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Hemihypoglossal-facial nerve anastomosis for facial nerve palsy

Zespolenie nerwu twarzowego z połową nerwu podjęzykowego w leczeniu porażenia nerwu twarzowego

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Abstract

Background and purpose: Commonly used classic hypoglossal (CN XII) to facial nerve (CN VII) anastomosis has the disadvantage of tongue hemiatrophy. Thus, various attempts have been made to modify this method to reduce the tongue damage. The aim of this report was to present the results of hemihypoglossal-facial nerve anastomosis (HHFA) technique in relation to facial muscles reanimation and hemitongue atrophy.
Material and methods: The first 7 consecutive patients who underwent CN VII anastomosis with half of the CNXII, for which the follow-up period exceeded 12 months, were analysed. During the procedure, CN VII was transected as proximally as possible after drilling the mastoid process. CN XII was separated longitudinally into two parts at a short distance to allow suture of the stumps without any tension. One half of CN XII was transected and sutured to the distal stump of CN VII. Recovery from facial palsy was quantified with the House-Brackmann grading system (HB). Tongue function was assessed according to the scale proposed by Martins.
Results: Features of initial reinnervation of facial muscles were visible after 6 months in all 7 patients. All patients achieved satisfactory outcome of CN VII regeneration (HB grade III) until the last control examination (12-27 months after surgery, mean 16). No or minimal tongue atrophy without deviation (grades I-II according to the Martins scale) was found in 4 patients. Mild hemiatrophy with tongue deviation < 30 degrees (grade III) was visible in 3 patients.

Streszczenie

Wstęp i cel pracy: W leczeniu porażenia nerwu twarzowego często stosuje się zespolenie z nerwem podjęzykowym. Wadą tej metody jest połowiczy zanik języka, dlatego od wielu lat podejmuje się próby jej modyfikacji, aby zmniejszyć uszkodzenia języka. Celem pracy jest ocena wyników zespolenia nerwu twarzowego z połową nerwu podjęzykowego w kontekście reanimacji mięśni twarzy oraz następowego uszkodzenia języka.
Materiał i metody: Analizowano wyniki leczenia 7 pierwszych, kolejnych chorych, u których wykonano zespolenie nerwu twarzowego z połową nerwu podjęzykowego, u których czas obserwacji przekraczał 12 miesięcy. W czasie zabiegu wypreparowywano pień nerwu twarzowego z wyrostka sutkowatego oraz jego zewnątrzczaszkowy odcinek aż do jego podziału. Wypreparowywano nerw podjęzykowy, rozdzielano go podłużnie na dwie części na krótkim odcinku, aby uzyskać zespolenie bez żadnego napięcia. Jedną połowę nerwu podjęzykowego zeszywano z kikutem dystalnym nerwu twarzowego. Wyniki reinerwacji mięśni twarzy oceniano wg skali House'a-Brackmanna (HB), natomiast nasilenie zbaczania i jednostronnego zaniku języka oceniano za pomocą skali zaproponowanej przez Martinsa.
Wyniki: Po upływie 6 miesięcy u wszystkich 7 chorych stwierdzono początkowe cechy reinerwacji mięśni twarzy. Do czasu ostatniej kontroli (12–27 miesięcy po zabiegu, średnio 16 miesięcy) u wszystkich chorych uzyskano satysfakcjonujący wynik

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Conclusions: In our experience, HHFA is effective treatment of facial palsy and gives a chance to reduce damage of the tongue.

Key words: facial nerve, hypoglossal nerve, facial palsy, hypoglossal-facial anastomosis.

regeneracji nerwu twarzowego (III stopień HB). Brak lub minimalny jednostronny zanik mięśni bez zbaczania języka (stopnie I–II wg Martinsa) stwierdzono u 4 pacjentów, a średniego stopnia zanik połowiczy ze zbaczaniem języka < 30 stopni (III stopień) u 3 pacjentów.

