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The use of intraoperative neurophysiological monitoring in dorsal resection of hemivertebrae

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BACKGROUND: Congenital disorders of vertebrae formation are a common pathology in children. Intraoperative neurophysiological monitoring is a mandatory procedure, although it may not be effective enough due to the immature neural structures and the use of inhalation anesthetics in young children.

AIM: To study aims to investigate the characteristic features of intraoperative neurophysiological monitoring in children with a congenital deformity of the spine during dorsal resection of the hemivertebrae.

MATERIALS AND METHODS: 42 patients aged 1–17 years with a congenital deformity of the spine underwent 46 resections of the abnormal vertebra from an isolated dorsal approach (egg-shell technique). Intraoperative neurophysiological monitoring at the stages of the operation included a muscle relaxant test (TOF), transcranial electrical stimulation of the motor cortex (TCeMEP), control of the approach to the nerve (N. Proxy), correct placement of the pedicle screw (Screw Integrity), and EMG recording of the electromyogram. The accuracy of the screw placement was assessed by the Gerzbien method, and the presence of neurological disorders was tested by the Frenkel scale. The effect of inhalation anesthetic (sevoran) on motor evoked potentials was monitored by regulating its delivery, and the dependence on the age of patients was evaluated.

RESULTS: The average age of patients was 7.7 ± 4.5 years, and the TOF value was 80.5 ± 17%. In 41 patients, the N. Proxy test was unremarkable, while in one patient, the 8–12 mA value did not require a change in the trajectory of the screws. From the beginning of sevoran and intraoperatively, motor evoked potentials from all tested muscles were recorded in 54.8% of patients; in children over 8 years old, this was observed in 92.8%, in children under 8 years old — in 35.7% of cases in their age groups. In other patients, motor evoked potentials were most often not recorded from the muscles of the thigh and lower leg after sevoran administration. In children over 8 years old in 7.2%, under 8 years old — in 83.3% of patients; Interestingly, in 7.2% of patients who are under 8 years of age, motor evoked potentials were not initially recorded from any muscle. Withdrawal of sevorane in 30.9% of patients allowed intraoperative motor evoked potentials to be obtained from all tested muscles in 100% of cases. For adequate management of anesthesia, 5 patients (50%) 1–4 years old and one patient 6 years old (5.6%) did not receive sevoran, and motor evoked potentials were recorded from the abdominal muscles. This allowed to assess the conduction only at the thoracic level and are required increased vigilance of surgeons when carrying out any corrective manipulations.

CONCLUSIONS: Intraoperative neurophysiological monitoring with dorsal hemivertebra resection is an effective method that allows controlling the neurological complications during manipulations on the spine.

Keywords: dorsal hemivertebra resection; neurophysiological monitoring; dorsal resection; motor potential potentials; hemivertebra; electrical stimulation; sevoflurane; egg-shell; Screw Integrity; N. Proxy.

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Особенности использования интраоперационного нейрофизиологического мониторинга при дорсальной резекции полупозвонков

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Обоснование. Врожденные нарушения формирования позвонков — частая патология у детей. Интраоперационный нейрофизиологический мониторинг является обязательной процедурой, которая может быть недостаточно эффективной из-за незрелости невральных структур, применения ингаляционных анестетиков у детей раннего возраста.

Цель — изучить особенности проведения интраоперационного нейрофизиологического мониторинга у детей с врожденной деформацией позвоночника при дорсальной резекции полупозвонков.

Материалы и методы. 42 пациентам в возрасте 1–17 лет с врожденной деформацией позвоночника проведено 46 резекций аномального позвонка из изолированного дорсального доступа (методика egg-shell). Интраоперационный нейрофизиологический мониторинг на этапах операции включал тест на миорелаксанты (TOF), транскраниальную электрическую стимуляцию моторной коры (TCeMEP), контроль приближения к нерву (N. Proxy) и правильности установки транспедикулярного винта (Screw Integrity), ЭМГ-запись электромиограммы. Корректность проведения винтов оценивали по методике Gerzbien, наличие неврологических нарушений — по шкале Frenkel. Регулируя подачу ингаляционного анестетика (севоран), контролировали его влияние на моторные вызванные потенциалы и выявляли их зависимость от возраста пациентов.

