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**Rehabilitation of patients with facial nerve injuries  
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The facial nerve is most often, as compared with other cranial nerves, damaged due to surgical interventions. In the first place, as the cause of iatrogenic damage, is neurosurgical treatment for neoplasms of the ponto-cerebellar angle and temporal bone, brain injuries. The neuropathy of the facial nerve is the cause of neurological and cosmetic defects that have a serious traumatic effect on the patient. The psychological consequences of facial neuropathy are more important for the patient than physical damage. Paresis of mimic muscles cannot be hidden and often leads to social maladjustment, isolation and a marked reduction in the quality of life. Facial neuropathy, in most cases, is not a life-threatening condition, but it definitely changes the patient's life. This article proposes an effective rehabilitation system, tested on 172 patients with facial nerve damage after neurosurgical treatment. The combined use of physiotherapy, massage, therapeutic gymnastics, including posture treatment with taping, during the early period of the disease, allows restoring nerve function and maintaining mimic muscles, as well as avoiding undesirable complications such as pathological synkinesis and corneal atrophy.

**Keywords:** neurosurgical treatment, neuropathy of the facial nerve, paresis of the facial muscles, rehabilitation.

## Relevance

According to WHO, facial nerve neuropathy is the most common type of mononeuritis, occurring with almost the same frequency (13–24 per 100 thousand population) in different countries of the world. There are many causes of facial nerve damage: infectious origin is the most frequent, the second cause is due to surgical interventions in the area of ponto-cerebellar angle, the third place is occupied by traumatic injuries of the facial nerve [1]. The use of microsurgical techniques for removal of ponto-cerebellar angle tumors currently allows most patients to maintain the anatomical integrity of the facial nerve, however, after surgery, its function suffers in more than 50 % of operated patients. In our practice, the most common are facial nerve neuropathies that occur after neurosurgical removal of ponto-cerebellar angle tumors [1–4].

A characteristic symptom of facial nerve neuropathy is paresis or paralysis of the facial muscles, manifested by asymmetry of the facial muscles in rest and during movement (score on the House-Brackman scale), impaired lacrimation, phonation, swallowing, and chewing [5]. Phonation, swallowing and chewing can be violated due to insufficient motility of the tongue, cheek, and pharyngeal muscles with a high level of nerve injury after neurosurgical intervention in the area of the cerebellopontine angle because facial nerve gave a stylohyoideus branch to the same muscle (m.stylohyoideus), it plays a role in the act of speech articulation, digastric branch to the posterior part of homonymous muscle (m.digastricus), which is involved in swallowing, chewing and speech and the lingual branch that connects to the lingual nerve. The disease has a significant emotional component-suffers the social adaptation and quality of the patients life. Psychological consequences of facial muscles paresis are more important to the patient than physical damage.

Paresis of the facial muscles cannot be hidden and often leads to social maladjustment, isolation and a marked decrease in the quality of life. Facial neuropathy in most cases is not a life-threatening condition, but it is definitely life changing.

Motor defect in facial nerve neuropathy leads to cosmetic a defect that not only has a psychotraumatic effect on the patient, but also violates acts of chewing, swallowing, changes the phonation. The most serious complication may be neuroparalytic keratitis due to lagophthalmus and lacrimation disorders, which eventually leads to scarring corneas, up to the point of vision loss. During the recovery of the facial nerve there could develop pathological synkinesias, which in combination with the above changes significantly reduce the quality of life of the patient.

There is no specific treatment, however, first of all it is necessary to cure the disease that led to neuropathy. The reasons may be different — local or general infectious processes, injuries, vascular and oncological diseases [6]. Degree of nerve damage and prognosis of further recovery is estimated using the electroneuromyography method [7; 8].