Wnioski: Zespolenie nerwu twarzowego z połową nerwu podjęzykowego umożliwia w naszym doświadczeniu satysfakcjonującą reanimację mięśni twarzy i daje szanse na zmniejszenie uszkodzenia funkcji języka.

Słowa kluczowe: nerw twarzowy, nerw podjęzykowy, porażenie nerwu twarzowego, zespolenie twarzowo-podjęzykowe.

Introduction

Despite a significant improvement in the results of cerebellopontine angle tumour surgery in recent decades, facial nerve (CN VII) palsy still occurs, especially after large vestibular schwannoma removal [1-3]. In the case of intraoperative loss of continuity of the CN VII, end-to-end anastomosis 'loco operationis' can be applied, during the same procedure. However, sometimes there are no technical conditions for such a manoeuvre, and in such cases a crossover anastomosis is performed with other cranial nerves during the second operation.

Nowadays, the hypoglossal nerve (CN XII) is the nerve most often used as a donor of axons for facial nerve neurotization. Simple hypoglossal-facial nerve 'end-to-end' anastomosis was, for the first time, described by Körte in 1903 and is still commonly performed [3-5]. The main disadvantage of this method is the inevitable loss of donor nerve function for the uncertain effect of facial nerve repair. In the case of total transection of the CN XII, hemiatrophy of the tongue and tongue deviation should be expected, sometimes followed by mastication, swallowing and phonation difficulties [6]. Thus, various attempts have been made to modify this method to reduce the tongue damage. Examples of such efforts may be additional anastomosis of the superior root of the ansa cervicalis with a distal stump of the CN XII [7] or facial-facial anastomosis [8]. In the latter case, reinnervation is conducted from the small branches of the contralateral facial nerve; therefore hypoglossal nerve damage is entirely avoided. In recent years, use of only part of the CN XII fibres rather than the whole nerve for anastomosis with the CN VII is gaining more popularity. This technique has been developed for about 20 years and now has a few modifications [9]. The aim of this report is to present the results of the hemihypoglossal-facial nerve anastomosis technique (HHFA) in relation to facial muscle reanimation and hemiatrophy of the tongue.

Material and methods

The first seven consecutive patients who underwent the CN VII anastomosis with half of the CN XII, for which the follow-up period exceeded 1 year, were analysed. The cause of facial palsy was previous surgery for vestibular schwannoma in 6 and petroclival meningioma in 1 patient. This group includes one patient after previously performed stereotactic radiation therapy for vestibular schwannoma, in whom the paralysis occurred after irradiation and before the tumour removal. The series comprised four women and three men, ranging in age from 28 to 62 years (mean 51 years). The duration of facial palsy before surgery ranged from 1 to 22 months (mean 10 months). In 3 cases of intraoperative disruption of the CN VII, the anastomosis was performed as early as 1 month after the surgery. The remaining four patients with anatomically preserved CN VII were observed for at least 6 months for reinnervation. They were operated on later because no clinical or neurophysiological features of regeneration were visible. The face paralysis lasted more than a year in three patients.

Description of the surgical technique

The operation was performed under general anaesthesia in the supine position with the head rotated toward the healthy side. The skin incision was made posterior to the pinna and extended down between the anterior edge of the sternocleidomastoid muscle and the posterior border of the ramus mandibulae to the level of the hyoid bone. The mastoid process was partly resected using a high speed drill in the first stage of the procedure. The facial nerve was skeletonized on its mastoid and tympanic portion. The extratemporal part of the CN VII was dissected to the border of the parotid gland. Then the CN VII was mobilized, transected as proximally as possible and was

