INTRAOPERATIVE NEUROPHYSIOLOGICAL MONITORING (NIOM) AND SURGICAL TACTICS IN CHIARI MALFORMATION TYPE 1.

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Abstract: The article presents the results of surgical treatment of 147 patients with Chiari malformation (CM) type 1 using intraoperative monitoring. During the surgical intervention, the tactics and volume of the surgical intervention are determined depending on the dynamic data of the NIOM. The analysis of the nearest and distant regression results of neurological deficit in patients operated with and without NIOM was performed.

Keywords: ectopy of tonsils, craniovertebral transition decompression, neurophysiologicintraoperative monitoring (NIOM), brainstem auditory evoked potentials (BAEP), median nervesomatosensory evoked potentials (SSEP).

The rapid development of modern computer technologies has defined a new stage in neurophysiologicintraoperative diagnostics. Even 25 years ago, few people heard about NIOM, and the initial documentary studies proving the effectiveness of BAEPand SSEPin surgical pathology of the stem and spinal structures appeared only 20 years ago (11,12,13). Neurosurgeons, anesthesiologists, and neurologists are all relevant in NIOM operations, and many types of brain and spinal cord surgery are safer and the risk of induced damage during surgery is reduced (14). Further improvements to NIOM protocols have not only prevented pathological lesions associated with surgical procedures but also made it possible to determine in real time the tactics, radicality and scope of surgery (4,12,14).

For the last 10 years, there have been publications on the results of operations with NIOM in spinal surgery for extra- and intradural tumors, intramedular spinal cord formation (13,12). There areseveral studies on the efficacy of NIOM in operations on middle and posterior fossa structures (7,11).

However, we have not found a single study that reveals IOM issues in type 1 Chiari malformation surgery. So far, we have not covered the choice of optimal surgical tactics and the scope of surgical intervention in the uncomplicated form of CM1, as well as CMA1 in combination with syringomyelia or hypertension-hydrocephalic syndrome based on data from NIOM. The abovementioned facts served as a reason for our scientific research.

Material and methods.

We have examined 147 patients with Chiari malformation type 1, who is on inpatient treatment in the Clinic OF RSSPMCN 2015-2020. All these patients were operated on for the underlying disease, 49 of them were men and 98 women aged 14 to 52 years.

Surgical intervention with the use of IOM was carried out in 77 patients with CM-1 type, 70 were operated on without neurophysiological monitoring. We used our previously proposed quantitative clinical-neurophysiological ball scale of subjective, objective and neurophysiological symptoms in the preoperative diagnostics of the examined patients with CM 1 type. Conclusions on the specified scale about subcompensated or decompensated stage of the disease caused the choice of the suggested surgical tactics in patients with CM of type 1. At the subcompensated form of CM1 type bone decompression was shown, if necessary, with additional Dura Materdissection. The presence of the decompensated form implied bone and dural decompression with extended dura mater plasty. The decompensated stage with sharply pronounced ectopy of amygdala in several patients of CM1 type determined the necessity of bone dural decompression with resection or coagulation of cerebellar amygdala.

General principles of CM1 operations with NIOM. We used the position "lying on the tummy" in most cases, as this type of placement is more convenient for subsequent installation of electrodes and headphones used in NIOM (Fig.1).

Fig. 1. laying plan in "lying on your tummy" "concord" position

The position "lying on the side" we also used for operations on CM1. However, this type of laying had some disadvantages during the IOM: there was a difficulty in installing the electrodes in the vertex-mastoid, the need to use only flat headphones, frequent artifacts from the underlying electrodes due to their mechanical irritation (Fig. 2).