Результаты. Средний возраст пациентов — 7,7 ± 4,5 года. Значение TOF — 80,5 ± 17 %. У 41 пациента тест N. Proxy — без особенностей, у 1 — значение 8–12 мА не потребовало изменения траектории проведения винтов. С начала подачи севорана и интраоперационно моторные вызванные потенциалы со всех тестируемых мышц зарегистрированы у 54,8 % пациентов, у детей старше 8 лет — в 92,8 % случаев, у детей младше 8 лет — в 35,7 % случаев в своих возрастных группах. У остальных пациентов на фоне подачи севорана моторные вызванные потенциалы чаще всего отсутствовали с мышц бедра и голени: у детей старше 8 лет в 7,2 % случаев, младше 8 лет — у 83,3 % пациентов; у 7,2 % пациентов до 8 лет изначально моторные вызванные потенциалы не регистрировались ни с одной мышцы. Таким образом, мы не могли адекватно оценить проведение по двигательным путям у 19 пациентов (45,2 %), у 13 из них (30,9 %) отмена севорана позволила получить моторные вызванные потенциалы интраоперационно со всех тестируемых мышц в 100 % случаев. Для адекватного ведения анестезиологического пособия 5 (50 %) пациентам 1–4 лет и 1 пациенту 6 лет (5,6 %) севоран не отменяли, и моторные вызванные потенциалы регистрировали с мышц живота, что позволяло оценить проведение только на грудном уровне и требовало повышенной настороженности хирургов при корригирующих манипуляциях.

Заключение. Интраоперационный нейрофизиологический мониторинг при дорсальной резекции полупозвонка обоснован, эффективен, позволяет контролировать неврологические осложнения в ходе манипуляций на позвоночнике.

Ключевые слова: дорсальная резекция полупозвонков; нейрофизиологический мониторинг; интраоперационный нейромониторинг; моторные вызванные потенциалы; полупозвонок; транскраниальная электрическая стимуляция моторной коры; севоран; egg-shell; Screw Integrity; N. Proxy.

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BACKGROUND

Congenital disorders of vertebra formation are the most common pathology of the spinal column during childhood. A significant proportion of these defects are isolated posterolateral or lateral hemivertebrae, leading to the development of rough rigid curvatures [1, 2]. This disease is treated by early surgical intervention, i.e., resection of the hemivertebra with full correction of the congenital deformity and stabilization of the minimum number of spinal motion segments with a spinal metal structure [3, 4]. Recently, the technique of removing an abnormal vertebra through the dorsal approach has become widespread [5]. However, this manipulation may lead to the development of neurological complications, which can be caused not only by direct mechanical damage, stretching, or compression of nerve structures but also by the impaired blood supply to the spinal cord [6–11]. Intraoperative neuromonitoring (IONM) makes it possible to prevent such situations, providing the operating physician with the opportunity to continuously monitor the functional state of the structures of the central neurological system, diagnose mechanical or ischemic damage to the nervous tissue that occurred during surgery, and avoid postoperative complications [12, 13]. Currently, IONM is becoming the global standard for the control of neurological complications during surgical interventions, in which nerve structures can be affected [14]. However, the use of IONM in pediatric practice has not been sufficiently evaluated. Given the immaturity of neural structures in very young patients, the effectiveness of neurophysiological monitoring may be low. Transcranial magnetic stimulation has demonstrated that the functional characteristics of the motor pathways begin to fully correspond to the parameters of adults only at age 12–14 years. The myelination of the corticospinal tract ends only in adolescence, of the pathways to the muscles of the lower extremities at age 11–12, and of the muscles of the upper extremities at age 12–17. The final maturation of the central section of the motor pathway is completed only in the second decade of life [15, 16].