If there is a partial violation of the conductivity, conservative therapy is performed, including medication therapy, therapeutic gymnastics, massage, physiotherapy, kinesio-taping, and logocorrection. With persistent facial nerve lesions and ineffectiveness of rehabilitation treatment within 3–6 months (in the absence of positive clinical dynamics and improvement according to ENMG data), surgical treatment is performed. Type of surgical treatment is selected individually. Main types of operations: reinnervation of the

facial nerve by additional, sublingual, and diaphragmatic nerves, facial nerve suture, facial nerve neurolysis, plastic surgery to correct cosmetic defects [6; 9–12].

## Purpose

Develop an effective algorithm for rehabilitation treatment of patients with facial nerve damage after neurosurgical operations at different stages of the disease.

## Materials and methods

In our study we included 172 patients with facial nerve damage due to surgical treatment of ponto-cerebellar angle tumors. The most of the patients had benign tumors. When there were no signs of facial muscle recovery for 2–3 months after operations, reinnervation of the facial nerve by sublingual or accessory nerves was performed. The detailed distribution of patients by type of surgical treatment is presented in the Table 1.

Table 1. The distribution of the patients according to the type of surgical treatment.

| No. | Operation  | Total | %    |
|-----|--|-------|------|
| 1   | Removal of vestibular schwannoma                                     | 114   | 66.3 |
| 2   | Removal of a dermoid cyst  | 4     | 2.3  |
| 3   | Removal of ependymoma of lateral inversion                           | 2     | 1.2  |
| 4   | Removal of meningioma of the top of the pyramid of the temporal bone | 27    | 15.7 |
| 5   | Removal of glioma of the medial hemispheres of the cerebellum        | 1     | 0.6  |
| 6   | Reinnervation of the VII nerve by the hyoid nerve                    | 15    | 8.7  |
| 7   | Reinnervation of the VII nerve by the accessory nerve                | 9     | 5.2  |
| 8   | Total  | 172   | 100  |

As can be seen from the table data, the main group compound patients who received surgical treatment for vestibular schwannoma — 66.3% (114 people), meningioma of the temporal bone pyramid — 15.7% (27 people) and after reinnervation of the facial nerve with the hyoid nerve — 14% (24 people).

The patients were divided into three groups by the time of treatment initiation: 123 (71.5%) patients of the first group started treatment immediately after surgery — removal of the ponto — cerebellar angle tumor (on 2–3 days), in the second group—25 (14.5%) rehabilitation was performed in the long — term period (3 months or more after facial nerve damage), in the third group — 24 (14%) patients after reinnervation in the long-term period, who admitted to rehabilitation 2–3 days after surgery-reinnervation of the facial nerve by accessory or sublingual nerve.

The age of patients in the first group was  $41.7 \pm 11$  years (M+SD),  $58 \pm 10.7$  years in the second group and  $44.3 \pm 8$  years in the third group, respectively. The average age of patients in the second group was significantly higher than the age of patients in the other

two groups,  $p < 0.001$ . In this regard, the data analysis took into account (excluded) the influence of age.

When evaluating by the House-Brackmann Facial Paralysis Scale (HBS), in 11.1% (19 patients) we observed the V st. violations of the function of mimic muscles, in 29.6% (51 patients) — IV st., in 32% (55 patients) — III st., in 21.5% (37 patients) — II st. Patients with IV and V stages prevailed. The distribution of patients by the stage of paresis for HBS is shown in the Table 2.

*Table 2. The distribution of patients in groups by HBS*

| House-Brackmann Facial Paralysis Scale | Groups       |               |                     | Total      |
|--|--------------|---------------|---------------------|------------|
|  | Acute period | Remote period | After reinnervation |            |
| II                                     | 10 (5.8%)    | 0 (0%)        | 0 (0%)              | 10 (5.8%)  |
| III                                    | 31 (18%)     | 6 (3.5%)      | 0 (0%)              | 37 (21.5%) |
| IV                                     | 44 (25.6%)   | 11 (6.4%)     | 0 (0%)              | 55 (32%)   |
| V                                      | 38 (22.1%)   | 3 (1.7%)      | 10 (5.8%)           | 51 (29.6%) |
| VI                                     | 0 (0%)       | 5 (2.9%)      | 14 (8.2%)           | 19 (11.1%) |
| Total                                  | 123 (71.5%)  | 25 (14.5%)    | 24 (14%)            | 172 (100%) |

