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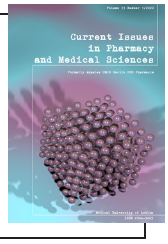

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Comparative analysis of the nerve transfer methodologies used during surgical treatment of peripheral facial paresis

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ABSTRACT

Introduction. When considering the array of biomedical problems associated with facial nerve palsy (FNP), it is apparent that the problem of choosing an effective type of facial nerve transfer is of paramount relevance. Hence, it is to the pursuit of a solution to the above stated problem that our study is devoted.
Materials and methods. We analyzed the data obtained as a result of assessing the outcome of 149 patients with trauma-caused FNP who had undergone surgical treatments in the period between 2001-2018. The FN nerve transfer techniques utilized were as such: for group 1 – the use as a donor nerve the branch of the accessory nerve innervating the sternocleidomastoid muscle (n=87); group 2 – the descending branch of the hypoglossal and the branch of the accessory nerve (n=62).
Results. In groups 1–2, the FN nerve transfer significantly improved FN function ($p < 0.01$; Wilcoxon Matched Pairs Test), and most patients (n=135; 90.6%) noted an improvement in the clinical status up to degree II-III on the House-Brackmann scale (good result).
Conclusion. The use of the accessory nerve branches to the sternocleidomastoid muscle, as donated, ensures restoration of FN function to levels II-III on the House-Brackmann scale in 89.7% of all operated patients, and the results it achieves do not differ from those of the technically more complex nerve transfer of FN by descending branch of the hypoglossal nerve with combination of branches of the accessory nerve.

INTRODUCTION

Facial nerve palsy (FNP) is a pathology of multifactorial etiology is characterized by, first of all, a decrease in facial muscle tone and activity, disruption of the parasympathetic innervation of the eye and aesthetically extreme defects [1-4]; and secondly, by a decline in quality of life and social integration, an increase in the probability of developing depression [5] or an anxiety disorder, and a decrease in active behaviors [5]. The worldwide annual incidence of FNP is 1.1-5.3 cases per 10.000 population [2,4]. Mechanical damage to the facial nerve (FN) suffered from craniocerebral and craniofacial injuries, as well as a wide range of iatrogenic injuries, such as those inflicted during the removal of tumors of the posterior cranial fossa (PCF) or postauricular and during surgical procedures for various other diseases of the peripheral part of the auditory analyzer, are some of the causes of FNP [1-4].

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The pathognomonic symptoms that in aggregate, compose the clinical picture of unilateral FNP, are [1-6]: aesthetically extreme flaccid paresis of the facial muscles accompanied by neurotic disorders of the affected sphere and social maladaptation, ophthalmic disorders – lagophthalmos and a dysfunction of the parasympathetic innervation of the eye, and inadequate moisture production and secondary injuries to the cornea [7]. With partial regeneration of innervation, pathologic synkinesis of the facial muscles may appear (the condition of the so-called "non-flaccid facial palsy" [7-9] and lacrimation or epiphora) [6]. The causes of synkinesis are aberrant regeneration of facial nerve fibers or excessive compensatory contractions of the contralateral facial muscles [8].

Most of the FNP cases resulting from trauma have in the first echelon of their treatment, neurotropic reconstructive surgical interventions [10,11]: neurorrhaphy, removal of the crushed area and neurorrhaphy, neurolysis (decompression of fibers or nerve trunk) and nerve transfer. The second echelon of treatment is surgery on the facial muscles and skin. The combined use of such aggressive treatments and procedures is, generally, referred to as "facial reanimation" and is utilized to restore the facial muscle motor functions and tone [10,11]. Another, albeit, more conservative form of treatment for FNP, is the, so-called, "facial rehabilitation" [9]. Finally, injections of botulinum toxin [7-9] or selective neurotomy are the procedures utilized in the treatment of regenerative synkinesis.

The efficacy of the administered treatments is assessed via a set of clinical parameters; however, we are currently limited in our ability to use digitalization of the evaluation of facial muscle motor activity or electroneuromyography to induce objectivity [12]; nonetheless, the most state-of-the-art methods, do employ three-dimensional monitoring of facial movements [13]. It can be stated, in a general manner that a differentiated approach, including the use of combined treatment methods, improves the patient's quality of life.