The use of inhalation anesthetics can negatively affect the emergence of motor responses during neuromonitoring and may not provide adequate control over the possibility of neurological disorders during surgery [9]. To obtain reliable data and exclude false-negative results, the depressant effect of anesthetics on the parameters of evoked activity should be considered [17–20]. High doses of inhalation anesthetics cause depression of synaptic impulse transmission, against the background of which the amplitude–temporal characteristics of the evoked potentials change, i.e., the amplitude decreases and the latency period increases [12]. In this case, the amplitude of the evoked motor response has no practical importance, since it depends on various factors, primarily on the individual conduction of nerve fibers. Only the presence of a response and a decrease in the amplitude during the procedure in comparison with the initial value is significant [10, 12]. Existing literature lacks data on the use of IONM in children. In dorsal resection of the hemivertebrae, the assessment of the IONM efficiency is the most important because of the use of this method in the surgical treatment of children.

This study aimed to assess the features of IONM in children with congenital spinal deformity during dorsal resection of the hemivertebrae.

MATERIALS AND METHODS

A retrospective single-center continuous study of patients who underwent surgery for congenital spinal deformity and performed by one surgeon was conducted in the Federal State Budgetary Institution “Federal Center for Traumatology, Orthopedics and Endoprosthetics” of the Ministry of Health of Russia (Cheboksary). From 2013 to 2019, a total of 78 procedures were performed. However, some of them were excluded from the observation group in accordance with the selection criteria.

The *inclusion criteria* were the presence of hemivertebrae, dorsal access surgery, fixation of no more than two spinal motion segments, and absence of primary neurological deficit.

The *exclusion criteria* were the presence of combined malformations and extended fixation of more than four levels.

The study included 42 children (26 girls and 16 boys) aged 1–17 years with congenital spinal deformities. These pediatric patients were divided into age groups: group 1 included nine children aged 1–4 years; group 2, 18 children aged 5–8 years; group 4, eight children aged 9–13; and group 4, seven children aged 14–17 years. This ranking system was selected as the most convenient to meet the aims of the research.

The average age of the patients was 7.7 ± 4.5 years. Abnormal vertebrae were localized in the lumbar (26 cases; 61.9%) and thoracic (16 cases; 38.1%) regions. A right-sided arrangement of the hemivertebrae was observed in 20 (47.6%) patients and was left-sided in 22 (52.4%). Segmented hemivertebrae were found in 22 cases (52.4%), semi-segmented in 16 (38.1%), and non-segmented in 4 (9.5%).

All patients underwent resection of one or several abnormal vertebrae through the dorsal approach with the correction of the congenital curvature and stabilization of the achieved result with a multi-support metal structure. Intraoperatively, after the skin incision, the dorsal spine was exposed. Then, transpedicular screws were installed in the adjacent vertebrae relative to the abnormal vertebrae, depending on the nature of the deformity; if necessary, the fixation was extended higher or lower by one or two segments, after which the ribs of the abnormal vertebrae were resected if the procedure was performed at the thoracic level. Then, the dorsal structures of the hemivertebrae were resected, and the root of the arch of the defective vertebra was visualized. Thereafter, decansion was performed through the root of the arch using the egg-shell technique. Then, the outer and dorsal shells of the vertebra were resected; after which, depending on the selected type of Bollini resection [21], the endplates were removed, and a discectomy was performed with the installation of an interbody implant (autobone). The intervention was completed by dipping the rods into the screw heads and executing corrective manipulations along the concave and convex sides of the curvature. At the final stage, the surgical wound was sutured in layers.

On average, the fixation length was 3.2 ± 1.1 segments. One segment was fixed in 11 cases (fixation was limited to two vertebrae adjacent to the removed hemivertebrae). Two segments were fixed in 15 cases, that is, two vertebrae adjacent to the removed one were instrumented, and one more vertebra was cranial or caudal, depending on the scoliotic deformity. Three segments were fixed in 16 cases following the same principle. The average number of fixing elements was 5.8 ± 2.3 screws.

Combined endotracheal anesthesia was used. Intubation was performed by the orotracheal method after intravenous administration of the muscle relaxant suxamethonium chloride. After intubation, the patients were switched to artificial ventilation. For maintenance anesthesia, fentanyl, propofol, and sevorane were used at a maximum alveolar concentration of 0.3%–2%.

