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Outcomes of various surgical techniques used in patients with closed traction injuries of the brachial plexus

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Abstract

Introduction Traumatic lesions of the brachial plexus and analysis of the outcomes of various surgical techniques in patients with this pathology are the relevant challenges in neurosurgery, neurology, traumatology, orthopedics and rehabilitation due to the high social and economic significance, incidence and poor short- and long-term outcomes in this cohort of patients. This study was aimed at comparing the outcomes of various surgical techniques in patients with closed injuries of the brachial plexus. **Material and methods** The study involved 96 patients with closed injuries of the brachial plexus divided into three groups according to the method of their surgical treatment. Patients of Group I (n = 33) underwent microsurgical neurolysis of their brachial plexus trunks; patients of Group II (n = 28) had microsurgical neurolysis of their brachial plexus trunks with stimulating multichannel electrodes implanted on the trunks of their brachial plexus; patients of Group III (n = 35) had microsurgical neurolysis with stimulating multichannel electrodes implanted on the trunks of their brachial plexus as well as the segmental spinal cord apparatus at the level of the cervical intumescence. The clinical status and functionality of the upper limb were assessed after 6 months with clinical and neurological tests, scoring methods, and electrophysiological monitoring. **Results** We analyzed the outcomes of various surgical techniques in patients with closed injuries of the brachial plexus to prove a significant improvement in the outcomes of Group III patients who featured a faster rate of pain regression in the injured upper limb as well as significantly positive changes in clinical, neurological and electrophysiological indicators. **Discussion** The reduction in the total regional pain syndrome and restoration of the affected limb function was more evident in Group III patients what supports the favor of microsurgical neurolysis in combination with two-level electrical stimulation for closed injuries of the brachial plexus. **Conclusions** The analysis of various surgical techniques in patients with closed injuries of the brachial plexus revealed a significant efficacy of microsurgical neurolysis in combination with electrostimulation of the injured nerve trunk and segmental spinal cord apparatus (Group III). It improves the outcomes in this cohort of patients.

Keywords: brachial plexus, closed injuries, surgical management, electrostimulation

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IINTRODUCTION

Among all injuries of the nervous system, injuries to its peripheral part make from 1 to 6 %, of which injuries of the brachial plexus (BP) and its branches account for 60 to 81 % [1-3]. This problem is of high medical and social relevance, since irreversible disability due to traumatic BP neuropathies reaches 26-70 % of cases. Persistent neurological deficit in the affected limb is observed in 84 % of the cases, and there is a complex regional pain syndrome (CRPS) in 24 % of patients [4-7].

A special cohort consisted of patients with axonotmesis-type injury to the BP trunks [8], in which the anatomical integrity of the nerve trunk is preserved, but its function is affected. In such cases, the use of only microsurgical neurolysis (MN) as the main method of treatment in combination with a full range of therapeutic measures may be insufficient and may not restore the useful function of the upper limb [9-12].

An analysis of the literature data showed that the use of methods of electrical stimulation (ES) of the spinal cord (SC) and BP trunks has been widely used in clinical practice and leads to an improvement in the results of complex treatment of patients with damage to peripheral nerve structures and pain syndrome of various etiologies [13-17]. However, there are still unresolved issues concerning both clear indications for the use of various ES techniques, the timing of surgical intervention, the choice of optimal parameters of pulsed current, the duration of procedures, and the development of new surgical techniques and their combinations. This dictates the need to search for new methods of complex treatment that improve outcomes in patients with closed BP injuries, what determines the relevance of this study [18-21].

Purpose This study was aimed at comparing the outcomes of various surgical techniques in patients with closed injuries of the brachial plexus (CIBP).

MATERIALS AND METHODS

The study was a monocenter, longitudinal, open, prospective study with a historical group, conducted in compliance with the Geneva Convention and approved by the local ethics committee of the Razumovsky Saratov State Medical University of the Ministry of Health of Russia (protocol No. 4, dated November 1, 2022). The criteria for inclusion of patients in the study were working age, the isolated nature of the BP injury, the postganglionic level of its damage, the severity of damage to the nerve trunks corresponding to grades II, III, IV according to the Sunderland classification [8], CRPS in the limb affected, previous ineffective conservative treatment for at least 3 months from the date of injury, a signed voluntary informed consent of the patient to participate in the study.

