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Score evaluation of intraoperative neurophysiological monitoring results of spinal deformity surgical correction in genetically caused systemic skeletal pathology

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Purpose Evaluate the dynamics of the pyramidal pathway functional state in spinal deformity surgical correction in patients with genetically caused systemic skeletal pathology based on the formal criteria of a significance degree of the electrophysiological response to a surgical intervention which were developed at the RISC *RTO*. **Materials and Methods** The analyzed sample of patients included two groups for comparison. Group 1 (main group) were 28 patients with spinal deformities due to systemic hereditary diseases. Group 2 (control group) consisted of 126 patients with spinal deformities (51 subjects with idiopathic scoliosis, 71 subjects with deformities of congenital genesis, and 4 subjects of other etiology). All the patients underwent instrumental deformity correction with further fixation of the cervical, thoracic, thoracolumbar spine using different variants of internal transpedicular fixation systems. The changes in motor evoked potentials (MEP) were evaluated as ranks 0 to 7 according to the severity of the response observed. **Results** All the variants of changes in MEPs were observed both in the main group and in the control one. Five types of steady (reproduced in different patients) rank combinations were identified which conformed to the main types of the patient's motor system response to spinal deformity surgical correction. **Conclusion** The use of the technology of MEP recording during surgical correction of spinal deformities in patients with systemic genetically caused skeletal pathology is a highly effective tool of preventing the development of intraoperative neurological complications. The proposed system of formal evaluation of the results of neuromonitoring allowed us to conduct a quantitative comparison of the character of intraoperative changes in the functional state of the pyramidal system in patients of different etiological groups depending on their age and intervention duration.
Keywords: intraoperative neuromonitoring, motor evoked potentials, systemic skeletal disorders

INTRODUCTION

Due to a complex nature of the pathology development in spinal deformities on the background of genetic diseases, they are rapidly progressing in the process of child's growth and require early surgical treatment. To prevent motor disorders of the iatrogenic nature by operative correction of spinal deformities, an intraoperative neurophysiological monitoring (IONM) with motor evoked potentials (MEP) has been currently used [1–4].

Because of high variability of clinical and physiological characteristics in patients with spinal deformities as well as due to the specificity of their response to anesthesia and surgical aggression, the dynamics of the MEP characteristics is individual for each case [5]. Therefore, it is difficult to formalize the description of the accumulated experience. This circumstance explains the fact that the main body of publications on this issue reflects the qualitative characteristics of the observed phenomena. Thus, there are disagreements in their interpretation [6].

The aim of our study was to assess the dynamics of the functional state of pyramidal pathways in the process of surgical correction of spinal deformities in patients with genetically determined skeletal pathologies on the basis of formal criteria for the degree of significance of the electrophysiological reaction to surgical intervention developed at the RISC for RTO.

MATERIAL AND METHODS

The analyzed sample of patients included two groups for comparison. Group 1 (main group) were 28 patients (15 males, 13 females) in the age from two years and four months to 25 years old (mean, 12.7 ± 1.2 years) with spinal deformities due to systemic hereditary diseases (36 IONM protocols). Group 2 (control group) consisted of 126 patients (41 males, 85 females) in the age from two years and four months to 25 years old (mean, 13.5 ± 0.5 years) with spinal deformities including 51 subjects due to idiopathic scoliosis, 71 subjects due to congenital genesis, and 4 subjects of other etiology (142 IONM protocols).

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All patients underwent instrumental correction of the deformity followed by fixation of the cervical, thoracic and thoracolumbar spine using various variants of internal transpedicular fixation systems.

Intraoperative neuromonitoring was performed using the *ISIS IOM system* (Inomed Medizintechnik GmbH, Germany). In the "free run" mode, the degree of presentation of the spontaneous activity in the tested muscles was controlled. MEPs were obtained by transcranial electrostimulation of the cerebral cortex with the help of subdermal spiral electrodes mounted on the scalp in the projection of the cortical representations of the indicator muscles which corresponded to the C3–C4 leads in the international EEG extraction system (10–20). The stimuli were packets consisting of five 1-msec multipolar impulses with an interstimulation interval of 4 msec, frequency of 1 Hz, and intensity of the order of 150 mA. By a irregular appearance of MEPs or their absence, unstable amplitude-and-time characteristics of the responses, transposition of the stimulating electrodes was performed until a stable reproducible response was obtained. The recording needle electrodes were installed unipolarly ("belly-tendon" type lead). The choice of indicator muscles for obtaining MEPs was determined by the area of surgical intervention on the spine.