The procedures were performed under IONM using the NIM-Eclipse System (Medtronic, USA) and included 5 tests:

1. The test for muscle relaxants (train-of-four, TOF) was performed to measure the degree of neuromuscular blockade, which made it possible to exclude false-negative results due to the effects of paralytic drugs. Neuromuscular blockade was monitored from the moment the muscle relaxants were administered until normal values were reached (>60%) by stimulating the corresponding nerve and recording the total motor evoked potential (MEP) in the innervated muscle.
2. Transcranial electrical stimulation of the motor cortex with the registration of MEPs was used to assess the functional state of the motor corticospinal tracts. MEPs were recorded in key muscles corresponding to the operated level. To obtain MEP, stimulating electrodes were placed under the scalp along a line one finger width forward (toward the nose) from points C_3 and C_4 and the corresponding projection of the motor cortex. Recording electrodes were placed in all patients in the rectus abdominis muscle (T_5–T_{11}), oblique abdominal muscle (T_{12}–L_1), lateral head of the quadriceps femoris muscle (L_2–L_4), tibialis anterior (L_4–L_5, S_1), or peroneus longus muscle (L_5–S_1). A feature of pediatric patients is the small size of the muscles, which required precision when installing needle electrodes. The first study was performed preoperatively, after the induction of anesthesia with sevorane. Then, the MEP was assessed upon screw placement along with the nerve proximity control (N. proxy test) and then repeatedly during corrective maneuvers by the surgeon, posing a potential threat of damage to neural structures. Moreover, the presence or absence of a motor response (criterion "yes" or "no") was taken into account, regardless of its magnitude from the muscles of the abdomen and lower extremities, as well as a decrease in the amplitude of the MEP by >70% of the initial one. In young children with difficult-to-obtain responses, anesthesiologists performed manual dosing of sevorane because of the depressive effect on the MEP. In the cases in which MEPs from the muscles of the lower extremities were not recorded, upon hemivertebra removal and corrective maneuvers, it was necessary to pause sevorane administration with temporary support with narcotic analgesics and propofol until the appearance of potentials, which indicates the safety of the corticospinal tract; sevorane supply was resumed thereafter.
3. N. proxy test allowed tracking of the correct channel formation for the pedicle screw. A loop was fixed on the surgeon's instrument, to which an electrical stimulus was applied with a current of 1–12 mA. With the correct passage of the instrument through the arch of the vertebra, an isoline appeared on the device's monitor. As the conductor approached the neural structures, electromyographic (EMG) responses of increasing amplitude to the minimum stimulus strength appeared. In this case, the surgeon changed the trajectory of the instrument until the EMG response disappeared.
4. The correct placement of the pedicle screw during fixation of the spine was monitored using a bulbous probe to which an electrical stimulus was applied (screw integrity mode). The correct placement of the screw strictly in the pedicle and the absence of defects in the walls of the transpedicular canal were evidenced by the lack of an EMG response or its appearance to a high-power stimulus. The presence of an EMG response was considered being near to neural structures because of the lack of bone tissue in the pedicle. Often, a similar situation was noted at the apex of the deformity along the concave side and was explained by the anatomical and morphological features of the vertebrae in this zone. When registering a stable high-amplitude EMG response, the position of the screw was controlled by using an image intensifier. If incorrectly positioned, the screw was removed. However, if it did not carry a strategic load or the conduction

trajectory was changed, in some cases, the pedicle screw was replaced with another fixing element (such as a hook or tape).
5. EMG recording. When registering an EMG response indicating proximity of neural structures, the surgeon changed the trajectory of the instrument.

According to postoperative computed tomography (CT) data, the length of instrumental fixation and the correctness of executing transpedicular supporting elements were assessed. Changes in IONM parameters were recorded during the procedure. The Gerzbien technique was used to assess the correctness of the pedicle screws. The deviation of the screw toward the spinal canal was considered potentially dangerous with respect to the occurrence of neurological disorders, and deviation of the screws lateral to the pedicle is a risk factor of radicular symptoms. The release of screws beyond the vertebral body along the anterior surface was not considered, since in some cases bicortical conduction was especially used for more reliable fixation. The presence or absence of neurological disorders was assessed using the Frenkel scale.