We used the electroneuromyography control, at first the initial parameters of conduction along the facial nerve were registered, then in dynamics — 1 month after treatment and 3 months later, if there was no positive dynamics. In the case of clinical and neurophysiological signs of reinnervation of mimic muscles, ENMG was no longer performed. If there was no improvement in nerve conduction, ENMG was repeated in 1.5–2 months, after the second course of treatment. On average, one patient was assessed using the ENMG method 3–4 times.

The rehabilitation course included physical therapy, therapeutic gymnastics, and, if necessary, sessions with a speech therapist. Physiotherapy in the 1<sup>st</sup> and 3<sup>rd</sup> groups was prescribed in 2–3 days after surgery, and in the 2<sup>nd</sup> group — on admission to treatment (3 months or more after facial nerve injury). We used the led radiation with a wavelength of 540 nm with an emphasis on the affected half of the face, contact, labile along cosmetic lines, for 5–10 minutes, for 3–5 days electrical stimulation of the facial nerve and facial muscles was started. SMT currents of the following parameters: IV type, frequency 30 Hz, the ratio of sending to pause 4: 6, the depth of modulation 50–75%, point electrodes, 2–3 minutes for each point, the current strength up to the sensation of moderate vibration, the total exposure time was no longer than 20 minutes, no. 10–15. The course was repeated after 1 month. For 3–5 days after the operation, massage of the neck-collar zone and point massage of the face, kinesiological taping and therapeutic gymnastics for facial muscles were prescribed. All active measures to correct facial movements were carried out with the active participation of the patient. Patients of the third group, with reinnervation of the hyoid nerve, in addition to exercises for facial muscles, reflex exercises were added — static tension of the muscles of the tongue and forced swallowing training.

Patients of the third group, with reinnervation with the additional nerve, in addition to gymnastics for facial muscles, exercises for the shoulder girdle muscles were performed. When patients showed clinical symptoms of dysarthria, dysphagia, and dysphonia, they got trainings with a speech therapist.

Since the first clinical manifestations of nerve recovery, the main focus was made on therapeutic gymnastics, buccal massage, and facial acupressure. In the absence of signs of friendly movements, electromyostimulation of facial muscles and exposure to 540 nm led radiation on the affected side continued. In the appearance of synkinesias electrical stimulation were excluded from treatment. Patients were prescribed only exposure to 540 nm wavelength led radiation along cosmetic lines up to 10 minutes, therapeutic gymnastics for post-isometric relaxation, taping, relaxing massage.

The effect of treatment was determined on the basis of two parameters that characterize the condition of patients before and after treatment — the severity of facial nerve damage by HBS and the amplitude of motor responses using the stimulation ENMG method.

The first examination of patients of the first and third groups was performed before the start of rehabilitation treatment 2–3 days after surgery, in the second group — in about 3–6 months after surgery. Control examination of patients was carried out at the end of each course of treatment, which consisted of 10–15 procedures of physiotherapy, therapeutic gymnastics and massage. Treatment courses were repeated after 1.5–2 months, for 6–12 months, the number of courses depended on the degree of damage to the facial nerve and the speed of its recovery.

## Statistical analysis

Distributions and event frequencies were compared using  $\chi$ -square ( $\chi^2$ ) criteria or the exact Fischer criterion. Correlations between metric and ordinal variables were calculated using Pearson and Spearman correlations.

To test the hypothesis of the effect of the start of treatment on the time of operation (groups 1–3) and the effect of treatment on the values of the amplitude of motor responses according to the stimulation ENMG, a mixed ANCOVA covariance analysis was used with subsequent Post Hoc comparisons with the Bonferroni correction (Bonferroni), excluding the influence of patients age. Statistical decisions were made at the 5 % level. The calculations were performed using the software package SPSS Inc.