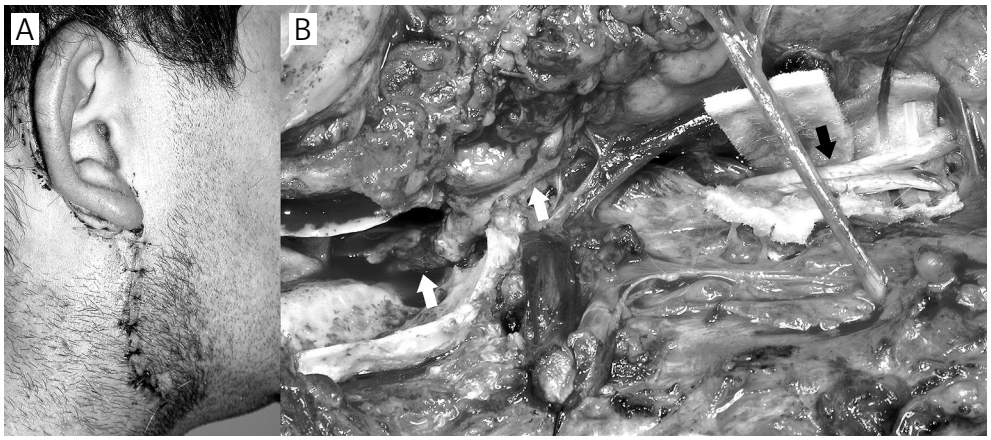

Fig. 1. A) Line of the skin incision. B) Operative polygon. The CN VII is skeletonized in the mastoid process and dissected in the extratemporal portion (white arrows). The CN XII and the superior root of the ansa cervicalis are identified (black arrow)

translocated caudally toward the CN XII. The CN XII was identified on the neck and prepared proximally and distally from the site where the superior root of the ansa cervicalis originates (Fig. 1). Using microscopic magnification and blunt dissection the hypoglossal nerve was separated longitudinally into two parts at a short distance (~1 cm). A well-identified stump was obtained, allowing suture of the stumps without any tension. One half of the CN XII was transected and routed toward the CN VII, while seeking to preserve the vascularization of the stump. The remaining part of the CN XII was left intact. The stump of the CN VII was sutured to half of the CN XII with about six stitches (8/0 or 10/0 monofilament nylon) to precisely match the stumps on the whole perimeter. The site of connection was reinforced by fibrin glue (Tissucol® in 2, Tachosil® in 5). Principles of the procedure were meticulous suturing of the stumps, assurance of tensionless anastomosis and avoidance of stump angulation at the site of connection. In four patients, coaptation of the superior root of the ansa cervicalis with the distal stump of the transected part of the CN XII was additionally performed. The wound was sutured in two layers. After surgery, the patients were trained in manual self-stimulation of the facial muscles and, from the first signs of muscles' reanimation, specific mimic exercises in the mirror were recommended.

Recovery from facial palsy was quantified by the House-Brackmann (HB) grading system [10] after 3, 6 and 12 months as well as later. Electromyographic evaluation was performed with a similar schedule to clinical examinations. The tongue atrophy and its deviation were assessed according to a scale proposed by Martins *et al.* [11]. The follow-up period ranged from 12 to 27 months (mean 16 months). The clinical data are shown in Table 1.

Results

During the first inspection 3 months after surgery, no patient had any clinical sign of reinnervation. Features of the initial reanimation of facial muscles were visible after six months in all 7 patients. All the patients achieved a satisfactory outcome of the CN VII regeneration (HB grade III) until the last control examination. No or minimal tongue atrophy without deviation (grade I-II according to the Martins scale) was found in 4 patients. Mild hemiatrophy with tongue deviation < 30 degrees (Martins grade III) was visible in 3 patients. No patient developed severe tongue hemiatrophy with deviation > 30 degrees (Martins grade IV) (see Fig. 2 and Table 1). Only one patient reported transient problems with phonation and swallowing after the surgery (currently Martins grade II). Of the 4 patients in whom the ansa cervicalis was additionally coapted to the distal half of CN XII, two patients achieved grade I and two patients grade III according to the Martins scale.