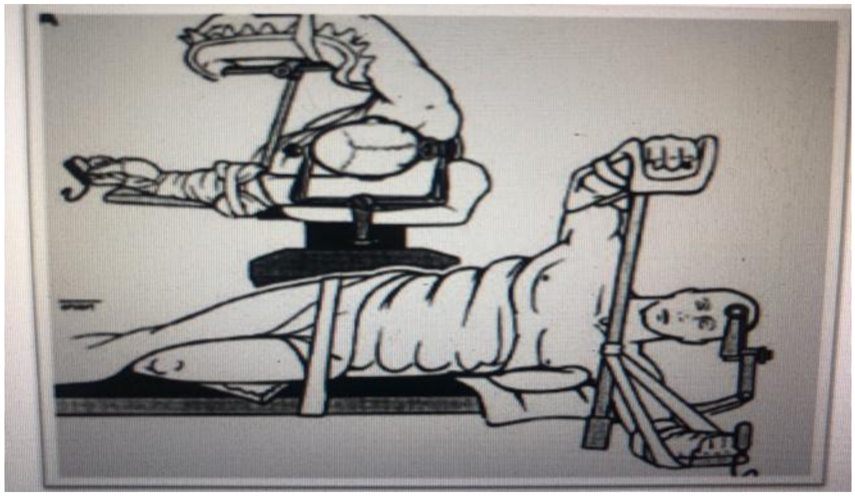

Fig. 2. laying plan in "lying on the side" position

In operations using the NIOM multimodal protocol, we used myorelaxants only at the stage of intubation, followed by gas narcosis of isoflurane with fentanyl.

The advantage of BAEPand SSEP methods is their low sensitivity to the effects of anesthesia and myorelaxant administration.

When performing NIOM, we used a 32-channel stationary neuromonitor ISIS Xpert (inomed). Based on the preoperative data, a multimodal protocol for intraoperative monitoring in patients with AK 1 type, including BAEP, SSEPand EMG of the lingual and accessory nerves, was developed. The use of motor EP caudal nerves derived from direct nerve stimulation was considered inappropriate for this type of surgical intervention because there was no need for their direct identification.

All electrodes were placed after intubation and placement of the patient before the treatment of the operating field. For BAEPmonitoring, we used standard vertex-mastoid removal (M1-Cz, M2-Cz), stimulation was performed through headphones with 0.1 msbiural clicks with 20 Hz feed frequency and 80 dB sound in the operating room.

In the course of CERS, the electrodes were placed according to the standard C4-Fz method - when n.medianus S was stimulated, C3-Fz when n.medianus D was stimulated. Stimulation was performed by electrical pulses in the projection of the median nerve at the wrist level with a current of 15-20 mA, frequency 2 Hz.

EMG monitoring by type of mechanogram was performed by default on the lingual-throat and accessory nerves, with recording electrodes set according to the muscle innervation presented below. If necessary, we supplemented the nerves under study based on the clinical syndrome.

Cranial nerve-innervation of muscles
III, IV, VI - Extraocular muscles
V - Masseter, temporalis
VII -Frontalis, orbicularis oculus, orbicularis
oris, mentalis, others
IX - Stylopharyngeus
X - Pharyngeal and laryngeal muscles
XI - Sternocleidomastoid, trapezius
XII - Tongue

Before the skin section, the baseline indicators of BAEP, SSEP and EMG were registered, which was the basis for the subsequent interpretation of data. Then EP and EMG parameters were registered after the skin incision, after skull fluttering, Dura materopening, Dura materplasticity and suturing of the skin incision. Considering the dynamic changes in the indices of different modalities, we determined the surgical tactics.

During the surgical intervention with the NIOM, we paid attention to the dynamics of both amplitude and time parameters for the BAEPand SSEP indicators. For BAEP, we considered the amplitude parameters of the components PⅢ and PⅤ, as well as the latency of the interpeak interval PⅠ-PⅤ. Moreover, the determining factor of the functional state of the stem structures according to the ASBP data was exactly the amplitude parameters: if the amplitude of PⅢ and PⅤ changed less than 2 times, the changes were moderate; if more than 2 times, the disturbances were pronounced. For EMG, we analyzed amplitude and time parameters N13/N20, N30/P37. At EMG, we estimated the presence of both minimal mechanical irritation of the examined cranial nerves - one-time Spike responses, and signs of serious damage in the form of pathological patterns (A-train).