The first test (recording of the so-called "basic" MEPs) was carried out 40–60 minutes after the injection of the muscle relaxant used in the initial anesthesia. The latent period of responses, amplitude, shape and reproducibility were evaluated. Subsequent tests were carried out after the implantation of support elements and at various stages of corrective maneuvers. The duration of monitoring in the main group varied within 1.0–9.5 hours (mean, 3.9 ± 0.3 hours), and in the control group, respectively, 1.1–9.0 hours (mean, 3.4 ± 0.1 hours).

In the process of each stimulating effect, the character of the reaction of the spinal cord motor pathways was evaluated in response to surgical manipulations. A decrease in the amplitude of more than 50 % of the baseline and an increase in the latent period exceeding 10 % were considered as diagnostically significant changes in the MEP characteristics. The reordered changes in the MEP characteristics were assigned a rank from 0 to 7 in accordance with the expresiveness of the response of the pyramidal system to the effects of a complex of surgical intervention factors at the time of testing. The set of changes in the rank evaluation of the MEP throughout surgical intervention was the basis for assigning the corresponding score to the identified type of reaction of the motor system (**Table 1**). The frequency of occurrence (ν) of the selected reaction types was determined by the formula:

$$\nu_i = \frac{n_i \times 100\%}{N},$$

in which n_i is the number of observations of the i-type of response, *N* is the total number of observations in the analyzed sample. The nature of the statistical distribution of the indicators in the groups compared was assessed as close to normal in accordance with the type of histogram, the magnitude of asymmetry and excess because of close values of the arithmetic mean, median and mode. Differences in the mean age and IOMN duration in the comparison groups were assessed using Student's *t*–test [7]. The standard error (*m*) was calculated for the arithmetic mean. Data processing used was Microsoft Excel 2010.

RESULTS

In both groups, the characteristics of the baseline MEPs obtained prior to the beginning of the surgical intervention were highly variable, which is due to the features of the functional status of the pyramidal system related to such factors as age, patient body size, peculiarities of the course of the main and concomitant diseases, and anesthesia.

In the main group, the baseline MEPs could not be obtained in the three observations (8.3 %). These all were patients who underwent repeated surgical interventions on the spine and had significant motor function impairments. In one of these cases, motor responses were obtained at the end of the operation. In the control group, the MEPs suitable for further electrophysiological control were obtained in all the patients.

All changes in the MEPs at subsequent tests were evaluated from rank 0 to 7 in accordance with the expressiveness of the observed reaction.

1. Preservation of the shape and amplitude/time parameters of the MEPs close to the initial ones at the moment of testing (rank 0).
2. Increase in the amplitude of the MEPs relative to the initial level, frequently accompanied by the appearance of additional phases (rank 1).
3. Moderate decrease in the amplitude of the MEPs, not accompanied by a significant change in its shape (rank 2).
4. Instability of amplitude/time characteristics and shape (significant fluctuations in the number and expressiveness of the phases) of the response (rank 3).
5. Significant decrease in the amplitude of the MEP (more than 50 % of the initial level) accom-

panied by fluctuations in its latency and depletion (reduction) of the shape, followed by restoration of the MEP characteristics close to the initial ones (rank 4a).

6. Significant decrease in the MEP amplitude (more than 50 % of the initial level) accompanied by fluctuations in its latency and depletion of the shape followed by retention of the depressed responses and/or further MEP suppression until complete disappearance (rank 4b).

7. Complete disappearance of the response (duration not more than 15 minutes) with a subsequent restoration to a level close to the initial one (rank 5).

8. Complete disappearance of the response with subsequent partial restoration (rank 6).

9. Complete disappearance of MEP without any signs of its recovery by the time of surgical intervention termination (rank 7).

