Accuracy of two different criteria for neurophysiological intraoperative monitoring (NIOM) in spine/spinal cord surgeries

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ABSTRACT

Objective: *Our objective was to compeer the accuracy between two warning criteria during the intraoperative neurophysiologic monitorization for spine/spinal cord surgery.* ***Method:*** *We used two different warning criteria to detect neurological damage. The first criterion was the amplitude reduction of the somatossensory-evoked potentials (SEP) or motor-evoked potentials (MEP) greater than 50% at least in one limb and the second criterion was the complete loss of one of the same potentials. These results were compared with the neurological examination and the sensitivity, specificity, positive likelihood ratio (PLR) and negative likelihood ratio (NLR) was calculated for each criterion.* ***Results:*** *The sensitivity, specificity, PLR and NLR were respectively for criterion 1 and 2 (0,92/0,58; 0,96/0,99; 24/46 and 0,09/0,57).* ***Conclusion:*** *The first criterion suggests a better sensitivity and accuracy as a warning criterion to avoid central neurological damage.*

KEYWORDS

Monitoring intraoperative, spine/surgery, sensibility and specificity.

RESUMO

Acurácia de dois distintos critérios para monitorização neurofisiológica intraoperatória (MNIO) para cirurgias na coluna/medula

Objetivo: *Nosso objetivo foi comparar a acurácia entre dois critérios de alarme durante a monitorização neurofisiológica intraoperatória, em cirurgias de coluna ou medula.* ***Método:*** *Foram analisados dois critérios de alarme distintos para detectar danos neurológicos medulares, sendo o primeiro critério a redução maior que 50% na amplitude do potencial evocado somatossensitivo ou potencial evocado motor em pelo menos um membro. O segundo critério é a perda completa de um dos potenciais. Os achados foram comparados com as alterações neurológicas e a sensibilidade, especificidade, razão de verossimilhança positiva e negativa foram calculados para cada critério.* ***Resultados:*** *A sensibilidade, especificidade, razão de verossimilhança positiva e negativa foram, respectivamente, para os critérios 1 e 2 (0,92/0,58; 0,96/0,99; 24/46 e 0,09/0,57).* ***Conclusão:*** *O critério 1 aponta para uma tendência de melhor sensibilidade e acurácia, como sinal de alerta de um possível dano neurológico central.*

PALAVRAS-CHAVE

Monitorização intraoperatória, coluna vertebral/cirurgia, sensibilidade e especificidade.

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Introduction

Although relatively uncommon,[1] spinal cord injury, is one of the most feared complications of spinal/spinal cord surgery. NIOM has been used clinically in the last thirty years, to identify the risk of deficits in time to intervene and prevent permanent deficits, although, there are still controversial opinions[1,2] about its effectiveness in preventing a postoperative neurological deficit. Recently an evidence-based guideline update[2] demonstrates that NIOM can detect an impending neurological deficit with reasonable sensitivity and specificity. On the other hand, the main argument against the NIOM is the heterogeneity in NIOM services, with techniques and criteria remaining unstandardized, and the thresholds at which a signal change constitutes a significant change may vary considerably from one neuromonitoring group to another.[1]

As for illustration, Kothbauer *et al.*[3] observed that only the presence or absence of CMAP responses correlated with clinical outcome, another approach is to establish a criterion, for example, a percentage reduction of amplitude, as threshold for informing the surgeon of significant changes[4] and at least, but certainly not the last, Calancie *et al.*[5] approach is to employ "threshold-level" monitoring. Once stable anesthesia and neuromuscular blockade are achieved, the minimal voltage threshold required to elicit a CMAP response in each monitored muscle is determined. Subsequent increases in threshold voltage, unexplained by technical, systemic, or anesthetic factors, are used as a guide for informing the surgeon of potential motor tract injury

In order to have a better understanding of this topic, we undertook a critical analysis of our cases in which NIOM was used, with emphasis on the correlation of two different NIOM criteria with postoperative clinical findings. The first criterion is the completely loss of any motor or somatossensitive potentials in at least one limb that was monitoring and the second criterion is the loss of 50% of the amplitude of any of those potentials with maximal stimulation in the case of motor response.