Results and discussion.

Bone decompression of the craniovertebral transition.

When analyzing the CNPHS scale data, a subcompensated form of CM1 type was determined in 88 patients, of which 43 patients with an uncomplicated form of CM1 had a surgical intervention using neurophysiological IOM. Presence of subcompensated form CM1 implied only bone decompression of craniovertebral transition.

Decompression of the craniovertebral region was performed by posterior median access. The skin incision was located from a point a centimeter above the outer occipital protuberance to C2 vertebrae. We did not observe any pronounced reactions of amplitude and time parameters of BAEPand SSEP when performing the skin incision. An unstable increase in the amplitude of the component PⅢ was noted in 2 patients associated with soft tissue coagulation. No negative reactions were observed in the EMG monitoring mode.

Next, we performed a craniotomy using a milling cutter hole and further resection of the bone with Kerrison cutters. The formation of the bone defect began at the back edge of the large occipital opening, gradually expanding the window to 3.0x3.0 cm. Having received the necessary bone defect, we stopped the surgical operations for 4-5 minutes in order to perform the next measurement of BAEP, SSEP. The reaction of amplitude increase of the components PⅢ and PⅤ at the baseline values of BAEPcharacterized the irritational disorders at the level of trunk structures at CM1. Changing these parameters by 30% of the initial values towards normalization, we considered as positive dynamics of the functional state of the stem structures. The normalization of latency indices of N13-N20, N30-P37 components after decompression was observed. In 24 patients with subcompensated form CM1 after bone defect creation, the reliable positive dynamics of BAEPand SSEP indices was registered with the restoration of the functional state of the stem structures. For these patients, we limited the volume of surgical intervention.

In 19 cases at NIOM after bone decompression, the improvement of amplitude parameters PⅢ and PⅤ was not more than 20% of basic parameters. Under such conditions, surgeons were recommended to extend the bone defect downwards with C1 posterior arc resection. In 4-5 minutes after this manipulation, we made another measurement of BAEPand SSEP parameters. Under such tactics, all 19 patients had positive dynamics and normalization of amplitude values PⅢ and PⅤ as well as time parameters N20 and N30 in comparison with the initial values. Irritative reactions at EMG were short-lived by Spike type and had no important role in determining the volume of surgical intervention.

After suturing the skin incision, we did not record any significant changes in the parameters of all modalities.

Thus, in all 43 cases of CM1 patients with subcompensated form, we obtained positive dynamics of the functional state of the stem structures after bone decompression of craniovertebral transition.