The object of the study was 96 patients with CIBP who were hospitalized at the Research Institute of Non-Surgical Diseases of the State Medical University from 2005 to 2022. The age of the patients ranged from 18 to 65 years, of which 67 were men (69.79 %), 29 were women (30.2 %). The study was conducted in three groups, homogeneous in terms of sex, age and severity of neurological deficit. Group I was 33 patients (historical group). The number of groups II and III was 28 and 35 patients, respectively (prospective randomized study). The criterion for dividing into groups was the method of surgical treatment: patients of group I (n = 33) underwent microsurgical neurolysis of the trunks of the brachial plexus; patients of group II (n = 28) underwent microsurgical neurolysis of the trunks of the brachial plexus and placement of stimulating multichannel electrodes on the trunks of the brachial plexus; group III patients (n = 35) underwent microsurgical neurolysis along with the installation of stimulating multichannel electrodes on the trunks of the brachial plexus and on segmental spinal cord apparatus at the level of the cervical intumescence. In order to identify compliance with the inclusion and exclusion criteria, a clinical neurological examination was performed using scoring evaluation systems and questionnaires: pain intensity was assessed using the VAS scale [22], and the Medical Research Council Weakness Scale (MRC) was used to quantify muscle strength [23]; to assess sensitivity disorders, the Govenko F.S. scale was used. [24], the degree of dysfunction of the affected upper limb was assessed using the 100-point Disability of the Arm, Shoulder & Hand Outcome Measure (DASH) scale [25]. All patients (n = 95) underwent electroneuromyography of the upper extremities (ENMG) in dynamics.

A personalized registration document was created for each patient, a coding card, the information from which constituted an electronic database [26].

Statistical analysis of the obtained results was carried out using the Statistica 13.0 software, Microsoft Office Excel 2019. Data processing was performed using nonparametric statistical methods, and the median and interquartile interval were also calculated. To assess the significance of differences in the dynamics of the studied parameter within the groups, the Wilcoxon test was used. To prove the differences in the effect of the type of operation when comparing three independent groups, the Kruskal-Wallis test, the criterion for comparing average ranks, were used, and statistical significance (p) was calculated taking in regard to multiple comparisons. Differences between the groups were considered significant at $p < 0.05$.

RESULTS

In the preoperative period, the majority of the patients in every group (I-III) had neuropathic pain syndrome of a high degree of intensity (according to the VAS scale, the median of its intensity was 8.0 (7.0; 8.0)), while there was no significant difference between the studied groups ($p = 0.849$).

The analysis of the indicators of sensitivity and muscle strength in the preoperative period showed that most patients had muscle paresis in the affected limb and a decrease in sensitivity, the indicators of which are presented in Table 1.

Table 1

Indicators of sensation and muscle strength before surgery

Group	Muscle power	Sensitivity
I	2.0 (1; 2)	1.0 (1; 2)
II	1.0 (0; 2)	1.0 (0; 2)
III	1.0 (1; 2)	1.0 (1; 2)

Notes: Me – median (25 and 75 percentile)

An assessment of the homogeneity of the three study groups did not reveal their differences both in terms of sensitivity ($p = 0.372$) and muscle strength ($p = 0.353$).

High and moderate deficiency was noted while assessing functional deficiency on the DASH scale, more likely due to the severity of CRPS; Me (Q1; Q3) in group I was 76.0 (66.0; 82.0) points, in group II – 78.0 (69.0; 84.0) points, in group III 74.0 (64.0; 83.0). There were no differences between groups before surgery in terms of DASH ($p = 0.596$).

According to preoperative ENMG data, all patients with CIBP had damage to the long or short PS trunks, along with this, the most pronounced changes were noted in the median and radial nerves, the values of which are shown in Table 2. In all cases (n = 96), ENMG parameters were characterized by a decrease in amplitudes with an increase in the latency of the M-response (Table 2).

Table 2

ENMG parameters of the upper limb in patients with closed brachial plexus injury in the preoperative period