Materials and methods

Patients

The protocol for this study was reviewed by the institutional review board of SARAH hospital and was granted an exempt status because it was an anonymous retrospective chart review. Outcomes data for all spine surgical procedures performed with multimodality spinal cord monitoring between March, 2011, and March, 2013, at a single institution were reviewed. A total of 265 procedures were performed in 114 male patients (42%), ranging in age from 4 to 83 years, with an average age of 32 years, at the time of the index procedure. There were 77 surgeries for cervical myelopathy, 126 surgical treatments for scoliosis, 24 fractures or intradural extramedullary tumors, 9 intramedullary spinal cord tumors and 25 other types like dorsal root entry zone procedures. Of the 265 patients, 4 were excluded because there were no potentials detectable (2,3%). Intraoperative records were examined in an attempt to identify the operative event that correlated with the neurophysiologic change as well as the effect of surgical and/or anesthesia-related intervention on the changes demonstrated by monitoring. Hospital and office charts were also reviewed to determine the preoperative diagnosis as well as the preoperative, immediate postoperative and most recent neurological data.

Anaesthetics

The anesthetic protocol used during surgery included a combination of the two drugs, remifentanil and propofol, with total intravenous anesthesia. Target-controlled infusion was used for propofol with a plasma concentration of 1,5-3 mg/ml and for remifentanil with 2-5 ng/ml. No muscle relaxants were used after induction and intubation unless for surgeon request.

Recording and stimulations

Cortical SEPs (Figure 1) were elicited by a 200 ms squarewave electrical pulse presented sequentially to the posterior tibial and/or median nerves at a rate of 3.7/s. Stimulus intensity was adjusted individually and ranged from 10 to 25 mA. Cortical potentials were recorded from corkscrew-type electrodes placed at Cz' for posterior tibial nerve stimulation (P37), C3' or C4' for median nerve stimulation (N20) and referenced to Fz (international 10-20 EEG system). Filtering was typically 30-1000 Hz, with a 50 or 100 ms analysis time; 100-200 averaging was stopped manually at such times as potentials were clearly reproducible was done.

MEPs (Figure 2) were elicited with a brief duration of transcranially applied electrical pulses (pulse width 1000 μs), fixed high-voltage (300 V) anodal electrical stimulus train (4 stimulus, interstimulus interval 4 ms), with a maximum of 220 mA, delivered with two corkscrew-type electrodes inserted over motor cortex regions at C1 and C2 (international 10-20 EEG system). MEPs were recorded with needle electrodes placed in the muscle. Although the choice of muscles used differed according to the pathology, those most commonly chosen were responses from the *abductor pollicis brevis* or the *abductor digiti minimi* muscle in the upper extremities and *tibialis anterior* or *extensor digitorum brevis* muscles in the lower extremities. The time base was 100-200 ms and the filter bandpass 30-3000Hz.

Commercially available neurophysiology instrumentation (Inomed – Isis IOM Neuroexplorer and Osiris stimulator – version 4.3) was used for the multimodal evaluation.

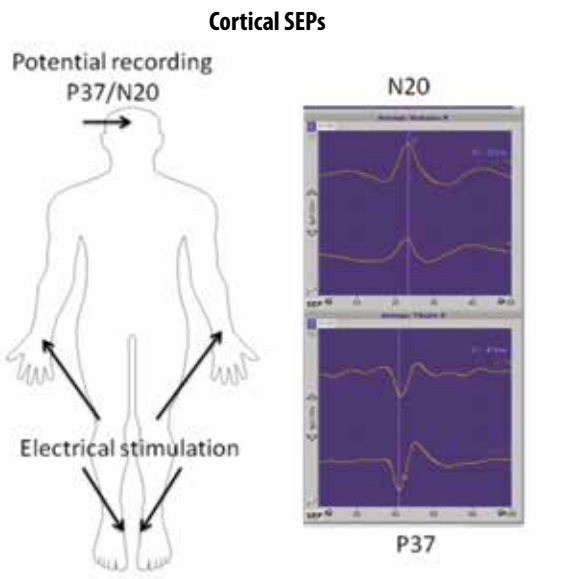

Figure 1 – The electrical stimulation of the tibial nerves and median nerves generates the P37 and the N20 potentials respectively.