When considering the array of biomedical problems associated with FNP, it is apparent that the problem of choosing an effective type of facial nerve transfer is of paramount relevance – and it is to the pursuit of a solution to the above stated problem that our study is devoted.

MATERIALS AND METHODS

Our study was conducted within the facilities of the State Institution "Romodanov Neurosurgery Institute of the National Academy of Medical Sciences of Ukraine" and in compliance with current bioethical standards.

We analyzed the treatment outcomes of 149 patients with traumatic FNP who had undergone surgical treatment in the period between 2001-2018. The criteria for inclusion in the study was: the presence of a persistent FN functional deficiency and the inefficacy of conventional treatments, as well as the presence of an electroneuromyographic (ENMG) – indicated complete conduction block; as for criteria for exclusion from the study: the presence of alcohol or drug addiction, and pronounced cognitive and mental disorders. The design of the research is a cohort study – a retrospective analysis of surgical outcomes on single center series. The most common etiology was iatrogenic FNP resulting from the removal of a posterior cranial fossa tumor (Table 1). The age of the patients was in the range of 3-73 years, a median age of 37 y.o. Also taken into account in the our analysis was the time that had elapsed since the FN injury was endured and when undergoing the surgical treatment; the median of which (in months) was found to be 12 months; finally, the duration of the postoperative follow-up period ranged between 12-24 months.

Moreover, a clinical assessment of the severity of the FNP and an ENMG study was performed as part of the diagnostic protocol. The clinical assessment was administered using the J.W. House and D.E. Brackmann scale (1985) (Table 2). The FN functionality index was expressed as points that corresponded to a digital index of the clinical score according to the House-Brackmann scale.

ENMG was used in individual clinical cases to verify the depth of the paresis of the facial muscles, the absence of positive functional dynamics and the presence of indications for surgical treatment of FNP. The ENMG procedure included an evaluation of spontaneous and induced muscle activity of the facial muscles during stimulation of the extracranial part of the trunk or branches of the facial nerve [14]. Stimulation was carried out by the BASIS EPM electroneuromyograph (OTE Biomedika, Italy) and Neuro-MVP-4 (Neurosoft, RF) through applying rectangular pulses of 0.05 ms duration, 1 Hz frequency, intensity within 20-35 mV (10-30 mA). The deployment speed is 10 ms/div, the sensitivity of the amplifier is 100-2000 μV for registration of nerve action potential, 100-10000 μV for registration of muscle action potential. The bandwidth of the frequencies used was 10-10000 Hz.

The benchmark for ENMG-confirmed FN plegia in the early stages of FNP was the detection, via percutaneous stimulation of the FN or its trunks, of the following: 1) lack of both facial muscle contraction and an M-response in response to electrical stimulation of the FN at the standard retromandibular point; 2) the absence of early (R1) and late (R2) responses of the trigemino-facial reflex blink on the affected side and contralaterally (R2, regardless of the side being stimulated); if the needle-like electrodes register the presence of electrical activity in the facial muscles, yet no accompanying spontaneous activity of the aggregate of the individual motor units is witnessed. Following this, a needle EMG was performed in those cases in which low or inconclusive (i.e. doubtful) M-responses were registered. Herein, a concentric needle electrode was inserted into the facial muscle motor points being studied. Spontaneous activity was recorded at rest and at any voltage. The recorded fibrillation potentials were denoted as signs of denervation of the muscle fibers in the innervation zone of the damaged FN (10-20 days after the injury). The low-amplitude polyphase potentials of the motor units, the potentials of the

Table 1. Distribution of patients with persistent FNP by etiology

Causes of FNP	Frequency (true value)	Percentage (relative)
Side effect of (PCF) tumor removal	91	611%
Inflammatory (osteomyelitis, otogenic)	13	8.7%
Side effect of parotid gland tumor (parotidectomy)	11	7.4%
Open wound — adverse effects on the FN (damage to the facial soft muscle tissue)	10	6.7%
Side effect of TBI	9	6.0%
Birth trauma to the FN	8	5.4%
FN neuritis	7	4.7%