## Results

After surgery, in all groups the most of patients had severe and moderate severity of facial nerve damage — 61.6 % (106 people), of which 11.1 % (19 people) had total paralysis of facial muscles. After a course of combined rehabilitation treatment, including therapeutic gymnastics, physical therapy, massage, and speech therapy, the best results were observed in patients who started treatment in the early postoperative period and continued training in the future (Figure 1, Table 3). Figure 1 shows the distribution of severity in % for HBS after treatment by group, depending on the degree of damage to the facial nerve before treatment.

Positive dynamics in the form of regression of facial muscle paresis by 1–2 points was observed in 90.7 % (156 people), in 9.3 % (16 people) of patients, no result was observed.

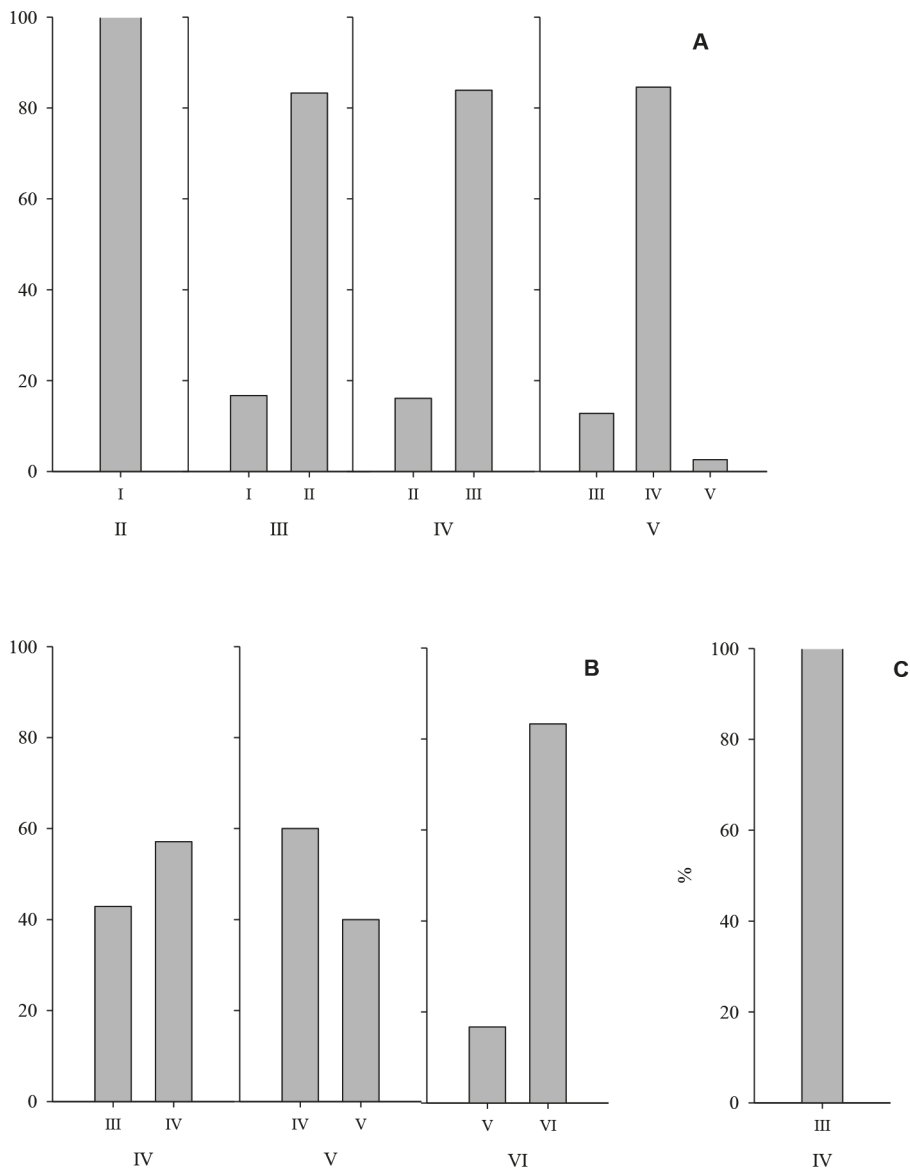


Fig. 1. Dynamics of HBS severity after treatment in different groups compared to the initial data. A — first group, B — second group, C — third group

