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Results of intraoperative neurophysiological monitoring in spinal canal surgery

Wyniki monitorowania neurofizjologicznego operacji kanału kręgowego

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Abstract

Background and purpose: Spine surgery carries the risk of neurological complications. Neurophysiological intraoperative monitoring (NIOM) plays some role in preventing adverse events. NIOM is a young technique, and because of its costs and additional personnel it requires constant evaluation of indications. Nowadays, it is generally assumed that if available, NIOM should be used in every intracanal surgical procedure. This study aimed to evaluate the efficacy and indications for NIOM in spine surgery in relation to procedure location.
Material and methods: Effectiveness of NIOM in spinal canal surgery was evaluated by comparison of the number of neurological complications in patients treated surgically with and without NIOM. A total of 74 consecutive patients were surgically treated for spinal canal pathology at the Department of Neurosurgery, 10th Military Hospital in Bydgoszcz. Thirty-eight patients operated on with the use of NIOM were compared to a historic population of 36 patients treated before the introduction of NIOM. The number of patients with neurological complications was analyzed in three groups based on surgical location: extradural, intradural extramedullary, and intramedullary procedures. Differences between groups were tested with the Fisher exact test.
Results: The number of neurological complications was significantly lower in the intramedullary procedure group with NIOM. There was no significant difference in the number of complications in patients undergoing intra- or extradural extramedullary procedures with versus without NIOM.

Streszczenie

Wstęp i cel pracy: Operacje kanału kręgowego są obarczone wyjątkowo dużym ryzykiem powikłań neurologicznych. Jedna z najważniejszych metod zmniejszania ryzyka powikłań operacji to śródoperacyjne monitorowanie neurofizjologiczne (*neurophysiologic intraoperative monitoring* – NIOM). Jest to technika młoda i ze względu na koszty aparatury oraz dodatkowego personelu konieczna jest ocena jej skuteczności i ustalenie wskazań do jej stosowania. Obecnie zakłada się, że jeżeli technika NIOM jest dostępna, to powinna być zastosowana w każdego rodzaju operacjach kanału kręgowego. Celem pracy była ocena skuteczności i zasadności NIOM w operacjach kanału kręgowego w odniesieniu do zakresu procedury.
Materiał i metody: Skuteczność NIOM w operacjach kanału kręgowego oceniono poprzez porównanie liczby powikłań neurologicznych po zabiegach z użyciem NIOM i bez zastosowania NIOM. Badaniem objęto 74 kolejnych chorych operowanych w zakresie kanału kręgowego w Klinice Neurochirurgii 10. Wojskowego Szpitala w Bydgoszczy. Wyniki leczenia 38 chorych operowanych z wykorzystaniem NIOM porównano z wynikami w historycznej grupie kontrolnej, którą stanowiło 36 kolejnych chorych operowanych przed wprowadzeniem tej techniki. Oceniono liczbę powikłań neurologicznych po operacjach w trzech grupach – zewnątrzoponowych, wewnątrzoponowych, zewnątrzrdzeniowych oraz wewnątrzrdzeniowych. Istotność różnic oceniano przy zastosowaniu testu dokładnego Fishera.

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Conclusions: NIOM decreases the risk of neurological complications in spinal cord surgery, but not in extramedullary spinal canal procedures.

Key words: neurophysiological monitoring, spine surgery, spinal cord tumors.

Wyniki: Po operacjach rdzenia kręgowego stwierdzono istotnie mniejszą liczbę powikłań w grupie chorych operowanych z wykorzystaniem NIOM. Nie stwierdzono istotnej różnicy pomiędzy wynikami operacji prowadzonych zewnątrzrdzeniowo – wewnątrzoponowo ani zewnątrzoponowo.

Wnioski: Śródoperacyjne monitorowanie neurofizjologiczne podczas operacji rdzenia kręgowego zmniejszyło liczbę powikłań neurologicznych, ale w przypadku operacji zewnątrzrdzeniowych nie wpłynęło istotnie na neurologiczny wynik leczenia.