Table 2. House-Brackmann scale (1985)

Grade	Description	At rest	In movement
I	Normal	Symmetry	Normal facial function
II	Mild dysfunction	Normal symmetry and tone	Forehead: moderate to good function Eye: complete closure with minimum effort Mouth: slight asymmetry
III	Moderate dysfunction	Normal symmetry and tone	Forehead: slight to moderate movement Eye: complete closure with effort Mouth: slight weakness with maximum effort
IV	Moderately severe dysfunction	Normal symmetry and tone	Front: none Eye: incomplete closure Mouth: asymmetric with maximum effort
V	Severe dysfunction	Asymmetry	Front: none Eye: incomplete closure Mouth: slight movement
VI	Total paralysis	Asymmetry	No movement

fibrillations, and then the low-amplitude M-responses of the mimic muscles of the innervation zone were denoted as signs of muscle fiber reinnervation – spontaneous or caused by stimulation of the trunk of damaged FN. When any of these ENMG phenomena were absent in the dynamics being observed, it was treated as an indication for surgical treatment.

The surgical method utilized in all the cases in this study was nerve transfer of the extracranial part of the common trunk of the facial nerve; the shared indication, among them, for surgical intervention if the anatomical integrity of the injured intracranial or intratemporal portion of the nerve was maintained, was that conventional methods of treatment were proving to be ineffective (i.e. lack of any dynamically positive functionality of the FN) and the ENMG results indicating a complete blockage of conduction.

The FN nerve transfer techniques utilized were as such: for **group 1** – the use as a donor nerve the branch of the accessory nerve innervating the sternocleidomastoid muscle (n=87); **group 2** – the descending branch of the hypoglossal and the branch of the accessory nerve (n=62).

The decisions as to the donor nerve and the nerve transfer type were made mid-surgery after mobilization of the distal part of the FN had taken place. These decisions were guided by surgical considerations such as the availability and thickness of the donor nerve trunks.

Regarding the nerve transfer of the FN, the branches of the accessory nerve were directed towards the sternocleidomastoid muscle (rr. musculares; m. sternocleidomastoideus in group 1), the initial incision was along the front edge m. sternocleidomastoideus, along the entirety of the length of its upper one third area; behind the parotid salivary gland at a depth of 2-3 cm in the region of the styloid opening. At this position, we isolated and cut the common trunk of the FN; at a point that is level with the corner of the lower jaw, the accessory nerve was isolated, and using a magnification of ×5, it was divided it into two portions (Fig. 1), the portion innervating the nodding muscle, was cut directly before its terminal branch, the proximal section was connected to the distal portion of the FN.

Seeing as the diameter of the branch, in an overwhelming majority of our observations, was significantly inferior to the diameter of the mobilized distal part of the FN, we proposed the use of a combined method of nerve transfer of the FN that uses the descending branch of the hypoglossal and the branch of the accessory nerve (group 2). It should be noted that the initial incision technique and the technique for crossing the FN and extracting the proximal portion branch of the accessory nerve innervating the sternocleidomastoid are similar to those described above; at the level of bifurcation of the carotid artery, ramus descendens nervi hypoglossi was isolated, mobilized and cut (most distally); the distal part of the portion of the FN innervating the subcutaneous muscle of the neck was cut and connected via a previously obtained autofragment n. suralis with the proximal part of the branch of the accessory nerve; the remaining portion of FN was connected to the descending branch of the hypoglossal nerve.

In all of our cases, the reconnection of the nerve trunks was carried out using the end-to-end method with the fascicular (perineural) suture technique using 9/0-11/0 filament (Prolene; Ethicon, USA), optical magnification (×5), and microsurgical instruments.