Each of the ranks we have identified of the MEP changes reflects the functional state of the pyramidal system by the moment of the ongoing test under the influence of the combination of operative intervention factors at that time (anesthesia, surgeon's actions, endogenous events, etc.). In the subsequent tests, the rank evaluation either remained at the same level (relative to the previous MEP dynamics) or changed up or down depending on the ability of the pyramidal system to translate the excitation wave from the motor cortex to the indicator muscle.

All of the listed variants of MEP changes were observed in both the main and control groups. Summarizing their dynamics throughout the operation, we identified five types of stable (reproducible on different patients) combinations of ranks, which, in our opinion, correspond to the main types of reaction of the patient's motor system to the operative correction of spinal deformities. They are presented in **Table 1**.

In both groups, despite a significant difference in the number of patients, the relative numbers of observations in which the MEPs were kept at a level close to the initial one throughout the entire operation (type I), had close values. Despite insignificant differences in the frequency of occurrence of transitional (II and III) types, the total relative amount of such observations in the main and control groups (26.5 % and 24.1 %, respectively) was practically the same. In general, the overall incidence of calm outcomes of neuromonitoring, in which, even despite short-term significant drops in the amplitude of the MEP (I-III types), their level was consistent with the initial one, also practically coincided for the main and control groups (76.5 % and 78.7 %, respectively).

In cases in which the results of neuromonitoring indicate a significant risk of postoperative motor complications appearance by a prolonged substantial reduction in the MEP amplitude (type IV) or complete MEP suppression (type V), the operating surgeon and anesthesiologist respond promptly to the current situation and take adequate measures (administration of glucocorticosteroids, control of the position of the screws and its correction if necessary, reduction of distraction efforts by prolonged traction). In most cases, the motor functions of patients remained at the level corresponding to the preoperative one. Totally, types IV and V were observed in the main and control groups in 23.5 % and 21.4 % of cases, respectively showing close values. It should be noted that in two observations of the main group, the progressive decrease in MEPs began after epidural blockade with naropin, or was caused not by a surgical or ischemic threat but by an increased sensitivity of the patient to the epidural anesthetic.

EMG signs of spinal cord root irritation were noted in one case (5.3 %) in the main and 10 cases (7.1 %) in the control group – short-term outbreaks of spontaneous EMG in the corresponding leads which subsided as a result of surgeons' actions correction after they received this information.

Table 1

Types of motor system responses to surgical correction of spinal deformities in main and control groups

Type	Rank combinations	Frequency of incidence			
		Main group		Control group	
I	0, 1, 2	n = 17	50.0 %	n = 77	56.4 %
II	0, 1, 2, 3, 4a	n = 5	14.7 %	n = 12	8.5 %
III	0, 1, 2, 3, 4a, 5	n = 4	11.8 %	n = 22	15.6 %
IV	0, 1, 2, 3, 4b, 5, 6	n = 6	16.7 %	n = 18	12.8 %
V	0, 1, 2, 3, 4b, 5, 6, 7	n = 2	5.9 %	n = 12	8.5 %

Note The rates are calculated without taking into account two cases with initially absent motor potentials

Figure 1 shows the ratio of the reaction intensity of the pyramidal system of patients in groups according to age and duration of intervention. As the latter indicator, the IOMN duration was used which is proportional to the duration of the operation (which indirectly characterizes its complexity) and the patient's time under anesthesia.

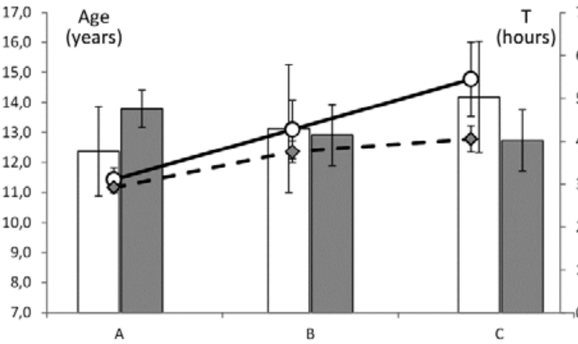

Fig. 1 Degree of MRPs depression (axis of abscissas) as a function of age (bars – axis of ordinates, on the left – age in years) and duration of surgical intervention (lines – ordinate axis, on the right – number of hours) in the main (white) and control (dark) groups. A – absence of negative changes (type I); B – subcritical changes (types II–III); C – critical changes (types VI–V)