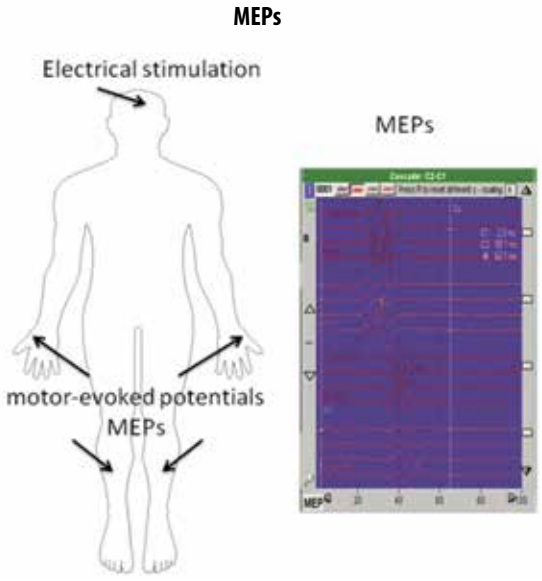

Figure 2 – The electrical stimulation of the scalp generates the motor evoked potentials on the thenar and the anterior tibialis muscles.

Monitoring procedures

Our intraoperative neurophysiological monitoring protocol begin with a baseline SEP and MEP signals obtained after induction and prior to incision. Ongoing surveillance of the spinal cord is a recurrent process that involves frequent MEP and SEP trials. MEPs trials are run with a stimulus capable of generating a supramaximal compound muscle action potentials (CMAPs) or the maximum stimulus that could elicit a CMAP without disturbing the surgery, at least every 2 minutes and more frequently during times of high surgical risk. If the potentials fall the electrical stimulus has been raised until motor amplitude reach more than 50% of the baseline. SEPs are averaged approximately every 30 seconds.

A clinically relevant neurophysiological change (Table 1) in SEPs was defined for the first criterion as an intraoperative limb amplitude loss of at least 50% or in the second criterion as a complete loss of the potential in at least one limb. For MEP analysis a relevant criterion was a segmental reduction in amplitude of 50% with maximum electrical stimulation (first criterion) or complete loss of at least one segment with maximum stimulation (second criterion). It was considered a positive test if it was found at least one of these four scenarios in the end of the monitorization or before the "Stagnera wake up test" if it had been done.

Table 1 – Neurophysiologic criteria

	MEP	SEP
Criterion 1 (MEP and/or SEP altered)	1 limb or more with ≥ 50% decrease of amplitude, compared with baseline	1 limb or more with ≥ 50% decrease of amplitude, compared with baseline
Criterion 2 (MEP and/or SEP altered)	1 limb or more with complete lose of amplitude	1 limb or more with complete lose of amplitude

Clinical correlation and statistics

A clinical finding was considered positive if there were a postoperative motor or sensitive deficit at one or more limb registered inside the patient record with the exception of an evident radicular commitment.

Statistical analysis to determine the success of the two criteria was calculated for the sensitivity, specificity, positive likelihood ratio (PLR) and negative likelihood ratio (NLR) for each criterion.

Sensitivity is the percentage of positive outcomes correctly indicated by the monitoring procedure. Specificity is the percentage of negative outcomes correctly indicated by the monitoring procedure. The likelihood ratio (LR) is the ratio of the probability of a particular test result for a person with the disease divided by the probability of that same result for a person without the disease. The LR indicates by how much a given diagnostic test result will raise or lower the pretest probability of the disease in question.