Słowa kluczowe: monitorowanie neurofizjologiczne, chirurgia kręgosłupa, guzy rdzenia kręgowego.

Introduction

Spine and spinal cord surgery carries an uncommonly high risk of neurological complications [1,2]. Lesions of the spinal cord or spinal roots markedly affect patients' quality of life. One of the paradigm shifts in surgery of the spine and spinal cord was the introduction of microsurgical techniques with great improvement in surgical results [3]. In the current 'digital age', another improvement in treatment is thought to be intraoperative neurophysiological monitoring (NIOM) [4,5]. Any technique resulting in fewer neurological complications after neurosurgical procedures is priceless. On the other hand, costs of hardware, additional personnel, and use of disposable materials as well as special anesthesia required during NIOM are not negligible. Moreover, the efficacy of NIOM in reducing the risk of neurological complications or improving outcome is not well proven in every kind of neurosurgical procedure.

Some papers and authors' experiences are published on the subject of NIOM in intramedullary surgery, discussing its role in improving outcome after surgical treatment of intramedullary spinal cord tumors [4-6] or brain stem surgery [7]. It is generally assumed that if NIOM is available in the operating theatre, it simply has to be used during every or most of the procedures involving the spinal canal. With improvements in NIOM techniques and newly available methods, in addition to the relative lack of data concerning the efficacy of NIOM in all (not only intramedullary) spinal canal procedures, further analysis is needed. We have assumed that NIOM may not be of equal value in all spinal canal procedures, and therefore the indications for monitoring may vary in relation to surgical field localization.

The aim of this study was to evaluate the effectiveness of NIOM in all spinal canal surgical procedures. In our analysis, we focused on three groups of neurosurgical intracanal procedures, divided into three classic groups according to anatomical localization of an operative field. Postoperative neurological outcome as the most important for patient's quality of life was the main outcome measure of NIOM efficacy.

Material and methods

Seventy-four consecutive spinal canal neurosurgical procedures were analyzed. The procedures were divided into two groups according to whether NIOM was used and into three groups according to the anatomical localization of the surgery. These groups were defined as intracanal extradural procedures, intracanal intradural procedures, and intramedullary procedures.

The population consisted of 24 patients operated on for intramedullary lesions, 38 patients operated on for intracanal extradural lesions, and 12 patients with extradural intracanal lesions (Table 1). Reoperations were excluded. Only disposable, non-sterilized electrodes were used.

Results of a consecutive group of patients undergoing intracanal procedures with the use of NIOM were compared to a historical group of consecutive patients undergoing intracanal procedures before introduction of NIOM. The historical control group was used due to ethical reasons concerning the controversial randomization of NIOM usage given the full availability of this technique.

Outcome was defined as not complicated or complicated. Any new postoperative neurological deficit in comparison to the patient's presurgical neurological status was considered a complication.

Statistical analysis was performed with the assumed significance level of $p = 0.05$. The significance of differences between groups was estimated with Fisher exact

Table 1. Population of patients operated on with and without neurophysiological intraoperative monitoring according to localization of the procedure

Surgical field	With neurophysiological intraoperative monitoring	Without neurophysiological intraoperative monitoring	Total
Extradural	5	7	12
Intradural extramedullary	20	18	38
Intramedullary	13	11	24
Total	38	36	74

test. Statistical analysis was performed with Statistica version 9.0 software (StatSoft).

In the analyzed group of patients, the method of anesthesia was uniform and according to published data [9-12]. Midazolam was used for premedication. Induction of general anesthesia was achieved with propofol, fentanyl, and vecuronium. Myorelaxant was used in only a single dose for endotracheal intubation and for changing of the patient's position. Neuromuscular block was monitored. Intravenous anesthesia was maintained with intravenous infusion of propofol and remifentanil. Infusion of remifentanil was started after a change of the patient's positioning. Up to this time, the analgesic drug was fentanyl administered during induction of anesthesia. Remifentanil dosage depended on the actual surgical situation, considering pain intensity and hemodynamic stability. The temperature of the patient was maintained with the help of a thermal mattress, infusion of heated fluids, and ambient temperature.