Statistical analysis of data was performed using Microsoft Excel 2007 programs (Microsoft Inc., USA) and GraphPad (GraphPad Software Inc., La Jolla, USA). In MS Excel, the correspondence of the sample values to the normal distribution was confirmed by a graphical method, and the results are presented as arithmetic mean and standard deviation. To assess the significance of differences in mean values in groups, we used paired Student's *t*-test and Fisher's exact test. Differences were considered significant at *p* values <0.05.

RESULTS

All screws were correctly inserted in 26 (61.9%) patients; in 16 (38.1%) patients, one or more screws were incorrectly inserted. Of the 243 screws implanted in 42 patients, 222 were considered correctly inserted. Moreover, 21 screws in 16 patients had deviated: 6 (28.6% of deviated screws and 2.5% of all installed) screws toward the canal 6 and 15 screws (71.4% of incorrectly installed and 6.2% of all installed) toward the lateral side (Fig. 1).

There were no deviations of screws above or below the pedicle toward the foramen. All patients had TOF value more than 60%, which indicated that muscle relaxants had no effects on IONM. According to the IONM protocol and N. proxy test values, 41 patients passed the test without features, that is, there was no direct contact with neural structures. At the L_1 level on the right, the test result in one patient was 8–12 mA, which was considered acceptable and did not require changing the trajectory of the screw. According to postoperative CT data, this patient showed an uncritical screw displacement toward the spinal canal. In the remaining patients with incorrectly positioned screws intraoperatively, no signs of compression and direct contact with neural structures were found during the N. proxy test.

Initial MEP data (baseline) were recorded at the induction of anesthesia, and dynamic test assessments were made throughout the procedure. The average age of the patients with a positive response to stimulation was 9.1 ± 0.8 years, which was significantly higher ($p = 0.0005$) than that in the group without response (3.3 ± 0.4 years). We found a significant dependence in our evaluation of the effect of age on obtaining a motor response, that is, the younger the patient, the less often motor responses were achieved (Fig. 2).

At the start of the procedure, before surgical manipulations, in all patients aged 9–13 years and in 5 (83.3%) patients aged 14–17 years, MEPs were recorded initially and during the procedure in the rectus and oblique muscles of the abdomen and muscles of the thigh and lower leg.

MEPs were recorded in the rectus and oblique muscles of the abdomen and muscles of the thigh and lower legs in 7 (38.9%) children aged 5–8 years and only in 3 (30%) of 10 children aged <4 years. This is probably due to the age-related characteristics of the maturation of the corticospinal tract and the influence of sevorane (Table).

Under anesthesia, no motor responses were obtained from the lower leg muscles in 7 (70%) patients aged 1–4 years, 11 (61.1%) patients aged 5–8, and 1 patient (16.7%) aged 15. Moreover, MEPs were not recorded with any of the tested muscles in 1 (10%) patient aged 3 years and 2 (11.1%) patients aged 5–8 years. Thus, we did not obtain the desired result in 18 patients aged <8 years and in 1 patient aged 14–17. The discontinuation of sevorane in 12 patients aged 1–8 years, in whom motor responses were absent with sevorane administration, made it possible to obtain potentials from the abdominal and lower leg muscles in all cases. In six patients, MEPs were recorded only from the abdominal muscles (5 children aged 1–4 years and