Before performing the anastomosis, five patients required implantation of a gold weight to the eyelid and in one lateral tarsorrhaphy was additionally carried out. The causes were severe lagophthalmos and conjunctivitis prophylaxis. Two of them developed keratitis with corneal opacity. Until the last inspection, only 2 patients still had gold weight implants. However, the closing of eyelids was strong enough to make a plan in order to remove it.

In all the patients, during the progress of reinnervation, some range of mass movements and synkinesis were seen. It was only significantly expressed together with hypertonia of facial muscles in one patient. These problems were transient in all the patients and decreased with the progress of rehabilitation.

Table 1. Clinical data of the seven patients after hemihypoglossal-facial nerve anastomosis (HHFA)

The patient and the cause of CN VII palsy	CN VII preservation during tumour removal and its function after surgery	Duration of CN VII palsy (months)	Technical details of the anastomosis	Follow-up duration (months)	Late outcome	
					CN VII function	Tongue appearance and function
F, 60 y.o. Surgery for VS on the right	Anatomically preserved No signs of regeneration at follow-up	20	HHFA + additional coaptation of ansa cervicalis with the distal half of CN XII Length of the split segment of the CN XII ~ 10 mm Sutures 10/0 + Tachosil®	12	HB grade III m. frontalis (+) m. o. oculi (+) m. o. oris (+)	Martins grade I
M, 57 y.o. Surgery for VS on the right	Not preserved	1	HHFA + additional coaptation of ansa cervicalis with the distal half of CN XII Length of the split segment of the CN XII ~ 10 mm Sutures 8/0 + Tachosil®	16	HB grade III m. frontalis (+) m. o. oculi (+) m. o. oris (+)	Martins grade III
F, 46 y.o. Surgery for VS on the right	Anatomically preserved No signs of regeneration at follow-up	11	HHFA Length of the split segment of the CN XII ~ 15 mm Sutures 10/0 + Tachosil®	12	HB grade III m. frontalis (+) m. o. oculi (+) m. o. oris (+)	Martins grade I
M, 62 y.o. Surgery for petroclival meningioma on the right	Not preserved	1	HHFA + additional coaptation of ansa cervicalis with the distal half of CN XII Length of the split segment of the CN XII ~ 15 mm Sutures 8/0+ Tissucol®	22	HB grade III m. frontalis (+) m. o. oculi (+) m. o. oris (+)	Martins grade I
F, 51 y.o. 1. Stereotactic irradiation 2. Surgery for VS on the right	CN VII palsy appeared after irradiation and before surgery Anatomically preserved during surgery No signs of regeneration at follow-up	22	HHFA Length of the split segment of the CN XII ~ 10 mm Sutures 8/0 + Tachosil®	13	HB grade III m. frontalis (+) m. o. oculi (+) m. o. oris (+)	Martins grade II
F, 54 y.o. Surgery for VS on the left	Not preserved	1	HHFA Length of the split segment of the CN XII ~ 5 mm Sutures 8/0 + Tissucol®	27	HB grade III m. frontalis (+) m. o. oculi (+) m. o. oris (+)	Martins grade III
M, 28 y.o. Surgery for VS on the left	Anatomically preserved No signs of regeneration at follow-up	17	HHFA + additional coaptation of ansa cervicalis with the distal half of CN XII Length of the split segment of the CN XII ~ 20 mm Sutures 8/0 + Tachosil®	13	HB grade III m. frontalis (–) m. o. oculi (+) m. o. oris (+)	Martins grade III

VS – vestibular schwannoma, m. frontalis – musculus frontalis, m. o. oculi – musculus orbicularis oculi, m. o. oris – musculus orbicularis oris, HB – House-Brackmann grading scale, CN VII – facial nerve, CN XII – hypoglossal nerve

