Acta Scientific MEDICAL SCIENCES (ISSN: 2582-0931)

Volume 8 Issue 11 November 2024

Review Article

Challenges in Intraoperative Neurophysiological Monitoring During Cervical Surgeries: Analysis of Surgeries Performed in the Dominican Republic in 2023

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DOI: 10.31080/ASMS.2024.08.1942

Received: August 21, 2024

Published: October 09, 2024

Abstract

In the Dominican Republic, the use of intraoperative neurophysiological monitoring in spine surgeries is becoming more frequent every day, such as: surgeries to correct deformities, tumors, and lumbosacral surgeries, however the daily use in cervical spine surgeries is a matter of debate. We performed 263 cases of spinal surgery in 2023 from which a sample of 50 cervical cases was extracted with the same monitoring protocol. In all cases, we used multimodal monitoring (free-run and triggered electromyography, somatosensory evoked potentials, motor evoked potentials and Train of four). The Somatosensory Evoked Potentials modality was the one that issued the most alerts due to the changes recorded in both latency and amplitude. The factors with which the changes were related were surgical manipulation during decompression, the use of halogenated gases above 1.5 MAC, the position of the neck and traction of the patient's upper limbs to perform the surgical approach. Despite the challenges we face daily performing this work, we must not forget that intraoperative monitoring is to prevent and reduce the probability of new deficit in the patient. We must advocate for standardized anesthetic protocols for patients undergoing spinal surgery, raise awareness among physicians to indicate intraoperative neurophysiological monitoring in all cases with a high risk of neurological structures injury. On our side, is our duty to remain in constant learning that gives us all the necessary tools to contribute in a timely and efficient manner to any neurophysiological alert during the cases we perform, thus managing to give a positive value to the role we have been developing within the operating rooms.

Keywords: IONM; Cervical Spine; Changes; Warning Criteria; SSEPs

Abbreviations

IONM: Intraoperative Neurophysiology Monitoring; SSEPs: Somatosensory Evoked Potentials; MEPs Motors Evoked Potentials; EMG: Electromyography; Tr-EMG: Trigger Electromyography; TOF: Train of Four; MAC: Minimum Alveolar Concentration; TIVA: Total Intravenous Anesthesia; DR Dominican Republic

Introduction

In the Dominican Republic, it is common to indicate IONM service for spine surgeries, especially in spinal deformities correction, spinal tumors, and even lumbosacral surgeries, however the use of IONM in cervical spine surgeries is still a matter of debate to perform IONM in our day-to-day work. We found that we assist more lumbar surgeries cases compared to cervical surgeries cases; in addition to this, the great challenge to perform IONM in DR is the variability of anesthesia protocols since not all centers have TIVA anesthesia protocol which makes it even more difficult to reproduce and verify reliable data we obtained during surgery.

Spine procedures performed for a range of cervical presentations are becoming more common and are expected to increase each year. A study is predicting a 13.3% increase in surgical volume from 2020 to 2040 for both, anterior cervical discectomy and fusion (ACDF) and posterior cervical decompression and fusion (PCDF) procedures [1].

IONM was first used in the assessment of nervous system integrity for spine procedures in the 1970s, primarily for scoliosis correction. Shortly thereafter, in 1990, the American Society of Neurophysiological Monitoring was founded with the purpose of investigating and improving the technology [2].

Historically, it has been recognized that IONM is a useful adjuvant to spinal procedures, especially those involving high degrees of surgical manipulation, such as in corrective procedures for cervical deformity or myelopathy. However, for more routine procedures such as disc herniation or moderate cervical stenoses, its routine use is still controversial [3].

The incidence of neurological deficits in cervical spine surgery has been relatively low, ranging between 0.2% and 3.2%. However, a trend was found in patients with cervical myelopathy to have false-positive signal alerts. The incidence of false-positive signal alerts in those with myelopathy was higher, at 29%, compared with those who were not myelopathic at 19%. This result replicates the higher rate of false-positive IONM alerts in patients with cervical myelopathy seen in previous studies. The incidence of positive signal drops in IONM for cervical spine surgeries was 25% with almost bimodal IONM protocol using MEP and SSEP, providing a sensitivity of 100% and specificity of 97.6% in detecting new neurological deficits. [4].

In recent years, an increase in the utilization of intraoperative neurophysiological monitoring (IONM) has been noted to avert these neurological complications. This technology allows intraoperative assessment of spinal cord function through real-time feedback from sensory tracts, motor tracts and individual nerve roots. Currently, the most employed IONM techniques for spinal procedures include somatosensory sensory evoked potentials (SSEPs), motor-evoked potentials (MEPs), and spontaneous (EMG) and triggered electromyography (Tr-EMG) for pedicle screws stimulation threshold.