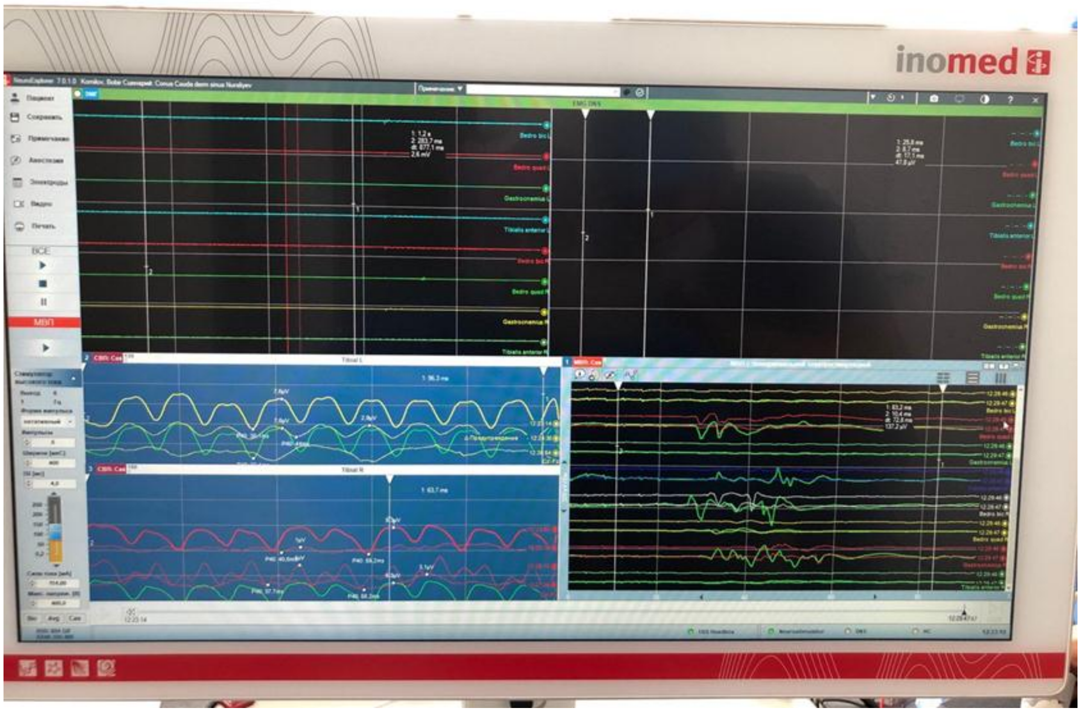

Fig.3. An example of a multimodal protocol (BAEP, SSEP, EMG) with dynamic changes at the stages of surgical intervention in decompression of craniovertebral transition in patient A. with subcompensated form CM1 (own observation)

Bone and dural decompression with Dura materplastics.

When analyzing CNPHS scores, the decompensated form of CM1 type was determined in 59 patients. The surgical intervention was performed with the use of neurophysiological NIOM 27 patients, the combination of CM1 with syringomyelia was determined in 17 patients, and hypertension syndrome was noted in 6 cases.

In this situation, we considered it expedient to perform the first stage of bone and dural decompression of craniovertebral transition with solid dura mater plasty. The stages of bone and dural decompression before the dura mater dissection were identical to the above.

Control measurements of the dynamics of different modalities at the NIOM were made according to the previous protocol. Prior to the stage of TMR dissection, in no clinical case with decompensated form CM1 we recorded normalization of parameters at the NIOM. At the stage of dura mater dissection, the amplitude parameters PⅢ and PⅤ at BAEPfluctuated upwards, which we considered to be a temporary irritative response. However, at registration of SSEP, on the contrary, a decrease in amplitudes of components N20 and N30 by 20-25% of basic values was noted, which is probably due to changes in intracranial pressure. Autopsy of the Dura materrequired extreme accuracy to prevent damage to the arachnoid shell and to preserve the cerebellar-medullary tank. There are several options for a Dura materincision, the choice of which depends on the surgeon. The most commonly used is a Y or semi-circular incision, which is more convenient for subsequent dura mater plastics. At this stage, we paid great attention to hemostasis, trying to gently use bipolar coagulation. In one case, there was venous bleeding from full-blooded dilated, stagnant veins, in which the NIOM showed a sharp depression of BAEP, indicating hypoxic changes in the brain stem.

In two patients with the manifestations of the decompensated bulbar syndrome in the mechanogram mode, we observed the phenomena of irritation and partial conduction disturbance on the lingual nerves after the dura mater autopsy (Fig.4).