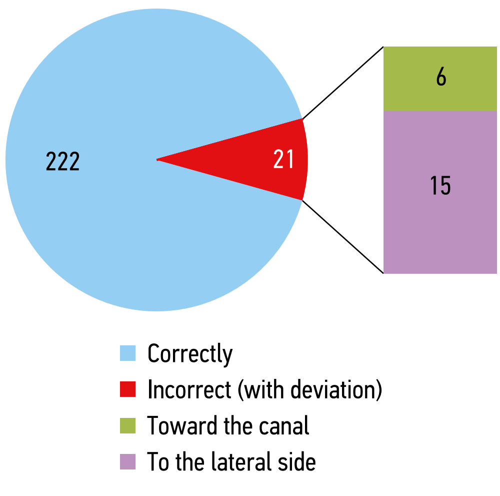

Fig. 1. Results of screw placement

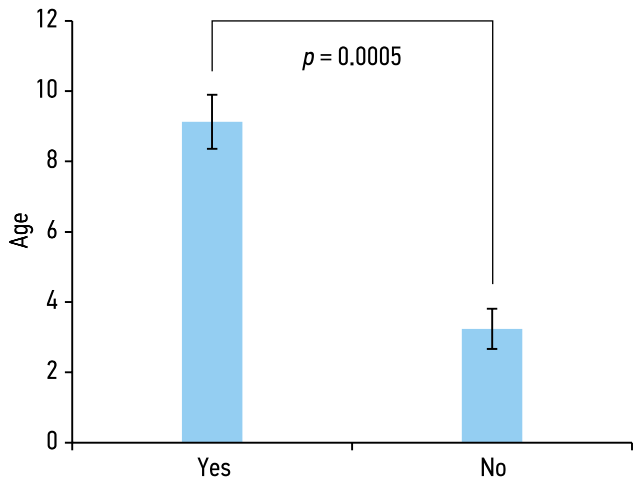

Fig. 2. Dependence of the presence or absence of initial motor evoked potentials on average age

1 child aged 6 years), but sevorane was not discontinued for adequate management of anesthesia. This made it possible to assess conduction only at the thoracic level, which required increased awareness of surgeons when performing corrective manipulations. In a 15-year-old patient with no responses despite sevorane administration, responses were recorded after sevorane was discontinued, which indicated the preservation of the motor pathways.

Thus, in 23 (54.8%) patients, MEPs were recorded initially and intraoperatively from all tested levels, while MEPs were recorded in 92.9% of cases in children aged >8 years and in 35.7% of cases in children aged <8 years ($p = 0.0007$). In other patients, MEPs from individual muscle groups were not recorded with sevorane administration. Most often, these patients lacked MEPs from the thigh and lower leg muscles, including 7.1% of cases in children aged >8 years and in 64.3% of patients aged <8 years ($p = 0.0058$). In 3 (10.7%) patients aged <8 years, MEPs were initially not recorded from any muscle; however, the elimination of the depressive effect of sevorane allowed us to obtain motor responses from all levels. In total, during the operation, MEPs from all levels were recorded in 36 (85.7%) patients, which indicated the integrity of the motor pathways.

A short-term decrease in the MEP amplitude of >70% from the leg muscles during corrective manipulations was recorded in one patient in the 9–13-year-old group, followed by recovery to the initial level despite structural weakening, glucocorticoid administration, and wound irrigation with warm isotonic sodium chloride solution.

Along with the MEP assessment, other IONM tests were also used. At the stage of the formation of the channel for the pedicle screw, the N. proxy test was performed, and the correct placement of the screws was checked using the screw integrity test. The results of these tests were independent of age and sevorane dose. When registering an EMG response indicating nearness to neural structures, the surgeon changed the trajectory of the instrument. Thus, no neurological complication was recorded, even if postoperative CT data revealed a slight deviation of 6/243 screws toward the spinal canal and 15/243 laterally.

DISCUSSION

The use of IONM during this intervention is explained by the need for the safe resection of the hemivertebra. Since dorsal resection is performed under the dural sac and near the root exit site, there is a risk of damage to the neural structures by the instrument.

Surgical interventions on the spinal cord and spine are associated with a high risk of postoperative complications, and the most severe is the development of persistent neurological deficits in the form of paralysis and dysfunctions of pelvic organs [22]. The dorsal resection of congenital hemivertebrae is also associated with the risk of neurological complications caused by instrument-related damage to

Table. Registration of motor evoked potentials with sevorane administration

Presence of motor evoked potentials with sevorane administration	Age (years)								Total, abs. number (n = 42)	Total, specific gravity, %
	1–4 (n = 10)		5–8 (n = 18)		9–13 (n = 8)		14–17 (n = 6)			
	Abs. number	Specific gravity, %	Abs. number	Specific gravity, %	Abs. number	Specific gravity, %	Abs. number	Specific gravity, %		
There is a response from the muscles of the abdomen and legs (level Th_6 to L_5–S_1)	3	30	7	38.9	8	100	5	83.3	23	54.8
There is a response from the muscles of the abdomen and legs (level Th_6–Th_{12})	6	60	9	50	–	–	1	16.7	16	38
No response	1	10	2	11.1	–	–	–	–	3	7.2