Nerve	ENMG indicators	Group 1	Group 2	Group 3
		Me (Q1; Q3)	Me (Q1; Q3)	Me (Q1; Q3)
Auxiliary	M-response (мА)	0.9 (0.8; 1.0)	1.0 (0.7; 1.3)	1.0 (0.9; 1.2)
	Latent period (LP) (msec)	3.8 (3.5; 4.4)	4.3 (3.5; 4.7)	3.7 (3.2; 4.5)
Musculocutaneous	M-response (мА)	0.7 (0.4; 1.1)	0.6 (0.3; 1.2)	0.9 (0.3; 1.4)
	LP (msec)	2.7 (2.0; 3.3)	3.0 (2.4; 3.5)	2.7 (1.9; 3.0)
Ulnar	M-response (мА)	1.2 (0.8; 1.5)	0.9 (0.4; 1.4)	4.2 (2.0; 7.1)
	LP (msec)	4.2 (3.8; 5.0)	4.1 (3.6; 4.6)	3.2 (2.0; 5.1)
n. Medianus	M-response (мА)	1.0 (0.7; 1.4)	1.1 (0.6; 1.5)	4.4 (1.9; 6.2)
	LP) (msec)	8.2 (7.1; 9.0)	7.5 (6.5; 8.3)	5.4 (3.5; 6.2)
Radial	M-response (мА)	1.0 (0.6; 1.3)	1.1 (0.7; 1.5)	4.8 (2.7; 6.4)
	LP (msec)	6.6 (5.5; 7.8)	6.5 (5.9; 7.2)	6.0 (4.3; 6.7)

Notes: Me – median (25 and 75 percentile), p > 0.05.

Thus, in patients of all studied groups (I-III), a syndrome of impaired conduction of the nerves of the upper limb was noted, and severe axonal damage prevailed both in the long and short BP trunks. In the postoperative period, all patients (n = 96) showed a decrease in the CRPS intensity, while its complete regression was not observed in any case. However, when comparing the rates of pain syndrome regression, a more pronounced decrease was recorded in group III ($p < 0.05$) (Fig. 1).

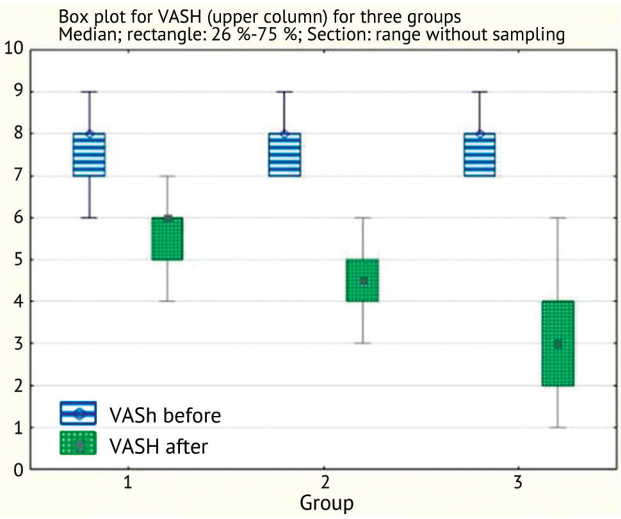

Fig. 1 Dynamics of pain syndrome in groups I, II, III of patients with CIBP

The dynamics of indicators of sensitivity and muscle strength in all the studied groups was weakly expressed, and there were no significant differences in the above indicators during the observation period up to 6 months ($p > 0.05$).

The assessment of functional insufficiency of the upper limb on DASH scale in the postoperative period showed that all patients (n = 96) had positive dynamics in improved function, while in groups I and II it was less pronounced compared to group III patients, which is associated with the fastest rate of CRPS reduction (Fig. 2)