The SSEP modality involves peripheral stimulation nerves in the upper and lower extremities. Commonly stimulated sites in the upper extremity include the median and ulnar nerves, while those of the lower extremities involve the peroneal and posterior tibial nerves. Leads placed along the sensory strip of the cerebral cortex will detect peripheral nerve fiber stimulation. SSEP is especially useful in posterior approaches to the spinal column due to the anatomical relationship between the dorsal column of the spinal cord and mechanical issues during the application of surgical instruments directly above the dorsal spinal cord pathway. Additional benefits of SSEP in monitoring nerve function include the positional issues of the patient and maintenance of resiliency to anesthetic inhalants or intravenous drugs.

To identify impending damage to the nervous system before it is irreversible, a set of so-called 'warning criteria' were proposed. These warning criteria can be rightfully triggered by surgical manipulation. However, anesthesia can also significantly impact the efficacy of the neurophysiologic measurements, potentially triggering warning criteria. Furthermore, diverse technical problems can cause changes in these neurophysiological signals. As a result, the efficacy of neurophysiological monitoring depends on good cooperation between the surgeon, anesthesiologist, and clinical neurophysiologist. It is crucial that the anesthesiologist(s) builds up experience with the clinical neurophysiologist and the surgeons so that this 'trinity' forms a team based on mutual trust and good communication [8].

The sensitivity and quality of the collected neurophysiological data are significantly affected by the anesthetic technique employed. All anesthetic drugs interfere with evoked potentials in one way or another and should be kept at constant levels during surgery. Intravenous bolus infusions or abrupt changes in the minimum alveolar concentrations (MAC) of inhalational anesthetics may compromise signal measurement. This is most easily achieved with TIVA which is the current gold standard in IONM without neuromuscular block, with propofol as hypnotic and remifentanil, sufentanil or ketamine as analgesic [9].

Based on our experience and early reports regarding the use of SSEPs for spinal cord monitoring suggested a 10% increase in latency of the primary SEP cortical response (i.e., N20 or P37), and/or a decrease of more than 50% in cortical peak to peak amplitude from baseline that is sustained for more than 10 min should be considered alarm criteria for the possible onset of a neurologic compromise and a basis for intervention. Recently, recommended adaptive warning criteria have included visually obvious amplitude reductions from recent pre-changed values and clearly exceeding variability, particularly when is abrupt and focal. The risk of a clinical deficit associated with a pathologic decrement varies with its reversibility. Quickly reversible (less than 30 to 40 min) decrements usually, but do not always, predict the absence of new postoperative deficits. However, such deficits become more likely with protracted (greater than 40 to 60 min) are especially irreversible decrements [10].

To perform cervical surgeries, the patient's position on the surgical table is key, whether for an anterior or posterior approach. Patient positioning is the joint responsibility of the surgeon and the anesthesiologist. Vascular and peripheral nerve injuries can occur during surgeries due to poor positioning. These are preventable complications but continue to occur. Numerous reports have shown the utility of upper extremities somatosensory evoked potentials (SSEP) in predicting impending neural injury related to positioning in spine surgeries [5]. In DR we currently perform tests before positioning the neck and after the position to obtain basal lines that help us visualize any change after the patient's position and issue an alert in time.

There are multiple articles related to plexopathies due to prone position during spinal surgeries, however there are also documented injuries associated with the patient's position in anterior cervical spine surgeries. Patients are at an increased risk of secondary neurological injury during prone positioning not only due to the amount of neck movement on positioning but also due to hemodynamic changes associated with general anesthesia. Currently, there is no standard of care for safe prone positioning of patients with cervical spine pathology [6].

There are cases in which changes in position have been recorded due to the traction of the limbs. This case study demonstrates that patients in the supine position for anterior cervical spine surgery are also at risk for position-related nerve injury. We found studies in which they recorded changes. The cause of the impending brachial plexus injury in this case was attributed to the obesity of the patient. Tucking the arms applied additional traction to the shoulders that were already pulled down and taped in place, likely stretching both the left and right brachial plexi. Allowing the patient's arms to rest naturally on the arm boards was necessary to reduce traction and avoid an impending nerve injury, leading to complete neurophysiological data recovery [7].

