the axons are lost. The exact amount of axon loss is pure supposition, as this information is unattainable without cross-sectional studies of the reinnervated nerve [6].

In our study, more patients had moderate dysfunction (grade III) of the tongue post-operatively. The mastication and pronunciation functions were preserved with only moderate tongue atrophy, which was milder than that seen in complete hypoglossal nerve transection. This is thought to be due to the regeneration ability of the nerve fibers. Although up to 40% of the nerve fibers are transected at surgery, leaving only a 30/30 initial distribution in the two halves, this may increase to 40/40 or 50/50 with reinnervation over time.

Sometimes it is impossible to perform the split technique. To achieve the tensionless anastomosis, the distal facial nerve stump should be sufficient to meet the hypoglossal longitudinal branch. For this reason, the technique of rerouting the intra-temporal part of the facial nerve for hemihypoglossal-facial anastomosis was proposed [19]. If the mastoid segment of the facial nerve has already been damaged or the facial nerve trunk is too short or unavailable, the split technique is not suitable for XII-VII nerve anastomosis. Consequently, the condition of the individual patient must be considered.

Analyzing the time factor, more favorable facial outcomes were obtained in the immediate group compared with the delayed group. This is because, when anastomosis is performed right after nerve injury, the nerve still receives signals from proximal motor fibers, although it might be via a different nerve. This may result in less degeneration and faster initiation of the recovery process after degeneration. It is important for better outcomes because prolonged denervation and muscular atrophy will require more physical training and recovery will take longer. In addition, a delay may lead to irreversible atrophy and fibrosis if regeneration does not occur.

There are controversies that age had a significant effect to prognosis [12] or no significant effect [17]. In this study, patient age or sex had no significant relationship with facial and tongue outcomes, regardless of anastomosis type.

If there is facial nerve injury and no available proximal facial nerve stump, we recommend an immediate XII-VII nerve anastomosis as an ideal alternative surgical step. However, if there is no evidence of facial nerve injury, the dilemma is how long a surgeon should wait and when the XII-VII nerve anastomosis should be considered. This is because a case with intact facial nerve sometimes shows evidence of recovery several months after tumor removal. Regarding the meta-analytic study, observation for 6 months did not affect the prognosis, but rather delayed XII-VII nerve anastomosis of more than 12 months showed poor facial function restoration [20]. Therefore, we recommend waiting at least 6 months with the anatomically preserved facial nerve. If the facial palsy persists, however, consider XII-VII nerve anastomosis as early as possible, especially within 12 months.

Conclusion

Several XII-VII nerve anastomosis techniques have been introduced. In our series, the split type XII-VII nerve anastomosis resulted in more favorable outcomes in terms of both the facial function and tongue atrophy.

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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