Scale proposed by Martins et al. evaluating tongue dysfunction: grade I – normal, grade II – discrete hemiatrophy, no deviation, grade III – mild hemiatrophy, tongue deviation < 30 degrees, grade IV – severe hemiatrophy, tongue deviation > 30 degrees [11]

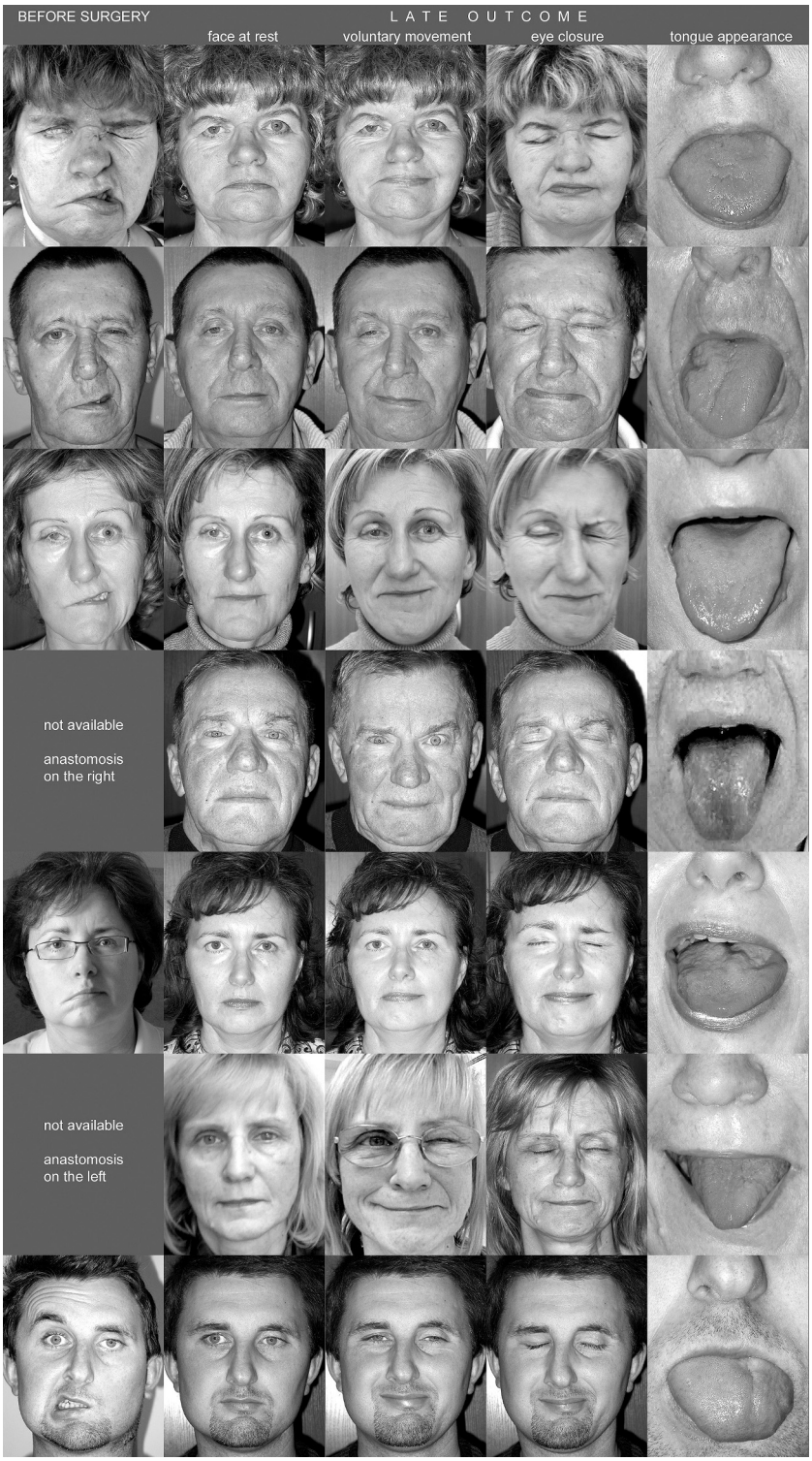

Fig. 2. Photographs of the seven patients showing preoperative appearance of the face and late postoperative outcome. The face symmetry is slightly distorted in patients 3 and 7 due to lateral tarsorrhaphy and/or gold weight on the eyelid