Materials and Methods

In 2023, we performed a total of 263 cases of intraoperative neurophysiological monitoring, from which a sample of 50 cases of cervical surgery was extracted, which were performed with the same monitoring protocol.

It is a retrospective, controlled study, in which cases of female and male patients were analyzed undergoing cervical surgery with an anterior and posterior approach, with a previous diagnosis of degenerative diseases. (canal stenosis, herniated disc) and cervical myelopathies. These surgeries were performed in different public and private centers in the Dominican Republic in 2023.

All the cases included was provided by a private company called Neuron NFC SRL®, from which the necessary data was extracted. The intraoperative neuromonitoring equipment was ISIS Express by Inomed® with its last Neuro Explorer software number 7.0.8.0. All the cases registered were under our "recipe for us" informed consent, signed prior to the procedure, which is a standard practice in Neuron NFC SRL® accompanied by a brief neurological examination. The surgeries were monitored with a multimodal protocol including the following modalities: Free-Scan Electromyography, Somatosensory Evoked Potentials, Motor Evoked Potentials, and Train of Four. Not all cases were performed with the same anesthesia protocol, some were performed with TIVA (Propofol, Remifentanyl, Ketamine and usually dexmedetomidine) and other cases used balanced anesthesia usually with a variety of combinations like remifentanil or propofol in continuous infusion, both with sevorane; and Sevorane alone with non-specific concentrations.

The standard protocol used in extracted cases was as follows:

- **Free run EMG (EMG):** Trapezius, Deltoids, Biceps, Triceps, Abductor Pollicis Brevis.

- **Somatosensory evoked potentials (SSEP) from:** Median or Ulnar nerve from upper extremities and Posterior tibial from lower extremities. We use needle and/or stickies electrodes depending on the signal, impedance or build of the patient (we noticed that Inomed® prefer needle electrodes) and for scalp recording we use single needle and/or corkscrews electrodes CPZ-FPZ-CP3-CP4-C5'-ERB POINT.
- **Stimulation parameters:** Pulse: 1-2; ISI: 1.2ms; Pulse width: 400; Rep rate: 3.11-3.7hz; average count: 150 – 200 and stimulation: 30 – 50mA.
- **Motor evoked potentials (MEP):** Transcranial stimulus with electrodes corkscrew or neddle electrodes placed on the scalp in C1 – C2 towards muscles: Trapezius, Deltoids, Biceps, Triceps, Abductor Pollicis Brevis, Tibialis anterior and Abductor Halluccis.
- **Stimulation parameters:** Pulse: 4 to 6; Pulse width: 400 – 800; ISI: 2,2 – 4.0ms; Stimulation: 100 – 250mA.
- **Train of four (TOF):** Stimulation in the posterior tibialis and recording in the Halluccis abductor.

For the development of the study, we considered the following variables:

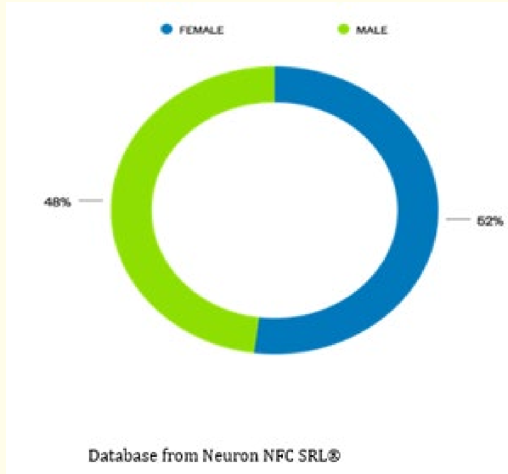
- Number of patients by gender.
- Type of anesthesia used.
- Changes recorded in latency and amplitude according to stimulated nerves.
- Changes recorded in somatosensory evoked potentials according to the nerve addressed.
- Factors that are related to the changes recorded.
- Nerves recorded by case.
- Matches between SSEPs and MEPs records.

Results

Table and graph: Number of patients by gender.

Female	26
Male	24

Table 1

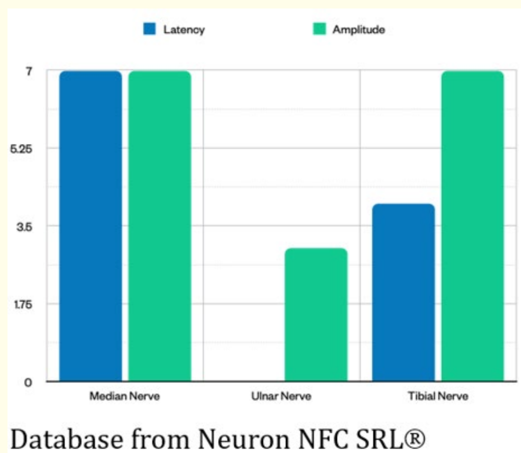


Graph 1

Results

52% of the cases performed were women and 48% were men who underwent cervical surgery.