Statistical processing of the results was carried out using the STATISTICA 10.0 software package on a personal computer. As neither the general population nor the clinical groups exhibit a normal distribution of the values of the FNP degree indicator (according to the House-Brackmann scale), the digitalized data was presented in the form M±m, where M is the median of the indicator value, m is the median error. We used nonparametric tests, since the distribution was different from normal, and the variables were discrete. The data was analyzed and the reliability of the existence of a significant difference in the index of FN function between clinical groups, as well as between the etiological subgroups of groups 1 and 2, was determined using the Fisher test. The significance of the existence of variance in the indicator before and after surgery was determined using the Wilcoxon Matched Pairs Test and Mann-Whitney U-test. Finally, for all of the calculations, the assumption of the difference being statistically significant was considered to be correct if the probability of the null hypothesis was less than 0.05 ($p < 0.05$).

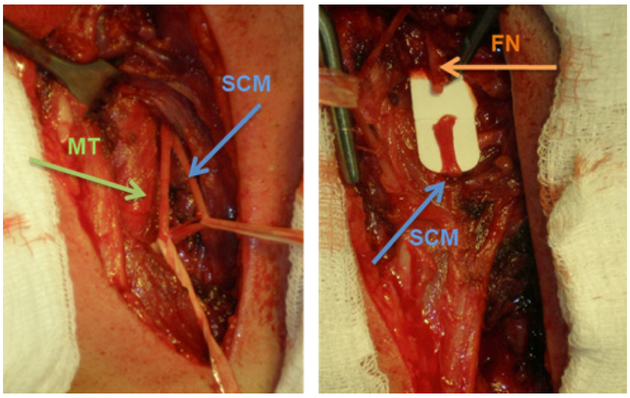

Figure 1. N. accessorius (donor; intraoperative observation, group 1) divided into two portions, where MT are the branches to m. trapezius, SCM – branches to m. sternocleidomastiodeus and FN – facial nerve

RESULTS AND DISCUSSION

It was found that for all the groups, the average clinical indicator of FN functionality (according to the House-Brackmann scale) at the time of surgery, was 6 points. At 12-24 months after surgery, the average score for the general population was 2.6±0.5 points, in group 1 – 2.7±0.7, group 2 – 2.6±0.6 (Fig. 2).

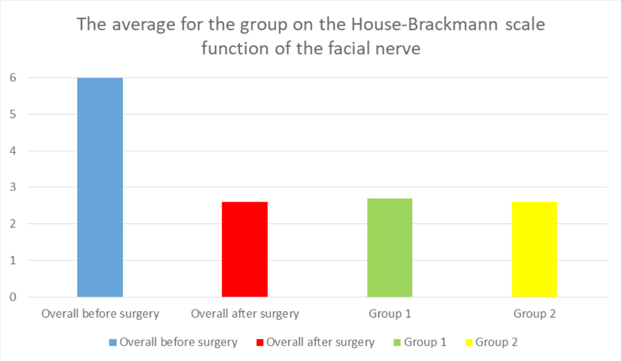

Figure 2. The results of the treatment of FNP, expressed in a score corresponding to the degree of FNP, according to the House-Brackmann scale

In group 1 and group 2, the FN nerve transfer significantly improved FN function (p<0.01; Wilcoxon Matched Pairs Test). In addition, patients in group 1 (n=78; 89.7%) and in group 2 (n=57; 91.9%) noted an improvement in the clinical status up to degree II-III on the House-Brackmann scale (Table 3), which corresponds to a satisfactory restoration of the function of the muscle that increases the angle of the mouth (m. levator anguli oris), the circular muscles of the mouth and a significant leveling of the asymmetry of the face, as well as restoration of the function of being able to completely close the eyelids. One of the positive side effects was the fading of inflammatory processes at the level of the cornea of the eye.

Table 3. Results of the surgical treatments for FNP

Clinical group	Number of patients (% percentage of the total number of patients, overall) FN functionality according to the House-Brackmann scale		Comparison in groups before and after surgical treatment (Wilcoxon Matched Pairs Test)	Average of the group (M±m)
	II-III	IV-V		
1	78 (89.7%)	9 (10.3%)	p=0.00	2.7±0.7
2	57 (91.9%)	5 (8.1%)	p=0.00	2.6±0.6
Total	135 (90.6%)	14 (9.4%)		2.6±0.5

The first signs forecasting a recovery of functionality after FN reinnervation were observed 4-6 months after surgical intervention; the maximum clinical effect was achieved within 9-14 months. Moreover, in 17 cases (11.4%), restoration of the function of all three main branches of the FN was observed.