EMG results

Six months after the anastomosis procedure, signs of reinnervation in the orbicularis oris and in the orbicularis oculi muscle were found in all patients. In all but one, the reinnervation of the frontalis muscle was recorded 12 months after the anastomosis. In all patients, contralateral reinnervation of the orbicularis oris muscle was found as well.

Discussion

Surgically created nerve connections are currently the mainstay of treatment of facial paralysis. If there is no possibility to perform direct end-to-end anastomosis of the CN VII, crossover connections with other nerves are used. Mostly, as a donor of axons, a CN XII is used. Glossopharyngeal, masseteric, accessory and phrenic nerves or the superior root of the ansa cervicalis are employed rarely, because of higher morbidity or lower effectiveness [12]. Nerve anastomosis in the treatment of CN VII paralysis has developed since the end of the nineteenth century. Drobnick and Faure are mentioned among the first to perform a facial nerve crossover anastomosis, but it is commonly believed that the first described operation is spinal accessory to facial nerve anastomosis. It was carried out by Sir Charles Ballance in 1895 [13,14]. The first hypoglossal-facial anastomosis was performed by Körte [4]. Despite the history of facial reanimation surgery being longer than a century, it still remains a challenge due to complex facial muscle function.

Classic hypoglossal-facial anastomosis involves transsection of a healthy CN XII, followed by connection of the proximal stump of CN XII to the distal stump of CN VII, which is sectioned near the stylomastoid foramen. The classic technique yields satisfactory results in approximately 2/3 of cases [3,5]. It is worth pointing out that it is not feasible to achieve HB grade I or grade II using this method, and grade III is considered as a good result. This follows from the fact that it is not possible to recover the full spontaneous expression of the face associated with emotions by reinnervation from the CN XII [15]. However, sacrifice of the CN XII always causes deterioration of the tongue function and appearance [16,17]. The tongue disability is usually not very inconvenient, but may be unacceptable to some patients as compared to benefits of the procedure [18]. In addition, the healthy donor nerve is irreversibly damaged for the uncertain result of other nerve treatment. Therefore, the use of CN XII as a donor nerve has evolved for years, thus leading towards a reduction in its damage.

One of the ways of reducing the tongue hemiatrophy, which has been well known for a long time, is the creation of an additional connection with the ansa cervicalis after classic hypoglossal-facial nerve anastomosis. After sectioning the CN XII and use of its proximal stump for the anastomosis with the CN VII, the superior root of the ansa cervicalis is coapted to the distal stump of the CN XII [3,7,18,19]. The effectiveness of this method is currently being undermined. A possible cause of its low efficiency is a small number of nerve fibres in the ansa cervicalis compared to the CN XII [11,19,20].

Surgeons experienced in various techniques of facial reanimation emphasize that the use of part of the fibres instead of the whole CN XII for anastomosis reduces tongue morbidity [16,21]. Histomorphometric studies have shown that a healthy CN VII contains about 7000 axons and a CN XII about 10 000 axons. In the potential site of anastomosis, the cross-sectional area of the healthy CN VII equals approximately 0.6 of the CN XII cross-sectional area. However, in damaged CN VII it drops below a half [22]. Today we can distinguish three modifications of hypoglossal-facial anastomosis, aimed at partial CN XII sparing: (1) hypoglossal-facial nerve interpositional-jump graft technique ('May technique') [6]; (2) split hypoglossal-facial nerve anastomosis [15], and (3) direct end-to-side hypoglossal-facial nerve anastomosis after mobilization of the intratemporal part of the CN VII ('modified May technique' or 'Darrouzet technique') [23-25].