Graph: Type of anesthesia used in cases.



Graph 2

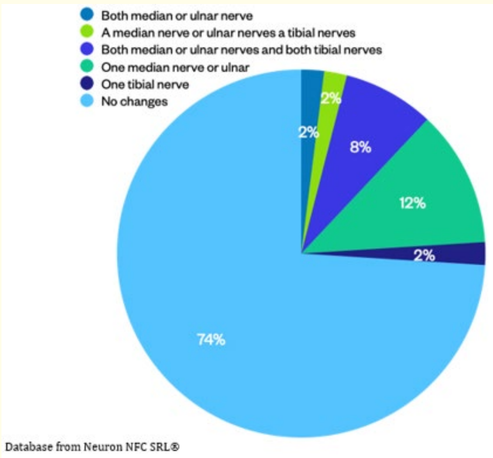
Results

64% of the cases performed with monitoring, Remifentanyl and Sevorane were used Balanced anesthesia; 25% the TIVA type was used and 10% of the cases only halogenated gases were used.

Table and graph: Changes recorded in latency and amplitude according to stimulated nerves.

Nerve	Latency	Amplitude
Median Nerve	7	7
Ulnar Nerve		3
Tibial Nerve	4	7

Table 2



Graph 3

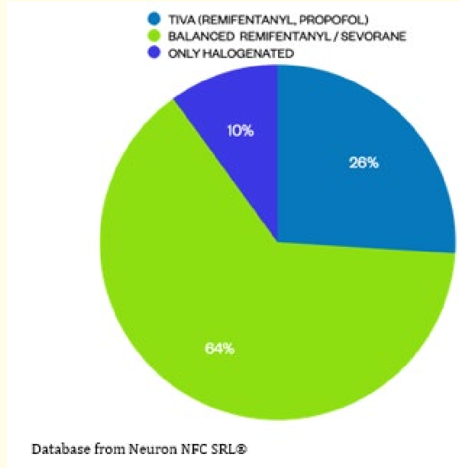
Results

The median nerve was the one that registered the most changes in both latency and amplitude during 7 surgeries performed followed by the tibial nerve which registered a change in amplitude in 7 cases. Ulnar only recorded amplitude changes in 3 cases.

Graph: Changes recorded in somatosensory evoked potentials according to the nerve addressed.

Nerve stimulated	Numbers of cases
Both median or ulnar nerves	1
A median nerve or ulnar and a tibial nerve	1
Both median or ulnar nerves and both tibial nerves	4
One median nerve or ulnar	6
One tibial nerve	1
No changes	37

Table 3



Graph 4

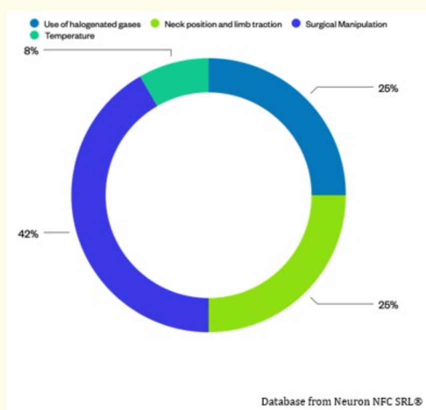
Results

From 50 cases performed with intraoperative monitoring, 37 cases did not register changes during surgery; 6 cases were registered with changes in SSEPs in a median and/or ulnar nerve; 4 cases registered changes in all 4 limbs (median and/or ulnar nerves and posterior tibial); 1 case registered changes in both stimulated nerves (median nerves and/or ulnares); 1 case registered changes in a median nerve and/or ulnar and posterior tibial) and 1 case registered changes in the tibial nerve.

Table and graph: Factors related to the changes recorded.