Neurophysiological monitoring was performed with the ISIS NIOM neuromonitoring device (Inomed Medizintechnik GmbH, Teningen, Germany). Somatosensory evoked potentials (SEP) and motor evoked potentials (MEP) were monitored during intramedullary procedures. For lesions located higher than the tenth thoracic vertebra, MEP as the spinal direct wave (D-wave) were also recorded.

SEP were stimulated with subdermal needle electrodes placed close to the ulnar and posterior tibial nerves with current intensity of 15-20 mA, pulse duration of 0.2 ms, and frequency of 2.7-4.5 Hz. Evoked potentials were recorded with subdermal needle electrodes placed at points described as C3/C4-Fz and Cz-Fz according to the 10-20 system for electroencephalography. Significant changes were defined as 50% decrease of SEP amplitude and 10% elongation of SEP latency.

Motor evoked potentials monitoring was performed with transcranial electric stimulation through corkscrew subdermal electrodes located at C1-C2 points according to the 10-20 system. Stimulation of left and right extremities was achieved with a change of C1-C2 electrical polarization. The recipient electrodes were placed subdermally over the adductor pollicis longus muscle, anterior tibial muscle, and sural triceps muscle. Each MEP stimulation was preceded by dutiful warning to the surgical team and during procedure cessation. MEP responses were not quantified; they were evaluated as present or absent.

The D-wave was registered continuously through the subdural or extradural three-contact electrode placed distally to the surgical field. The proximal D-wave electrode was not used. Electrical stimulation was the same as for MEP monitoring but with single pulses. A 50% reduction in amplitude and 10% latency elongation was considered significant. Amplitude decrease of 30-50% was considered a warning.

Intracanal procedures were also monitored with electromyography (EMG). EMG potentials were registered with subcutaneous needle electrodes placed over the monitored muscle. In every case, the muscles in the planned innervated myotomes were monitored with special attention paid to muscles crucial for quality of life. EMG was monitored continuously with graphical and acoustic interfaces. Spontaneous activity increase was defined as radicular irritation. EMG was also used for spinal root localization with monopolar and bipolar stimulation with current 0.2 mA and 3 Hz frequency.

Results

Postoperatively, neurological status worsened in 17 patients; in 57 patients there was no change (Table 2). Generally, if we did not take into consideration the localization of the surgical field, the number of complications was significantly lower in the group of patients in which NIOM was used. There were three cases of neurological worsening after surgery with NIOM and 14 cases of worsening after procedures without NIOM. There were 35 cases with no complications with NIOM and 22 cases with no complications without NIOM.

According to our aim, more detailed analysis of surgical outcome took into consideration the localization of

Table 2. Neurological complications in 74 patients with lesions in the vertebral canal operated on with and without neurophysiological intraoperative monitoring. Fisher exact test reveals a highly significant difference in the complication rate ($p = 0.002$)

Surgery	With neurophysiological intraoperative monitoring	Without neurophysiological intraoperative monitoring	Total
Complicated	3	14	17
Not complicated	35	22	57
Total	38	36	74

Table 3. Neurological complications in 24 patients with intramedullary lesions operated on with and without neurophysiological intraoperative monitoring. Fisher exact test reveals significant difference in the complication rate ($p = 0.01$)

Intramedullary procedures	With neurophysiological intraoperative monitoring	Without neurophysiological intraoperative monitoring	Total
Complicated	3	9	12
Not complicated	10	2	12
Total	13	11	24

the surgical field – extradural, intradural extramedullary, and intramedullary. It clearly showed a significantly lower number of neurological complications in patients undergoing surgery for intramedullary lesions (Table 3).

There was no significant difference in the number of complications between monitored and not monitored groups operated on for extramedullary lesions, both intradural as well as extradural. The rate of neurological worsening was relatively low, although such complications occurred only in patients operated on without NIOM. In extradural procedures, there were two complications in patients treated without NIOM and five good outcomes in both groups. After intradural extramedullary procedures, there were three complications without NIOM, 20 good results with NIOM, and 15 good results without NIOM.