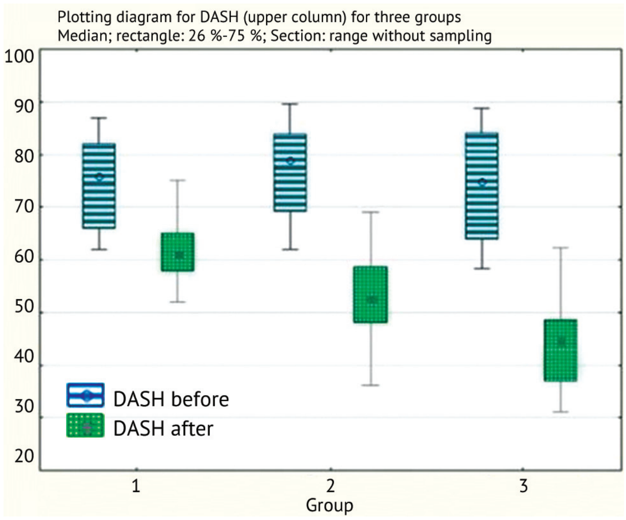

Fig. 2 Dynamics of functional deficit on DASH scale

The recovery of electrophysiological parameters correlated with clinical data by examination of the long BP trunks in all cases, while the most pronounced dynamics was noted while examining the median nerve, which consisted in an increase in the amplitude of the M-response and a decrease in the latent period both at the distal and proximal points of stimulation. The median indices of the amplitudes of the M-response at the distal point of stimulation corresponded to: in group I – 2.2 (2.0; 2.6), in group II – 3.8 (3.3; 3.9), in group III – 3.9 (3.3; 4.4). At the proximal point of stimulation: in group I – 2.4 (2.1; 2.8), in group II – 3.7 (3.3; 4.1), in group III – 3.9 (3.6; 4.3) ($p < 0.01$) (Fig. 3). At the same time, an improvement in the LP parameters of the median nerve was also noted as at the distal point of stimulation: in group I – 5.3 (4.6; 6.2), in group II – 5.1 (4.3; 5.9), in group III – 5.4 (4.6; 6.0), and in the proximal point: in group I – 9.9 (9.1; 10.8), in group II – 9.7 (9.4; 10.6), in group III – 9.3 (8.8; 9.7) ($p < 0.01$).

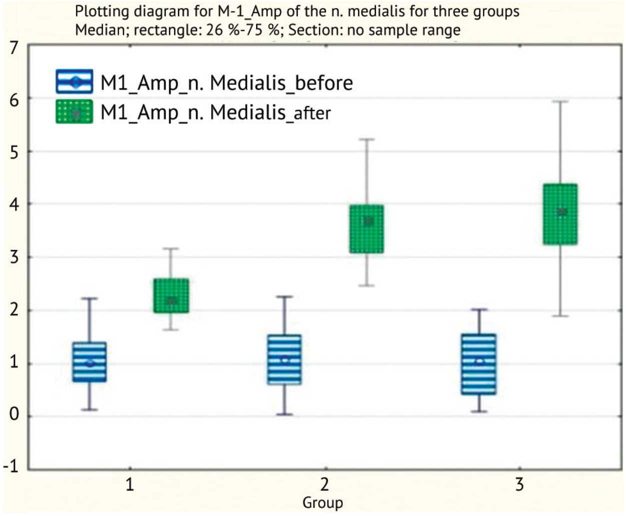

Fig. 3 Dynamics of M-response indicators of the median nerve

The amplitude of the M-response (mV) for the ulnar nerve in the postoperative period was 2.0 (1.8; 2.2) in group I, 3.0 (1.9; 3.5) in group II, and 3.8 (3.2; 4.2) in group III ($p < 0.01$); for the radial nerve in group I – 2.2 (2.0; 2.6), in group II – 3.8 (3.3; 3.9), in group III – 4.4 (3.6; 4 .8) ($p < 0.01$) (Fig. 4 and Fig. 5).

Thus, the recovery of the conductivity of long BP trunks was observed in all groups; however, it was more pronounced in group III (n = 35), which indicated a significant effectiveness ($p < 0.05$) of the MN technique in combination with two-level ES compared to only MN (group I) or MN in combination with single-level ES (group II).

The positive dynamics of ENMG parameters was also more significant in group III compared to groups I and II while investigating short Bp trunks. In the postoperative period, the quantitative indicators of the amplitudes of the M-response of the musculocutaneous nerve corresponded to: in group I – 1.5 (1.2; 2.1), in group II – 3.1 (2.0; 3.3), in group III – 3.4 (2.8; 3.9). Latency period indicators in group I were 2.4 (2.0; 3.1), in group II – 2.3 (2.1; 3.2), in group III – 2.0 (1.4; 2 .5) ($p < 0.01$).

Quantitative indicators of the amplitudes of the M-response of the axillary nerve were 1.3 (1.2; 2.1) in group I, 2.6 (1.7; 3.0) in group II, 3.4 (3.0; 4.0) in group III. LP indicators in group I were 3.3 (3.0; 3.9), in group II – 3.3 (2.8; 4.0), in group III – 2.7 (2.2; 3.2). When comparing ENMG data of the axillary nerve in patients of all studied groups, a more significant positive dynamics with the Kruskal-Wallis criterion was noted in the patients of group III (n = 35).

Thus, the ENMG data of long and short BP trunks revealed that MN in combination with a two-level ES (group III) is a more effective technique for CIBP. No significant differences were found ($p = 0.061$) by comparing the results of treatment in regard to gender.