neural structures. IONM has proven its effectiveness and is gradually becoming an integral condition of modern spinal surgery, allowing the prevention of severe postoperative neurological complications. Prospects for the development of this method are associated with clarification of its indications and optimal stimulation parameters, with the development of noninvasive methods of intraoperative transcranial stimulation in patients under anesthesia [22]. The general principles of monitoring in the operating room are summarized in the works of J.M. Guerit: "An open agreement should be reached between the surgeon, anesthesiologist, and neurophysiologist, according to which the use of monitoring techniques should not be accompanied by the risk of damage to brain structures; the surgeon agrees to await the completion of neurophysiological studies in order to correlate his actions with the results of monitoring; the anesthesiologist agrees to adapt his technique to the registration of the MEP and to keep the neurophysiologist constantly aware of the patient's parameters" [22].

According to current guidelines, spinal cord surgery must be performed under the control of both somatosensory evoked potentials (SSEPs) and MEPs induced by transcranial electrical stimulation throughout the procedure. Many studies have confirmed earlier reports that SSEP monitoring can provide adequate electrophysiological control of only the sensitive tracts of the spinal cord. Normal SSEP parameters during surgery do not guarantee the absence of motor neurological deficits in the postoperative period [12].

The IONM methodology is described in detail in special manuals; however, less attention has been paid to the use of IONM in children. Spinal surgeries in children aged >12 years under the control of SSEP and wake-up test have been described [23]. During IONM, inhalation anesthetics should be avoided, but in pediatric anesthesiology, sevorane is often used, but it has a depressive effect on the parameters of evoked activity. In the absence of MEP, the recommendation was to suspend the surgical procedures and take corrective measures to restore MEP [24]. In this case, the patients underwent an awakening test (Stagnara test), which detects movements in the limbs; after which, the patients were switched to combined anesthesia, while SEPs and MEPs were obtained [13].

To execute the surgical procedures safely, MEPs should be monitored at all levels of the motor tract. Their absence from the leg muscles can be associated with both the influence of sevorane and surgeon's maneuvers to remove the hemivertebra and to perform during corrective steps. If the risk of damage to the motor tract is highest, it is necessary to stop sevorane completely, with temporary support with large doses of drugs and propofol, until the appearance of potentials, indicating the safety of the corticospinal tract. Thereafter, sevorane supply is resumed.

If MEPs are lost, the procedure should be completed, as there is a very high risk that the patient will develop severe motor impairment [24]. On induction of anesthesia, we did not observe motor responses from the low leg muscles in 19 patients; however, the discontinuation of sevorane allowed us to register MEPs in 13 of them. Sevorane was not canceled in the remaining six patients in the 1–6-year-old group; the absence of MEP from the target muscles was explained, apparently, by the depressive effect of the sevorane and the immaturity of the corticospinal tract in children. The appearance of motor deficit was not recorded.

The expediency of the N. proxy test was recognized [22]. This test was used to assess the correct position of transpedicular screws and control their approximation to neural structures to prevent the development of segmental neurological complications. Sound and visual signals of the monitor, warning the proximity of nerve structures, made it possible to avoid iatrogenic damage. Only 2.5% of the screws were deflected toward the canal, and none of them caused neurological symptoms in the postoperative period.

CONCLUSION

MEP as an important test for controlling the occurrence of neurological complications was recorded from all tested muscles during the main stage of surgery in 85.7% of patients. In 6 (14.3%) patients, MEPs were obtained only from the abdominal muscles, which required increased attention from the surgeon.

A significant ($p = 0.0005$) dependence of the initial response to electrical stimulation of the motor cortex on age was revealed. On average, the group with a positive response to stimulation was significantly older ($p = 0.0005$) than the group without response.

To obtain reliable information about the functioning of the motor tracts in young children, MEPs should be registered with temporary cancelation of inhalation anesthetics. If its cancelation is impossible, surgeons should be more alert during the procedure to prevent neurological complications.

The use of IONM during the resection of the hemivertebrae from the dorsal approach is justified and effective.

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The authors obtained written voluntary consent from patients (or their legal representatives) to publish medical data.

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