Use of halogenated gases	3
Neck position and limb traction	3
Surgical manipulation	5
Temperature	1

Table 4

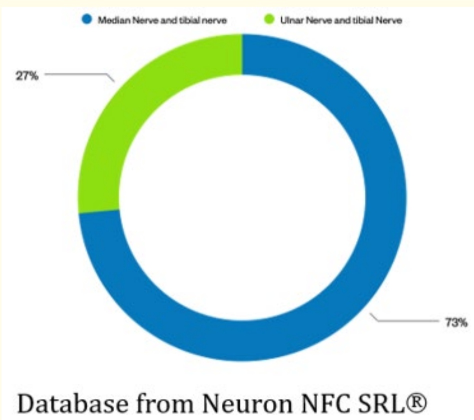


Graph 5

Result

42% of the factors that were related to the changes recorded in SSEPs during surgeries were attributed to surgical manipulation; 25% were related to the use of halogenated gases above 1.5 MAC; 25% were attributed to changes due to patient position, in this case neck position and limb traction; 8% were related to patient temperature and the non-use of thermal blankets in the surgical area.

Graph: Stimulated nerves according to registered cases.



Graph 6

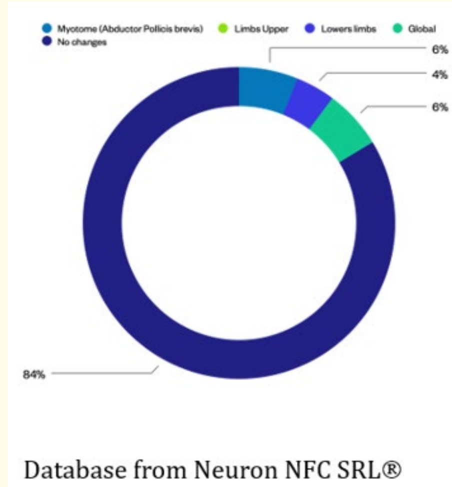
Results

73% of the cases, the median and posterior tibial nerve were monitored and 27% of the cases we monitored the ulnar and posterior tibial nerve.

Table and graph: Matches between SSEPs and MEPs records.

Myotome (Abductor Polliccis Brevis)	3
Upper extremities	0
Lower Extremities	2
Global	3
No changes	42

Table 5



Graph 7

Results

84% of the cases there were no changes in the motor response of the patients studied; 6% of the cases there were changes in the Global registry which included the 4 limbs; 6% registered changes in specific muscles in most cases Abductor Pollicis Brevis and 4% registered changes only in the lower limbs.

Discussion

One of the greatest challenges to performing intraoperative neurophysiological monitoring in the Dominican Republic is the variability in anesthesia protocols, since not all centers have a standard protocol to perform spinal surgery cases, which hinders the veracity and reproducibility of the data obtained during IONM. Protocols vary from the use of a watch dispenser or infusion pump, using propofol, remifentanil, ketamine, in conjunction with dexmedetomedine, to TIVA type anesthesia, in other cases Remifentanyl and Sevorane, or even just use of halogenated gases.

Due to the great variability of the praise obtained in the cases we monitored, we set ourselves the objective of analyzing the different changes registered in the cases, and the factors related to them. With the sample taken for analysis of the cases performed, we found that with a total of 50 cases performed with intraoperative neurophysiological monitoring under the same registration protocol, in 42% of the cases we issued alarms due to decreased amplitude and prolonged latency due to surgical manipulation during surgery, the changes recorded were abrupt and focal. with a coincidence of 6% in which changes in the motor response were recorded in a specific myotome, the alert was quickly and timely until the maneuver was reversed and the return near baseline lines was returned.

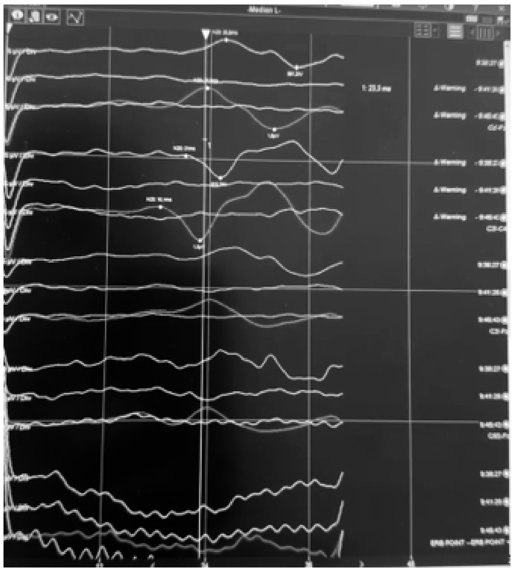


Figure 1: Changes recorded in SSEPs during decompression in case of posterior cervical surgery. Note the changes in elongated latency and then decrease the amplitude by more than 50% in Left Median.