The technique described by May *et al*. involves inserting an interpositional cable graft from the great auricular or sural nerve, between the stumps of the CN VII and just partly sectioned CN XII [6]. The disadvantages of the modification are that sprouting axons must overcome two connection points and there is also a need for harvesting and sacrificing yet another healthy nerve as a donor for the cable graft.

Another modification is a longitudinal division of the CN XII in two parts, one of which goes further into the tongue and the other is transected distally. The CN VII is cut off near the stylomastoid foramen. The anastomosis is performed after transposition of the transected part of CN XII in the direction of the CN VII stump [15,26]. However, a major drawback is the fact that the CN XII has a unifascicular structure. In addition, axons of the CN XII do not run parallel, but intertwine with each other. Therefore, longitudinal splitting of CN XII may result in a loss of its fibres [27]. A recent morphometric study has shown that in order to perform this type

of anastomosis without tension, the split segment has to be longer than 32 mm [9].

The modification we used is similar to the direct end-to-side hypoglossal-facial nerve anastomosis, which has been described by various authors, including Darrouzet, Sawamura and Atlas [23-25]. It involves elongation of the available CN VII stump by skeletonization of its mastoid and even tympanic portion. Then its end is coapted to the partially transected CN XII, somewhat similar to grafting trees. Based on morphometric studies carried out by Socolovsky and Campero, dissection of the CN VII in the mastoid process elongates the stump by about 16 mm. The average length of the extratemporal portion of the CN VII to its main division is 19 mm. In total, this gives an up to 35-mm long nerve stump available for transposition, and the distance from the division of the CN VII to the CN XII loop is about 32 mm [9]. It gives the possibility to perform tensionless direct anastomosis. Although drilling the mastoid process significantly elongates the CN VII stump, it is not always guaranteed that the anastomosis will be performed without any tension [28]. Considering the lack of tension at the connection site as a priority, we modified the original description of the method a little. The CN XII fibres were divided in each case, as in the 'splitting method', but in a short distance. The length of the split portion of the CN XII was usually about 1 cm. In this way, an accurately identified stump was obtained, that created good conditions for stitches around the whole perimeter of the merged nerves. The anastomosis without tension and without angulation of the stumps at the junction was achieved in each case. The CN VII should be cut off as proximally as possible but it also must be kept in mind that the exposure of CN VII in the mastoid process may be the cause of injury of the horizontal semicircular canal. Therefore, the procedure is most suitable for patients with pre-existing vestibulocochlear nerve damage.

Similar to other series, resumption of function of the orbicularis oris muscle was observed first, followed by the orbicularis oculi muscle [15]. In our series, waiting for the return of activity in the frontal branch was the longest. The least satisfactory results of reinnervation were eventually obtained in the frontal muscle. Similar observations have been published by Arai *et al.* [15], who interpreted such results by the relatively low number of axons in the frontal branch. Although our study is limited to seven cases, noteworthy is the fact that in all patients a satisfactory outcome of facial reanimation was obtained. It confirms the fact that half of the CN XII is sufficient for effective reinnervation of the CN VII.

In our series, mild hemiatrophy with tongue deviation < 30 degrees was observed in 3 out of 7 patients. Similarly, in a recently published series of direct end-to-side facial-hypoglossal nerve anastomosis, slight tongue hemiparesis was noted in 42% [21].

An additional coaptation of the superior root of the ansa cervicalis to the distal half of CN XII in two out of four patients did not prevent tongue hemiatrophy and deviation. Martins grade III was observed in the patient in whom the split portion of CN XII was the longest (approximately 2 cm). Hence, we can speculate that it is reasonable to split the CN XII at a distance as short as possible, proximally to the superior root of the ansa cervicalis. In addition, after the division but before intersection of one of the CN XII halves, performance of electromyography (which we did not do) can help to select the part which has less contribution to tongue innervation [15,26]. Alternatively, the posterior part of the CN XII trunk can be chosen for the anastomosis, because it also includes the ansa cervicalis fibres. Thus more axons going to the tongue in the remaining part of CN XII are preserved [22].