Statistically significant differences were not obtained, when comparing the effectiveness of the two surgical methods (group 1 and group 2). It can also be stated that no significant differences were found (p >0.05; Mann-Whitney U-test, Table 4). Also, we found no significant difference in the distribution of nerve function scores on the House-Brackmann scale in group 1 and group 2 (p >0.05; Fisher exact test, Table 5).

In analyzing each of the tested surgical methods, a significant improvement in the patient's condition was observed at the expected time of the postoperative period. Since neither of the two most frequently used methods – group 1 and group 2 – showed any significant differences, their use in each, individual clinical case should be justified by technical considerations. It was previously believed [15] that isolated nerve transfer by a single nerve donor limits the recovery of FN function. Our observations disprove these assumptions. Taking into account the fact that simultaneous nerve transfer of the FN with the branches of the accessory nerve (group 1) is technically more economical, requires less time and participating personnel, this method should be considered as the basic one. The use of other nerve transfer methods is justified when there is a pronounced discrepancy between the cross-sectional area of the reinnervated part of the FN and the branch of the accessory nerve, individual anatomical features of the progression of the accessory nerve or its branches, comorbidity of the accessory nerve, or a number of other situational considerations.

According to the literature reviewed [15], the secondary deficit arising from the separation (segregation) of branches of n. accessorius from innervated muscles is manifested by motor or static deviation of the scapula, asymmetry of the muscles of the shoulder girdle, restriction of shoulder abduction, including when shoulder joint pain is also present. At the same time, the function of the upper limb was not significantly affected; in most cases, the described symptoms regressed in response to the reinnervation of the trapezius muscle with fibers of the descending branch of the hypoglossal nerve. Productive motor disorders with the indicated variant of FN nerve transfer (group 1) are synergies of facial muscles and muscles of the shoulder girdle.

In general, for extracranial lesions of the FN, for obvious reasons, the use of direct neuroraphy without tension or autoplasty, in the case of diastasis of the distal and proximal sections during the acute trauma period in the absence of contraindications, has been demonstrated. The method of choosing the reinnervation of the distal part of the FN with the technical impossibility to mobilize a section of the proximal stump sufficient for performing nerve suture is nerve transfer by the branches of the accessory nerve.

In cases where the length of time between the onset of the FNP and the initial office visit is more than 18-24 months, and, also, due to the fact that it is commonly known that patients are unable to diligently follow-through all the instructions that come with physical rehabilitation of the facial muscles, it is our opinion, that priority should be given to conventional methods of physical rehabilitation and, possibly, electrostimulation treatment, as well as static methods of facial correction.

Table 4. Comparison of the effectiveness between two surgical methods of facial nerve reinnervation (Group 1 and Group 2)

Method of reinnervation	Number of patients with FN House-Brackmann scale function II-III	Number of patients with FN House-Brackmann scale function IV-V	Total	The validity of the difference in FN function between groups in general, Mann-Whitney U-test
Group 1	78 (89.7%)	9 (10.3%)	87	p=0.5951
Group 2	57 (91.9%)	5 (8.1%)	62	

Table 5. Comparison of House-Brackmann functional index distribution after two types of nerve transfer (Group 1 and Group 2)

Clinical group	House-Brackmann scale II-III	House-Brackmann scale IV-V	Total	The significance of the difference in the discrete distribution of nerve function values by House-Brackmann scale in group 1 and group 2, Fisher exact test, one-tailed
Group 1	78 (89.7%)	9 (10.3%)	87	p>0.05
Group 2	57 (91.9%)	5 (8.1%)	62	

CONCLUSION

The use of the accessory nerve branches to the sternocleidomastoid muscle as donors ensures restoration of FN function to levels II-III on the House-Brackmann scale in most of operated patients and the results it achieves do not differ from those of the technically more technically more complex, time consuming and expensive method nerve transfer of FN by descending branch of the hypoglossal nerve with combination of branches of the accessory nerve.

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