Note: On the axis abscissas-severity of HBS, the upper row of digits shows the distribution of patients by severity after treatment in groups with the severity indicated in the lower row of digits. On the ordinate axis — the distribution of patients by severity, as a percentage.

In the first group only in one case there were no positive changes after treatment (2.6 %) with V grade at HBS in the second group improvement was noted in 57.1 % of (8) with IV grade, 40 % (2 people) with grade V and 83.3 % (5 participants) with grade VI of HBS. In the third group, all patients improved by one degree of severity.

Table 3 shows the distribution of differences between pre-and post-treatment severities.

Table 3. Dynamics of severity by HBS

|        |                            | Change in severity in points | Periods |        |                     | Total |
|--------|----------------------------|------------------------------|---------|--------|---------------------|-------|
|        |                            |                              | Acute   | Remote | After reinnervation |       |
| Number | HBS Before/after treatment | -2                           | 16      | 0      | 0                   | 16    |
|        |                            | -1                           | 106     | 10     | 24                  | 140   |
|        |                            | 0                            | 1       | 15     | 0                   | 16    |
|        | Total                      |                              | 123     | 25     | 24                  | 172   |
| %      | HBS Before/after treatment | -2                           | 13      | 0      | 0                   | 9.3   |
|        |                            | -1                           | 86.2    | 40     | 100                 | 81.4  |
|        |                            | 0                            | 0.8     | 60     | 0                   | 9.3   |
|        | Total                      |                              | 100     | 100    | 100                 | 100   |

Distributions differ significantly between groups,  $\chi^2(4, N=172)=93.84, p<0.001$ . In the first and the third groups there was an improvement of one degree of severity significantly more often compared to the second group,  $p<0.001$ , and significantly less often there were no change,  $p<0.001$ .

When analyzing the relationship between the severity of facial neuropathy by HBS with age and initial treatment — In the first group, there was no correlation between the severity and age either before or after treatment; in the second group, the severity and age after treatment significantly correlated,  $r=0.574, p=0.003$ , which meant that the function of facial muscles was more affected in patients of the older age group — more than 50 years.

Since the differences in the severity of HBS facial nerve damage before and after treatment were associated with age,  $r=0.298, p=0.001$  and  $r=0.466, p=0.019$  in the first and second groups, respectively, in the future, patients were divided into two age groups — less than 50 years and older than 50 years. In the third group, the differences were equal in all patients, so the calculation of the correlation was not possible. Then the distributions between the three groups were compared separately in each age group (Figure 2).

As a result, in the group aged  $\leq 50$  years, the distribution of treatment effects by severity did not differ between the groups, whereas in the group of patients  $> 50$  years, these differences were highly significant,  $\chi^2(4, N=57)=36.98, p<0.001$ . In the second group, older patients showed significantly less improvement in severity after treatment compared to patients in the first and third groups.