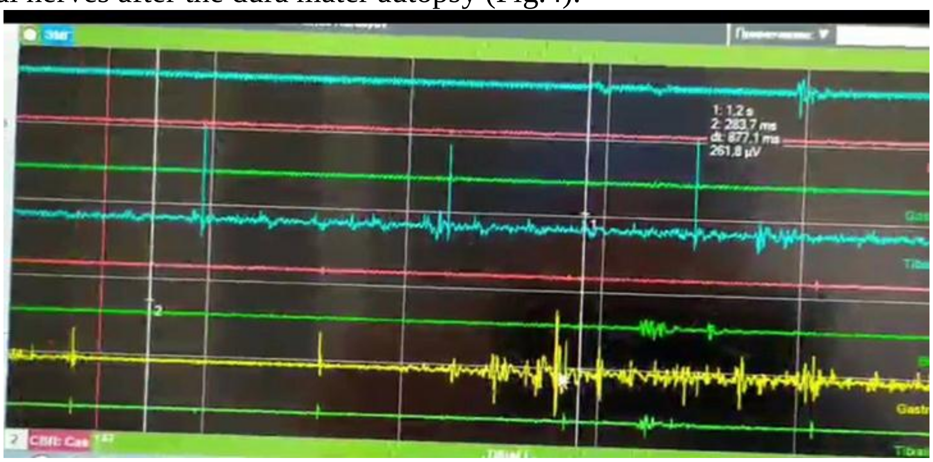

Fig.4. (own observation)

The plasty of the dura mater defect in most cases (23 patients) was performed using autoaponeurosis, in 4 cases the plasty was performed with synthetic materials. At the end of this manipulation, we again measured the parameters of the multimodal protocol. At the same time according to BAEPdata in 18 patients, the amplitudes PⅢ and PⅤ changed towards normalization by 30%, whereas in 9 cases no improvement of these indices was noted. At the analysis of ASPP in 22 studies the latency values of PS N13-N20, N30-P37 were shortened by 0.2-0.3 ms that indicated the improvement of afferentiation at a ponto-medular level. Unfortunately, in 5 patients with AC of type 1 in combination with syringomyelia of cervical and cervical thoracic regions we did not notice any improvement in parameters of BAEPand SSEP, even after decompression and dura mater plasty. For example, in a patient with syringomyelia of the cervical section with anterior spinal syndrome manifestations, asymmetrical coarse depression of SSEP parameters on n.medianus D stimulation was registered after dura mater plasty (Fig.5).

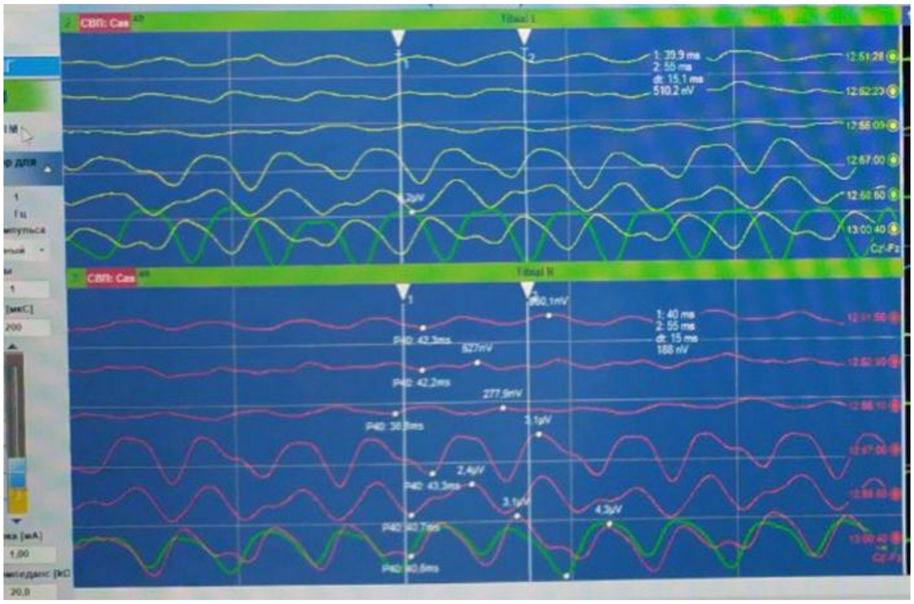

Fig.5.Depression of SSEP indices on median nerve stimulation on the right side of the patient with cervical syringomyelitis (own observation).