We observed no local complications that could be related to NIOM: there were no infections due to needle electrode insertions, fractures due to corticospinal tract stimulation, or seizures. In three cases the D-wave was not recordable at the beginning of the dissection.

Discussion

Intraoperative neurophysiological monitoring is becoming more widely used in spine and spinal cord surgery, thus allowing the surgeon to predict lesions of neurological structures or to evaluate such lesions [4-7]. In these cases, intraoperative monitoring of motor evoked potentials is most commonly used, as well as somatosensory evoked potentials monitoring and EMG. The main advantage of NIOM is a potential early warning before serious and irreversible neurological injury. Another advantage of NIOM is its ability to define particular structures in the central and peripheral nervous system, that is, to delineate nuclei or to differentiate and define particular nerves and spinal roots. It is especially important in patients with anatomy altered secondarily to tumor infiltration.

Methods for providing evidence-based evaluation of NIOM of spinal canal surgery is troublesome and doubtful due to ethical considerations and a relatively low patient volume, especially in centers where neurophysiological monitoring is fully available. Therefore, one method of evaluation is the comparison of all consecutive patients operated on with the use of NIOM versus all patients operated on for the same conditions before implementation of this technique in the same department, as previously used by some authors investigating NIOM [5]. This type of control is termed a historic control group.

In our study, 74 patients operated on by one surgical team due to lesions located in the spinal canal were analyzed. The NIOM technique was implemented in 2008. From this date onward, 38 patients were operated on, all with use of this monitoring technique. For a control group, 36 consecutive patients operated on due to spinal canal lesions before introduction of NIOM were analyzed.

The main measure of NIOM efficacy was immediate neurological outcome, simplified into three groups of patients without further quantification of complications. We did not analyze the influence of NIOM on treatment effectiveness, such as tumor resection extent or surgical duration time. We did not find any sound published data on this subject, possibly due to extreme methodological difficulties in planning of such research.

The results suggest that NIOM increases the safety of general spinal canal surgery, defined as a reduced risk of neurological postoperative worsening. This is consistent with generally accepted beliefs among neurosurgeons. However, further analysis reveals a significant effect of NIOM only in intramedullary surgery. This is not a novel conclusion, but may be of relevance with the standards used in this study. Similar results were published by Sala in 2006 and 2007 [4,5]. However, Sala used more extensive monitoring with more channels, especially for MEP. Our standard procedure was slightly simplified with, for example, six channels for extremity monitoring and only one electrode for D-wave monitoring. In three cases, the D-wave was not recorded. Other authors have reported such technical difficulty as well [13].

Somewhat surprisingly, contrary to general belief, there was no significant difference in neurological risk among extra- versus intradural extramedullary procedures. We found no evidence of improved safety of intracanal extramedullary procedures with NIOM. However, NIOM also plays a role in defining local anatomy, allowing the localization of structures critical for the patient's quality of life. Additionally, there is a non-measurable benefit associated with NIOM in terms of increased comfort of the surgeon, shortened procedure duration, and augmented oncological resection extent.

Many factors during the course of surgery may influence the methodology of NIOM analyses. One of the most important factors is the anesthesiological procedure. Proper anesthesia technique (choice and dosage of medication) and appropriate control of patients' physiological parameters must be considered.

Most drugs used in general anesthesia have some influence on evoked potentials [8-11]. The main dilemma of anesthesiologists is the choice between inhalation anesthesia and total intravenous anesthesia [12]. In our study population, all anesthesiological aspects were taken into consideration and surgery was performed under intravenous anesthesia; therefore the examined population may be considered uniform from this point of view.

Conclusions

Intraoperative neurophysiological monitoring provides a significant reduction in the rate of neurological complications after spinal canal surgery. The value of this technique was specifically seen in intramedullary procedures whereas no benefit was demonstrated in patients with extramedullary spinal lesions.

Disclosure

Authors report no conflict of interest.

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