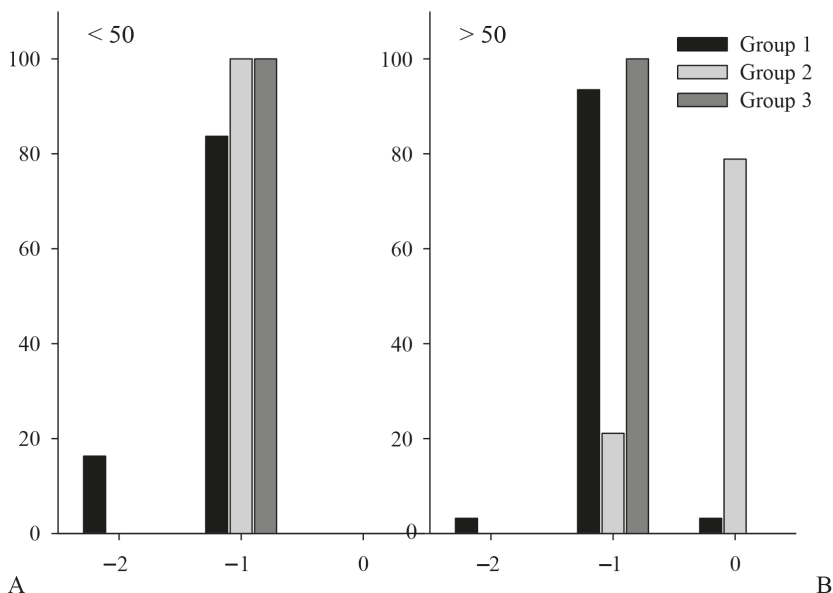


Fig. 2. Dynamics of the severity of facial nerve damage by HBS in two age groups: A — group of patients  $\leq 50$  years old, B — patients  $> 50$  years old

Note: On the axes of the abscissas — the difference between the degree of severity after treatment and before treatment (-2, -1, 0—a change of 1 St. on HBS).

When performing stimulation ENMG and evaluating the dynamics of the amplitude of motor responses in the first and second groups, the associations between changes in the amplitude before and after treatment with age were:  $r = -0.528$ ,  $p < 0.001$  and  $r = -0.533$ ,  $p = 0.006$ , respectively, which indicates a greater effectiveness of the treatment in younger patients than in older patients. In the third group, the dependence of the amplitude changes on age was not revealed.

After the course of rehabilitation, the most patients in group had moderate and mild facial nerve dysfunction — 55.8% (96 patients), normal function of facial muscles was achieved in 9.3% (16 patients).

The decrease in the degree of paresis occurred faster and more significantly in the group with initially less pronounced facial nerve damage, with a decrease in the amplitude of motor responses according to ENMG data of no more than 70% compared to the healthy side. Positive dynamics in the group with a severe degree of damage, with a decrease in the amplitude of motor responses according to ENMG data of more than 70%, was less rapid, in 2.9% (5 patients) in the early postoperative period, total paralysis of the facial muscles was preserved (Table 4).

Graphical changes in amplitudes according to the stimulation ENMG data are shown in Figure 3.

The covariance analysis showed the significance of the main effects and interactions of factors: significant treatment effect,  $F(1.168) = 88$ ,  $p < 0.001$ ,  $N_2 = 0.344$ , significant interaction of factors treatment effect and age,  $F(1.168) = 40$ ,  $p < 0.001$ ,  $N_2 = 0.191$ , the interaction of factors treatment effect and group,  $F(2.168) = 20.8$ ,  $*** p < 0.001$ ,  $N_2 = 0.199$ . In



addition, the main effects are significant-age,  $F(1.168)=9.7$ ,  $** p=0.002$ ,  $N2=0.054$ , and group,  $F(2.168)=6.2$ ,  $** p=0.003$ ,  $N2=0.068$ .

Table 4. Dynamics of amplitude characteristics in different groups

|  | Group 1     | Group 2     | Group 3     |
|--|-------------|-------------|-------------|
| Before treatment, mV                   | 0.362±0.016 | 0.238±0.031 | 0.385±0.011 |
| After treatment, mV                    | 0.590±0.021 | 0.274±0.035 | 0.483±0.012 |
| Differences after-before treatment, mV | 0.228±0.012 | 0.035±0.008 | 0.098±0.006 |

Note: The table shows the values of  $M \pm SE$ . Group 1 — patients in the early postoperative period, group 2 — patients in the long-term period after surgery, group 3 — patients after reinnervation of the facial nerve.