Figure 1 is interesting in that it shows two opposite, statistically not insignificant ($p > 0.05$) tendencies in the relationship between age and the intensity of the motor system response to the operation impact. In the main group, more pronounced intraoperative MEP changes are frequently common for older patients and in the control group for younger ones.

Enhancement in the intensity of the reaction with increasing duration of IOMH occurs in both groups. However, in the main group it is more pronounced and coincides with the manifestation of age-related differences. The mean duration of monitoring with critical and subcritical MEP changes is statistically significantly higher than in calmly completed operations by 75 % in the main group ($p = 0.032$) and by 39 % ($p = 0.001$) in the control group. That is, in systemic skeletal pathology, the older is the patient and the longer is the operation, the greater is the risk of intraoperative problems. In controls, the risk of long operations is more noticeable in younger age.

The reasons for these differences become clear after considering the features of the distribution of individual manifestations of the pyramidal system response in the groups, depending on patient’s age and the duration of the operation (**Fig. 2**).

In the control group, the mass of observations is evenly distributed over the entire range of analyzed indicators. At the age of 10 years, all reaction variants are encountered uniformly in these patients, regardless of the operation duration. In the older age, critical manifestations are more often observed in prolonged operations.

In the main group, the tendency towards grouping the neutral type of reaction (white circles) in the lower part of the graph is more pronounced, and the critical variants (black triangles) are in its upper half, more on the right, in the older age. This situation is quite obvious – the longer is the operation the greater is the load on the body's regulatory systems and more likely is the occurrence of problems. In contrast to the control group, in patients with systemic skeletal pathology, the proportion of long-term operations with critical changes in MEPs is greater in the adolescence age. This explains the group peculiar features identified in **Figure 1**.

Thus, the use of modern technologies for operative correction of spinal deformities is accompanied by a minimal frequency of appearance of electrophysiological signs of development of neurological complications, except for a small number of cases (within 10 %), in which the increased danger of damage to motor tracts is due to peculiarities of the pathology.

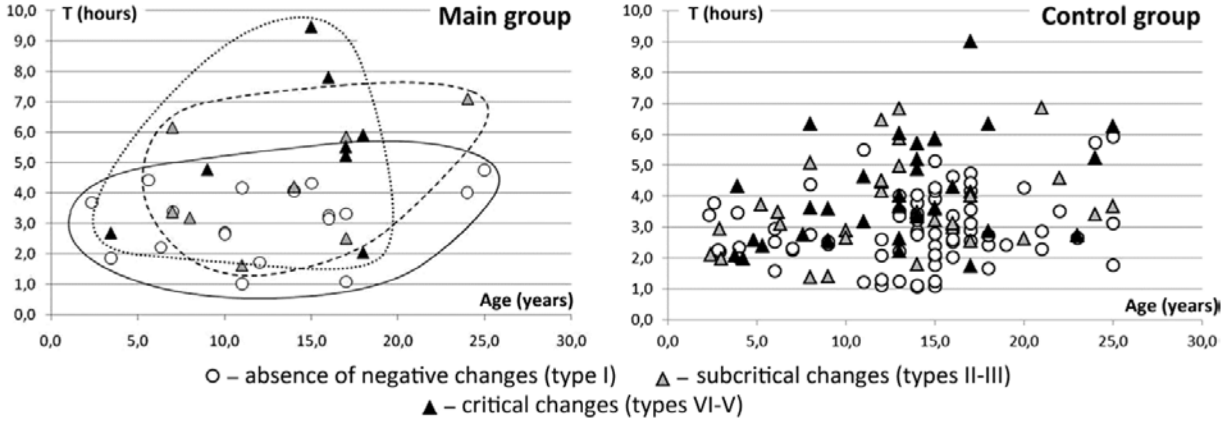

Fig. 2 Distribution of individual manifestations of the MEP reaction to surgical intervention depending on age (abscissa axis) and duration of surgical intervention (ordinate axis) of patients in the groups. For the main group, the regions of localization of the observations of the first, transitional, and critical types are marked by solid, dashed and dotted lines