In the early period of muscle reinnervation, mass movements and synkinesis were seen in all the patients, but only in one patient were they significantly expressed and coexisted with muscle hypertonia. This is a common problem of crossover nerve anastomosis [29]. The causes include misdirection of regenerating axons, and hyper- and polyinnervation of the mimic muscle endplates. Some observations on new facial reanimation techniques may indicate that the use of part, instead of the whole hypoglossal nerve, may reduce the intensity of synkinesis and mass movements, because the CN VII is not overloaded by sprouting axons [11,27,30]. In all our patients, the aforementioned disturbances gradually decreased along with the progress of rehabilitation.

Rehabilitation of the face muscles after CN VII anastomosis with another nerve is particularly important and is also more challenging than, for example, rehabilitation after Bell's palsy or 'end-to-end' direct nerve repair. The patient must learn to control the various muscles of the face, thinking about voluntary movements of, in this case, the tongue. After the creation of a surgical connection between the CN VII and CN XII, appropriate tongue exercises translating into facial movements are indicated, preferably in front of a mirror. It is worth mentioning that the blink reflex may return [31] and there is a possibility to learn selective movements of the face

without thinking about the tongue, especially using biofeedback rehabilitation [30,32,33]. This indicates significant potential of brain plasticity, which probably we cannot yet fully exploit.

Timing of the surgery

It is clear that in the case of a loss of CN VII continuity during the tumour removal, when there is no possibility for intraoperative direct reconstruction, extratemporal crossover anastomosis should be performed as soon as possible. In our group, such patients were operated on within a month after tumour removal. More difficulty is found in the question of surgery timing, when the CN VII was anatomically preserved but its function does not return. On the one hand, the longer we wait, the more facial muscle atrophy is evident [34]. On the other hand, making the decision about crossover nerve connection too early eliminates the chance of physiological regeneration, which could provide a better cosmetic result. Clinically visible features of facial muscle reinnervation can occur in different periods after the CN VII injury, but the first symptoms usually appear before half a year. However, the best results of the anastomosis are achieved when it is carried out within a year after the onset of paralysis. In the series of Falcioni *et al.* [35], only 19% of patients in whom the hypoglossal-facial nerve anastomosis was performed later than one year after the onset of palsy achieved a satisfactory outcome (HB grade III). A meta-analysis of the results of hypoglossal-facial nerve anastomosis, published in 2007 by Yetiser and Karapinar, also confirmed the greater effectiveness of surgery performed within 12 months after the CN VII injury [17]. Hence, it seems reasonable to decide on crossover nerve connection 6 to 12 months after the injury, if there are no clinical or neurophysiological features of facial muscle function.

On the other hand, in the paper of Chang and Shen, the duration of facial paralysis is of no importance for the effectiveness of surgery [19]. Similarly, our limited experience indicates that the anastomosis is also effective if performed in the second year after the CN VII injury. In three cases, the anastomosis was performed later than one year (17-22 months) after the tumour removal. The obtained results were not worse than in the other patients. This leads to the suggestion of not giving up on the possibility of anastomosis in patients with long-lasting paralysis. This particularly applies to patients with an anatomically preserved CN VII during tumour removal, but with no clinically apparent facial muscle reinnervation for many months after surgery. However, in the case of long-lasting paralysis with visible muscle atrophy, better solutions are free-muscle transplantations and muscle transpositions for reanimation of the face [36,37].

Conclusions

In our experience, hemihypoglossal-facial nerve anastomosis is effective treatment of facial palsy and gives a chance to reduce damage of the tongue with its clinical consequences.

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Disclosure

The authors report no conflict of interest.

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