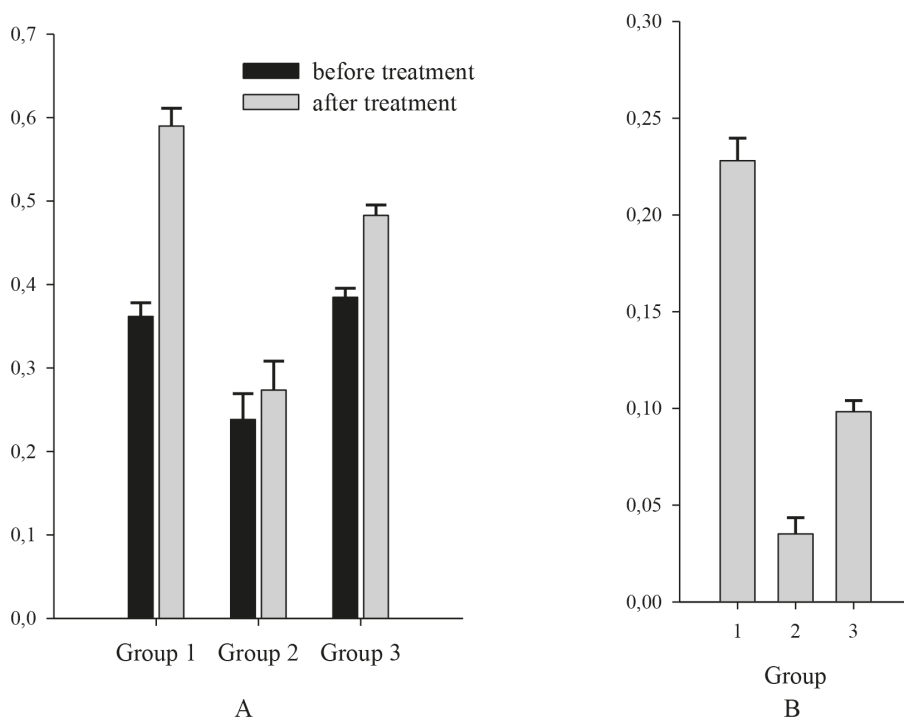


Fig. 3. A — average values of amplitudes ± errors of average amplitudes in dynamics, B — average differences after-before treatment ± errors of averages

In all three groups, there was a significant effect of treatment (after-before),  $p < 0.001$ . Before treatment, groups 1 and 2, as well as 2 and 3, differed significantly. After treatment, all three groups differed. The largest effect of treatment was observed in the first group (Table 5), in patients in the early postoperative period of the disease. It means that the rehabilitation treatment of such patients should be started immediately after the surgical treatment.

Table 5. Significance obtained from multiple comparisons of treatment dynamics in groups, Bonferroni test

|                  | Groups        |               |               |
|------------------|---------------|---------------|---------------|
|                  | 1-2           | 1-3           | 2-3           |
| Before treatment | * p = 0.021   | -             | * p = 0.015   |
| After treatment  | *** p = 0.000 | * p = 0.048   | * p = 0.044   |
|                  | Group         |               |               |
|                  | 1             | 2             | 3             |
| Before/after     | *** p = 0.000 | *** p = 0.000 | *** p = 0.000 |

Note: Group 1 — patients in the early postoperative period, group 2 — patients in the long-term period after surgery, group 3 — patients after reinnervation of the facial nerve.

In addition, it should be noted that correlations were found between changes in the amplitude values after-before treatment and changes in severity when excluding the influence of age,  $r = -0.612$ ,  $p < 0.001$  and  $r = -0.787$ ,  $p < 0.001$ , respectively. In other words, the more the severity of HBS decreased, the more the amplitude of motor responses increased.