The mentioned 5 patients with CM1 in combination with syringomyelia were further suggested to drain the syringomyelic cavity in the second stage.

The combination of CM1 and HHS was observed in 6 patients during NIOM, with normalization of BAEPand SSEP parameters in about 30% of the initial ones registered after dura mater plasty in 5 examined patients. In a single case, the expressed irritational phenomena and conduction slowing down at ponto-mesencephalic level remained without dynamics, in connection with this patient ventriculoperitoneal bypass was further performed.

Further, we measured the indices after suturing the dura mater, the fluctuations of which had insignificant transient character, connected with mechanical manipulations.

Thus, in bone dural decompression with dura mater plastics, dynamic improvement of BAEP, SSEP and EMG indices according to the NIOM data was observed in 21 patients, which testified to the adequate choice of the surgical intervention volume; 6 patients of this group had to undergo further surgical stages.

Mobilization of cerebellar tonsils with their subsequent resection was conducted in 7 patients with NIOM. The stages of measurements of multimodal values were supplemented by the evaluation of BAEPand SSEP after amygdala resection or coagulation. It should be noted that the amplitude parameters of BAEPreacted sensitively to temporary coagulation exposure with a sharp increase of more than 2 times. This fact indicated the irritation of stem structures and required the surgeon to stop the manipulations until the components were reduced to the basic values PⅢ and PⅤ. Hypoxic pathological reactions according to BAEPdata characterized by amplitude depression PⅢ-Ⅴ and PS extension P Ⅰ-Ⅴ at amygdala resection were noted in 2 patients. In these clinical cases a moderate neurological deficit was registered in the postoperative period.

The closest and distant results of CM1 surgical treatment according to the clinical neurophysiological scale (CNPHS).

The dynamics of neurological status in patients with CM1 type in the postoperative period depending on surgical tactics is described in the works of some authors (1,2,3,5,6). The literature presents data on the results of postoperative complications depending on the volume of craniovertebral transition decompression, creation of reserve spaces of a large brain tank (the authors). Dynamics of neurological manifestations and postoperative complications were studied using different variants of the material for dura mater plastics (8,9,10). However, when estimating the dynamics of neurological disorders in the postoperative period, they are often based on subjective sensations of the patient or the opinion of the doctor. At the same time, the notions of "significant improvement", "insignificant improvement", "without changes", "with worsening" have relative, qualitative character and make it difficult to objectify the patient's postoperative state. Neurophysiological tests - BAEP, SSEP, ENMG, carried out in different time stages after the surgery are the most informative and exclude the subjective evaluation factor.

Considering the abovementioned facts, we decided to use the clinical neurophysiological CNPHS scale proposed earlier by us when estimating the dynamics of neurological disorders in patients with CM1 type in the nearest and distant period. Scores - from 1 to 18, received at examination of the patient before the operation, were considered as initial. Standard concepts were introduced to simplify the analysis in the postoperative period: "with improvement", "without dynamics", "with worsening". Score "without dynamics" was determined in those patients whose initial scores differed only by 1 point upward or downward (for example, in a patient with a decompensated form of CM1 type before surgery - 17 scores on CNPHS, and after surgery - 16 scores - state "without dynamics").

Rating "with worsening" was noted when the initial preoperative scores on a scale increased by more than 1 point (for example, in a patient before surgery - 15 points on CNPHS, and after surgery - 17 points - condition "with worsening"). It should be noted that the usual qualitative notions of evaluation of the postoperative condition of a patient with AC1, now with the use of the scale had an objective quantitative reflection in points.

We have analyzed postoperative results in patients in subcompensated and decompensated form of CM1 type, which was operated on in the clinic of RSSPMCN with the use of NIOM- 77 patients and without this allowance-70 patient. All patients were divided into 4 groups: Ⅰ group- patients with subcompensated form CM1according to initial CNRNS scale data, operated without NIOM; Ⅱ group- patients with subcompensated form CM1 according to initial CNRNS scale data, operated with NIOM; Ⅲ group - patients with decompensated form CM1 according to CNRN scale, operated without NIOM and Ⅳ group - patients with decompensated form CM1, operated with NIOM. The nearest surgical results were estimated at 7 days after the surgery; intermediate results - at 3 months and distant results - at 1 year after the surgery. The obtained data are presented in the tables below.