Results

Neurophysiologic monitoring has started in 265 patients. In four patients, monitoring was not continued after measurement of the reference values. These patients showed virtually no clinical neurologic functions. A positive clinical outcome was identified in 14 patients, four of them reversed in the three days after the surgery (transitory).

The results after application of the two criteria are listed in tables 2 and 3. If criterion 1 was used, 13/14 positive outcomes would have been detected, so almost all neurologic event would have occurred unnoticed. Hence criterion 1 yields a sensitivity of 0.93 with a negative likelihood ratio of 0.07. However, six of the 247 negative clinical outcomes would have been misclassified as positive, yielding a specificity of 0.97 and a positive likelihood ratio of 31.

If criterion 2 was used, five false-negative and two false-positive outcomes would have been obtained, yielding in comparison with criterion 1, a decreased sensitivity (0.64) and a worst negative likelihood ratio (0.36), whereas the specificity of 0.99 and positive likelihood ratio of 64 would have been increased.

Table 2 – Criterion 1

	Clinical outcome +	Clinical outcome -
IOM +	13	6
IOM -	1	241

Table 3 – Criterion 2

	Clinical outcome +	Clinical outcome -
IOM +	9	2
IOM -	5	245

Discussion

Combination of SEP and MEP monitoring provides assessment of entire spinal cord functionality in real time and given known risk of neurologic compromise during complex spinal surgery, NIOM has been developed to inform the surgeon of onset of impairment. The goal of NIOM is to permit change of intraoperative strategy to minimize or reverse deficit. The advent of NIOM also potentially permits more aggressive maneuvers than might otherwise have been undertaken such as deformity correction or tumor resection.

Our study has some limitation as a retrospective study usually has, where the methodological analysis of the clinical outcome was done looking the hospital charts without the same protocol for all patients, with possible underreports from the surgeons, as well the changes of the SEP and MEP during the surgery.

Accepting the limitations of evaluating monitoring outcome criteria in a clinical setting, we attempted to evaluate two different sets of criteria related to defined clinical outcomes. When two different warning criteria were applied retrospectively, it appeared that at least one amplitude decrease of at least 50% (criterion 1) would be a sufficiently stringent warning criterion to ensure that almost no neurologic events go undetected. Application of less strict criteria (criterion 2), leads to a loss in sensitivity. Although there is a gain in specificity, the importance of preventing the clinical consequences of a false-negative (undetected neurologic event) is so great that the advantage of using the loss of 50% of the amplitude potential does not justify the risk of permanent neurologic damage waiting a complete loss of the potentials.

The essential problem of trading sensitivity for specificity must be acknowledged. Detection and prevention of postoperative neurologic deficits demands a high sensitivity; however, this will come with more false alarms. Each alert sounded in the operating room for changes in the NIOM data understandably provokes anxiety in the surgeon.

LR may be categorized as indicating high probability of disease, moderate probability, low probability, or no probability of disease. Within each level of the test result it is possible to calculate the LR and to use this ratio to estimate the posttest probability of disease. LRs ratios greater than 10 and less than 0.1 generate large and often definitive changes from pretest to posttest probability, LR between 5 and 10 and between 0.1 and 0.2 lead to moderate changes in pretest to posttest probability, and LR between 2 and 5 and between 0.2 and 0.5 result in small changes in probability. LR between 1 and 2 and between 0.5-1 rarely alter pretest probability.[6]

Despite traditional spinal IOM literature suggests that NIOM is effective in identifying patients at a high risk for sustaining new spinal cord injuries[7-15] as well as animal research has supported human experience,[16-18] there is a heterogeneity in IOM services and this should be reviewed to see what accounts for the difference in false-positive and false-negative cases in the literature.

Conclusion

This study suggest that the reduction of amplitude potentials (SEP or MEP) higher than 50% with maximal stimulation for MEP could be a better warning alert than the complete loss of any of these potentials.

Competing interests

The authors declare no conflict of interest.

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