Patients were being observed after treatment for 6–12 months. During this period differentiated courses treatment were carried out, depending on the degree of neurological deficit. When there was an excessive increase in the tone of facial muscles, electrostimulation procedures were stopped and only therapeutic gymnastics, kinesiotaping and led therapy were performed. The patients treated according to the proposed method did not have abnormal voluntary movements, synkinesias and atrophic keratitis of the cornea of the eye during the course of treatment and in the long-term period.

## Discussion

In our study, the age of the majority of patients was between 35–60 years, which coincides with the literature data, according to which facial nerve neuropathies due to the ponto-cerebellar angle tumors are more often observed in people of working age, which confirms the social significance of this pathology [13–15].

The results of the study confirmed the literature data on the correlation of the amplitude of motor responses according to the ENMG with the severity of damage to the facial nerve and paresis of the facial muscles [1; 7; 8]. It is recommended to examine ENMG not immediately after the course of treatment, but 2–3 weeks later, in order to exclude the phenomenon of increased excitability of muscles in the process of electrical stimulation and see the effect of treatment in its “pure form”.

Here is shown a positive effect of combined, differentiated treatment aimed at improving the conduction along the facial nerve and preserving the function of the facial muscles in patients in the early postoperative period. After the treatment, positive dynamics like the regression of facial muscle paresis by 1–2 points was observed in 156 (90.7%) patients, 16 (9.3%) patients did not show results. In total, before treatment, moderate and

mild dysfunction was observed in 27.6 % of patients, and after treatment — in 65.1 %,  $\chi^2(1, N = 172) = 64, p < 0.001$  (McNamara criterion). The best effect of treatment was obtained in the first group of patients, after removal of brain tumors and who started treatment in the early period of the disease. This confirms the literature data on the benefits of early recovery treatment in patients with neurosurgical pathology [6; 8; 11; 15].

The influence of age on the recovery process is confirmed. The best result was observed in patients aged less than 50 years. In the older age group, the improvement of facial nerve and facial muscle function was slower and to a lesser extent. This means that the treatment of older patients requires a more thorough approach and possibly longer time.

## Conclusion

Thus, the algorithm of combined individual treatment of patients who have undergone surgery for the ponto-cerebellar angle tumors, as well as after reinnervation of the facial nerve in the early period of the disease, includes in the acute period methods of electrostimulation, photochromotherapy, therapeutic gymnastics, acupressure and logotherapy; when friendly movements appear, electrostimulation is canceled and the patient receives only physical therapy, photochromotherapy, massage and, if necessary, Logotherapy. In the long term, the set of prescribed methods will depend on the clinical manifestations. Trainings are conducted with the control of electroneuromyography, which is performed for each patient at least 2–3 times. The proposed algorithm allows us to achieve the restoration of facial nerve function in a more complete volume and avoid undesirable complications, such as atrophic keratitis and pathological synkinesias with the formation of facial hemispasm in the future. The decrease in the degree of paresis occurred more significantly in the first group that started treatment immediately after surgery, in the second group (long-term period), the improvement was less frequent than in the first and the third groups (patients after reinnervation).

After surgery, patients with severe and moderate facial nerve dysfunction prevailed — 126 (73.2%), of which 13 (7.5 %) had total paralysis of facial muscles. Positive dynamics in the form of regression of facial muscle paresis by 1–2 points was observed in 156 (90.7%) patients, in 16 (9.3%) patients the result was not observed.

Before treatment, moderate and mild dysfunction was observed in 27.6 % of patients, and after treatment — in 65.1 %,  $\chi^2(1, N = 172) = 64, p < 0.001$  (McNamara criterion). The best results were observed in patients aged less than 50 years. This means that the treatment of older patients requires a more thorough approach and possibly longer time.

Patients with facial neuropathies that require long-term rehabilitation courses, including after surgery in the area of the ponto-cerebellar angle, are specific to our Institute. The tactics of neurorehabilitation of such patients require further observation and study. This article does not consider the effects of treatment depending on the etiology and method of reinnervation. This is a topic for further research and, as a representative group of patients is obtained, a topic for future publications.

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