DISCUSSION

The absence of significant deviations in the frequency of occurrence of the types of the pyramidal system electrophysiological reaction to surgical correction of spinal deformities in the main and control groups that was detected by us suggests that in patients with genetically determined systemic skeletal pathology, the dynamics of the functional state of the conducting spinal cord pathways is similar to the pattern of changes in patients of other etiological groups. A significant proportion of observations in which unfavorable changes in the MEPs were completely absent or reversible (the state of the pyramidal system corresponds to the preoperative level at the end of the operation,) indicates a high safety degree of modern technologies for intervention on the spine in various types of pathology. Absence of severe clinical manifestations of motor function impairment (or their aggravation, in case of initial presence) even after emergence of critical neurophysiological patterns (type IV and V) during the surgery indicates that timely and adequate measures were undertaken by the surgeon and anesthesiologist in response to the appearance of danger signs.

The transformation of MEPs in types II–IV of reaction is caused not so much by direct action on the nervous tissue but by the insufficiency of the body's regulatory systems, their limited ability to adapt in the conditions of complex and prolonged surgical intervention. This is more evident in patients with genetically determined systemic skeletal pathology than in other etiological groups.

Thus, the use of MEP recording technology in the process of surgical correction of spinal deformities in patients with genetically determined systemic skeletal pathology is a highly effective tool for preventing the development of intraoperative neurological complications. The system of formal evaluation of the results of neuromonitoring proposed by us made it possible to quantitatively compare the character of intraoperative changes in the functional state of the pyramidal system of patients of different etiological groups, depending on their age and duration of intervention.

REFERENCES

1. Khit' M.A., Kolesov S.V., Kolbovskii D.A., Morozova N.S. Rol' intraoperatsionnogo neirofiziologicheskogo monitoringa v predotvrashchenii razvitiia posleoperatsionnykh nevrologicheskikh oslozhnenii v khirurgii skolioticheskoi deformatsii pozvonochnika [The role of intraoperative neurophysiological monitoring in preventing the development of postoperative neurological complications in the surgery of the spine scoliotic deformity]. *Nervno-myshechnye bolezni*, 2014, no. 2, pp. 36-41. (In Russ.)
2. Gibson P.R. Anaesthesia for correction of scoliosis in children. *Anaesth. Intensive Care*, 2004, vol. 32, no. 4, pp. 548-559.
3. Hsu B., Cree A.K., Lagopoulos J., Cummine J.L. Transcranial motor-evoked potentials combined with response recording through compound muscle action potential as the sole modality of spinal cord monitoring in spinal deformity surgery. *Spine*, 2008, vol. 33, no. 10, pp. 1100-1106. doi: 10.1097/BRS.0b013e31816f5f09.
4. Pelosi L., Lamb J., Grevitt M., Mehdian S.M., Webb J.K., Blumhardt L.D. Combined monitoring of motor and somatosensory evoked potentials in orthopaedic spinal surgery. *Clin. Neurophysiol.*, 2002, vol. 113, no. 7, pp. 1082-1091.
5. Wassermann E.M. Variation in the response to transcranial magnetic brain stimulation in the general population. *Clin. Neurophysiol.*, 2002, vol. 113, no. 7, pp. 1165-1171.
6. Jameson L.C. Transcranial Motor Evoked Potentials. Chapter 2. In: Koht A., Sloan T.B., Toleikis J.R., eds. Monitoring the Nervous System for Anesthesiologists and Other Health Care Professionals. New York, Springer-Verlag, 2012, vol. XXXVI, pp.27-45.
7. Sergienko V.I., Bondareva I.B. *Matematicheskaia statistika v klinicheskikh issledovaniiakh* [Mathematical statistics in clinical studies]. M., GEOTAR-Media, 2006, 304 p. (In Russ.)

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