In the analysis of postoperative results on the 7th day after the surgery with the use of clinical neurophysiological scale in the groups of patients with subcompensated form CM1 "improvement" - (i.e. reduction by more than 1 point from the initial values) was determined in 18 (40.0%) patients operated without NIOM control and 20 (46.5%) patients operated with NIOM. However, in more than a half of Ⅰ and Ⅱ groups - 27 (60.0%) and 23 (53.5%) patients in the early postoperative period were not registered on the CNPN dynamics scale by points. Negative results - "with worsening" on the score scale by 7 days after the operation were not determined either in Ⅰ group or in Ⅱ group of patients.

When analyzing the scores in patients with decompensated form CM1 in Ⅲ group operated without NIOM and in Ⅳ group with NIOM, the values - "with improvement" from the initial scores were revealed in 8 (32.0%) and 13 (40.6%) examined respectively. The majority of patients of both groups (Ⅲ and Ⅳ) had no dynamics on the CNPN scale, 2 patients in both groups with decompensated form CM1 received the assessment "with worsening" in the early postoperative stage. The prevalence of the assessment "without dynamics" on CNPH scale for 7 days after the operation in patients of all 4 groups was quite expected and indicated both painful muscle-reflex disorders in the postoperative scar zone and irritation according to EP with reactive edema phenomena.

Further, after 3 months, we analyzed postoperative results on CNPH scale in the above 4 groups of patients with CM1.It should be noted that in both Ⅰ and II groups of operated patients with subcompensated form of CM1 the number of cases "with improvement" on the scale points significantly prevailed and made 24 (77.4%) in Ⅰ group and 28 (93.3%) in II group respectively. It should be noted that in the group of patients with subcompensated form CM1 operated without NIOM, the number of patients "without dynamics" was significantly higher in comparison with the group of patients operated with NIOM. In Ⅰ group of such patients, there were 7 (22.6%) people, and in the Ⅱ group, there were only 2 (6.67%) cases. In the case of decompensated CM1 form, the analysis of intermediate postoperative results indicated positive dynamics in 10(55.6%) of Ⅲ group and 13(59.1%) Ⅳ group according to CNPH scale. It should be noted that in the group of patients with subcompensated form CM1 operated without NIOM, the number of patients "without dynamics" was significantly higher in comparison with the group of patients operated with NIOM. In Ⅰ group of such patients, there were 7 (22.6%) people, and in the Ⅱ group, there were only 2 (6.67%) cases.In the case of decompensated CM1 form, the analysis of intermediate postoperative results indicated positive dynamics in 10 (55.6%) patients of Ⅲ group and 13 (59.1%) Ⅳ group according to CNPH scale points. Absence of any significant clinical and neurophysiological changes was determined in 8 (44.4%) and 7 (31.8%) patients in Ⅲ and Ⅳ groups respectively, which we supposed in the preoperative period by initial CNPHS scores. Two patients in each of the groups-11.1% and 9.1% with decompensated form CM1 had negative dynamics by CNPHS scores. The condition of these 4 patients has not improved since the early postoperative period.