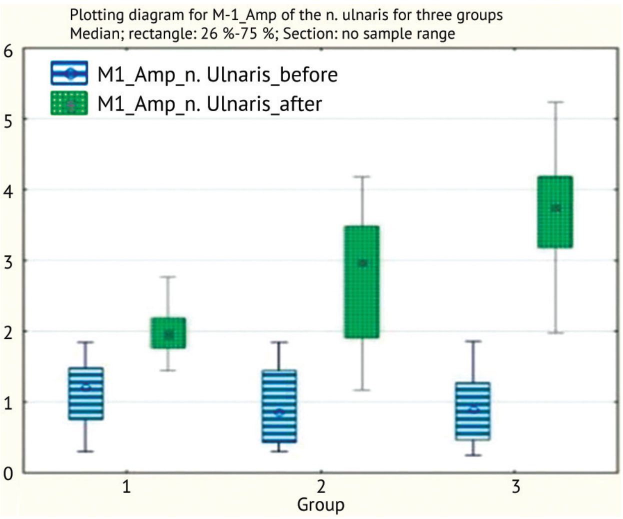

Fig. 4 Dynamics of M-response indicators of the ulnar nerve

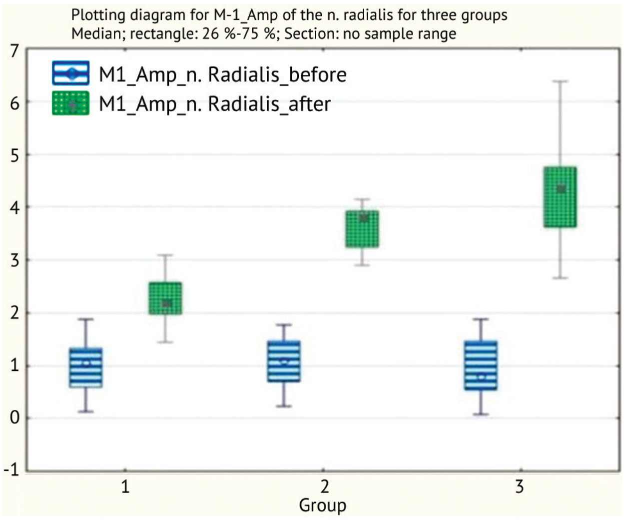

Fig. 5 Dynamics of M-response indicators of the radial nerve

DISCUSSION

The present study demonstrates the effectiveness of the MN technique in combination with two-level ES that was manifested by a significant decrease in CRPS in the affected limb, which was associated with a simultaneous effect on the central mechanisms of pain regulation (insertion of electrodes into the epidural space of the SC at the level of the cervical intumescence) and on the BP trunks. This was confirmed by dynamic clinical and electrophysiological data in all patients of group III (n = 35), by an increase in the amplitude and a decrease in the latency of the M-response, which was significantly different from patients in groups I and II. Most likely, this was associated with the activation of the formation of neurotrophic factors due to the mutually reinforcing effect on both the segmental apparatus of the spinal cord and on the trunks of peripheral nerves [27-30].

The results obtained correlate with the literature data. Thus, I.A. Meshcheryagin and A.A. Skripnikov [31] used similar technologies for the surgical treatment of patients with closed nerve injuries and observed a complete regression of pain in 92 out of 94 patients. A.T. Khudyaev and I.I. Martel [32] applied microsurgical neurolysis and courses of epineural electrical stimulation and revealed that in more than 76.53 % there was a decrease in sensory disorders, restoration of the motor function of the affected limb, regression of the pain syndrome and the return of patients to their professional activities.

CONCLUSION

A comparative analysis of the use of different surgical methods for treatment of patients with CIBP demonstrated a significant effectiveness of the MN technique in combination with ES of the BP trunks and the segmental spinal cord apparatus at the level of the cervical intumescence, which improved the results of treatment and manifested itself in a faster rate of pain relief in the affected upper limb and improvement in electrophysiological parameters.

Conflict of Interest *The authors declare no conflict of interest.*

Funding *The study was carried out as part of the research work of RITON SSMU "Development of a system for supporting medical decision-making in the complex treatment of injuries of the peripheral nervous system using electroneuromodulation methods" (state registration number NIOKTR 121032300173-9).*

Ethical expertise *The study was approved by the local ethical committee of the SSMU named after V.I. Razumovsky (protocol No. 4 dated November 01, 2022), and was carried out in accordance with ethical standards developed in accordance with the Helsinki Declaration of the World Medical Association.*

Informed consent *All study participants signed an informed consent form.*

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Bazhanov S.P. – conceptualization, methodology, validation, writing (reviewing and editing), visualization.
Shuvalov S.D. – formal analysis, research, data processing, writing (initial version), visualization.
Korshunova G.A. – research, data processing, visualization.
Ostrovskij V.V. – control, project management.