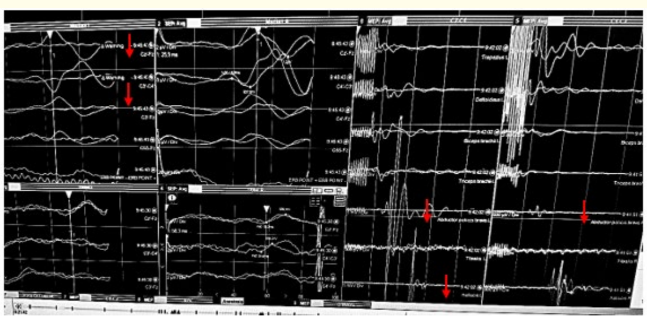


Figure 2: Note the focal change in the Left Median and loss of motor responses in both Abductor Pollicis Brevis, as well as a decrease in amplitude in the left Abductor Halluccis, during decompression.

In the same order, we continued to analyze the data and noticed that in 25% of the cases was the surgical position of the patient, which made us issue a new alert, due to the hyperextension of the neck and traction of limbs that is frequently performed to achieve the surgical approach in cases of anterior cervical surgery. In these cases the registration of the upper extremities was affected, median nerves and ulnars, and even posterior tibial nerves, which we observed changes in latency and amplitude decreased in a scaled way, until it decreased more than 50% compared to the basal, after the position of the neck is reversed and the tension to the traction of the limbs is reduced, We managed to get the lines to be close to the basal again.

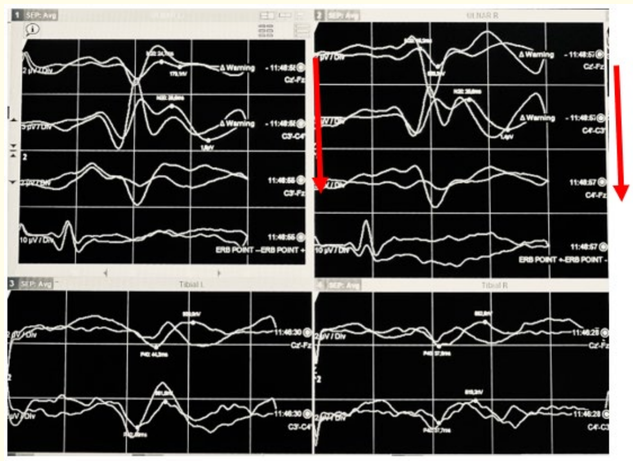


Figure 3: Note the decrease in both median amplitudes, after traction of limbs in anterior cervical surgery.

In another 25% of the cases, the common factor was the use of halogenated gases in surgery above 1.5% MAC, in this case the changes recorded were global, affecting the 4 limbs, increasing latencies and decreasing amplitudes by about 50%.

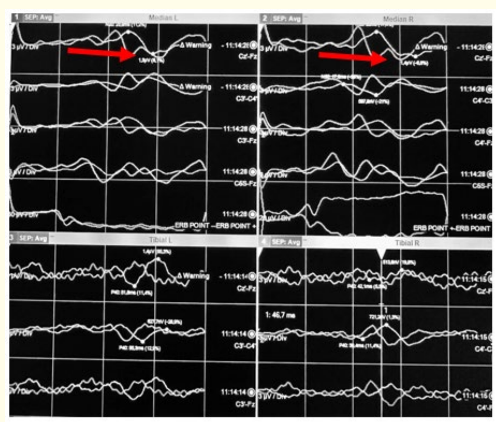


Figure 4: Global elongated latencies due to the use of halogenated gases above 1.5 MAC.

Conclusion

For the development of this study we present limitations because the sample analyzed is not significant, however the findings found were relevant due to the variability of the changes recorded in the SSEPs during the monitoring of the cases carried out and their related factors, so we reach the following conclusion: Despite the challenges we face daily carrying out this work, we must not forget that Intraoperative Neurophysiological Monitoring is to prevent and reduce the probability of new deficit in the patient, so we must advocate for standardized anesthetic protocols for patients with spinal surgery, raise awareness among physicians for the indication of intraoperative neurophysiological monitoring in all cases in which important structures are considered at high risk of injury during surgery. For our part, it is our duty to maintain constant learning that provides us with all the necessary tools to contribute in a timely and efficient manner to any alert during the cases we perform, thus achieving a positive value to the role we have been developing within the operating rooms.

Acknowledgements

Thanks to Neuron NFC SRL® and their teamwork for his unconditional support and to Mr. Ernesto Lima for his time guiding us.

Conflict of Interest

Declare no financial interest or any conflict of interest.

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