The distant results of surgical treatment with and without NIOM with subcompensated and decompensated form CM1 were analyzed 1 year after the operation.In Ⅰ group of patients with subcompensated form of CM1 positive dynamics by scores at CNPHS evaluation was determined in 14 (66.7%) patients, whereas in the II group objective evaluation "with improvement" in scores was revealed in 15 (93.8%) cases. It should be noted that in the group of operated patients with subcompensated form CM1 the condition "without dynamics" was determined in 7 (33.3%) patients, while in the Ⅱ group we revealed only one such patient.When analyzing the dynamics of CNPHS scores in the operated patients with the decompensated form of CM1, we found positive results in Ⅲ group in 6 (37.5%) and Ⅳ group-9 (52.9%) cases respectively. It should be noted that half of the patients of Ⅲ group operated without NIOM control did not observe the dynamics of the state in the distant postoperative period, whereas in Ⅳ group there were fewer such patients and made 35.3% of observations. In both groups with decompensated form CM1, we identified two patients with negative dynamics in the evaluation by CNPHS scores 1 year after the surgery. All 4 of these patients underwent bone dural decompression with resection or coagulation of tonsils, which, in our opinion, contributed to the development of amygdala edema and secondary liquorodynamic disorders in the craniovertebral transition region.

Table 1.

Results of neurological condition dynamics of patients with CM1 on the 7th day after the operation.

	subcompensator without NIOM n=45		subcompensator with NIOM n=43		decompensator without NIOM n=25		decompensator with NIOM n=32	
	number	%	number	%	number	%	number	%
Withimprovement	18	40.0	20	46.5	8	32.0	13	40.6
Without dynamics	27	60.0	23	53.5	15	60.0	17	53.1
With worsening	-	-	-	-	2	8.0	2	6.25

Table 2.
Results of neurological condition dynamics of CM1 patients in 3 months after the operation.

	subcompensator without NIOM n=31		subcompensator with NIOM n=30		decompensator without NIOM n=18		decompensator with NIOM n=22	
	number	%	number	%	number	%	number	%
With improvement	24	77.4	28	93.3	10	55.6	13	59.1
Without dynamics	7	22.6	2	6.67	8	44.4	7	31.8
With worsening	-	-	-	-	2	11.1	2	9.1

Table 3:
Results of neurological condition dynamics of CM1 patients 1 year after the operation.

	subcompensator without NIOM n=21		subcompensator with NIOM n=16		decompensator without NIOM n=16		decompensator with NIOMn=17	
	number	%	number	%	number	%	number	%
With improvement	14	66.7	15	93.8	6	37.5	9	52.9
Without dynamics	7	33.3	1	6.25	8	50.0	6	35.3
With worsening	-	-	-	-	2	12.5	2	11.8

So, based on CNPHS scores, we determined that with subcompensated form CM1 negative postoperative results were not recorded regardless of the use of NIOM control during the operation. However, the number of cases "without dynamics" in the group of subcompensated patients without NIOM was significantly higher, while in the opposite group, only one patient had no positive dynamics. This difference in results is due to the adequate volume of bone decompression and, if necessary, bone and dural decompression in the dynamic control of surgical procedures with NIOM. In the decompensated form of CM1, the positive results, regardless of the NIOM application, were significantly lower, which was due to the initial severity of the patients' condition. At the same time, five patients of Ⅳgroup with "no dynamics" assessment according to CNPHS required the second stage of surgical intervention with drainage of syringomyelitis cyst, in one patient with HHS ventriculoperitoneal bypass was performed. According to the results of remote postoperative results, 12 patients with subcompensated form CM1 operated without the use of the NIOM faced a question about the necessity of operation with the expansion of bone and dural decompression volume and dura mater plasty. There were no operations in the group of patients with subcompensated and decompensated form CM1 operated under the NIOM control, which indicated the adequately selected volume of the surgical intervention.

Conclusions.

1. The use of NIOM in surgical intervention in patients with Chiari malformation type 1 allows not only to prevent damage to structures at the craniovertebral transition level but also during the operation to adequately assess the volume of bone decompression and the need for further bone-dural decompression with dura mater plastic.

2. In the course of the NIOM, fluctuations in the amplitude parameters of BAEPand SSEP have the most significant importance for the evaluation of the functional state of the stem structures.

3. the NIOM does not influence the neurological deficit dynamics in the nearest postoperative period, while in the late operational period it excludes the risk of reoperation due to insufficient volume of surgery.

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