Clinical Neurophysiology 126 (2015) 1264–1270

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Role of multimodal intraoperative neurophysiological monitoring during positioning of patient prior to cervical spine surgery

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ARTICLE INFO

Article history:
Accepted 17 September 2014
Available online 2 October 2014

Keywords:
Intraoperative neurophysiological monitoring
Cervical spine surgery
Neck positioning

HIGHLIGHTS

- Neck positioning during cervical spine surgery may lead to spinal cord injury.
- Intraoperative neurophysiological monitoring (IONM) helps to prevent spinal cord injury during neck positioning.
- Transcranial motor evoked potentials (TcMEP) showed a higher sensitivity than somatosensory evoked potentials (SEPs) in detecting mechanical injury to the spinal cord during neck/or arm positioning.

ABSTRACT

Objective: To determine the use of multimodal intraoperative neurophysiological monitoring (IONM) during positioning procedures in cervical spine surgery.
Methods: IONM data was collected from 75 patients from the onset of positioning to the end of the surgical procedure. These included: transcranial motor evoked potentials (TcMEP), somatosensory evoked potentials (SEP) and free running electromyography (EMG) recordings. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (PNV) were calculated.
Results: IONM warnings were given in 5 cases during neck positioning. These consisted of the disappearance of TcMEP in all the cases, while two cases showed a loss of SEPs as well. Four of these patients presented a complete recovery of TcMEP and SEPs after neck repositioning. The patient in which this recovery was not present, woke up with new postoperative neurological deficits. Sensitivity, specificity, PPV and NPV of TcMEP during cervical positioning were all 100%. Sensitivity of SEPs was 40%; specificity and PPV were 100%; and the NPV of SEPs was 95.9%.
Conclusion: Multimodal IONM is a useful method to prevent spinal cord injury during neck positioning in cervical spine surgical procedures. TcMEPs showed the highest sensitivity in detecting injuries to cervical spine related to neck positioning.
Significance: Multimodal IONM should not only be considered for detecting intra-operative warnings, but also during positioning.

1. Introduction

Intraoperative neurophysiological monitoring (IONM) is not used as a routine in spine surgery in many centers, although it is a standard of care in scoliosis procedures (Tomé-Bermejo et al., 2014). Indeed, irreversible changes during IONM are predictive of severe adverse neurological outcomes (level of evidence class A) (Nuwer et al., 2012) which is why it is becoming more popular in cervical spine procedures because it seems to be producing better functional results (Li et al., 2012; Clark et al., 2013).

Certain studies point out that the combination of somatosensory evoked potentials (SEPs) and motor evoked potentials (MEPs)

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http://dx.doi.org/10.1016/j.clinph.2014.09.020
1388-2457/

in IONM is more effective than the use of only one of these methods for the detection of neurological injury during the surgical procedure (Pelosi et al., 2002; Costa et al., 2007; Sutter et al., 2007; Clark et al., 2013). However, neurological injury may not only appear during the surgical procedure itself, but can also occur during neck or arm positioning before surgery (Bose et al., 2004; Jahangiri et al., 2011). Therefore, IONM should be considered during this early stage of the surgical approach to prevent neurological injury that may turn out to cause new motor and/or sensory clinical deficits and consequently a worse functional outcome. To the best of our knowledge, apart from some case reports, no research has focused on this issue.

The aim of the present study is to evaluate the use of SEPs and MEPs in detecting injury to the nervous system during neck and/or arm positioning for anterior and posterior cervical spine procedures.

2. Materials and methods

2.1. Patients

Seventy-five consecutive patients (22 female; mean age of 60.15, SD = 15.1) who were undergoing cervical spine surgery from January to September 2013 were recruited for the study. Table 1 summarizes the diagnoses of this patient cohort and Table 2 indicates the cervical levels that were approached. IONM was performed in all patients and consisted of SEPs, MEPs and EMG recordings during the whole surgical procedure, from positioning to re-positioning in bed after surgery.

2.2. Anesthesia

Midazolam was used for sedation and total intravenous anesthesia (TIVA) was used in all patients (Valverde Junguito et al., 2007). Induction was done with propofol 3 mcg/kg, remifentanil 0.15–0.25 mcg/kg. After induction, intravenous rocuronium 30 mg was only administered for intubation purposes. No further doses of neuromuscular blocking agents were used after that. Anesthesia was maintained by infusion with propofol (range, from 2 to 3 mcg/L) and remifentanil (0.5 mcg/kg/min). Before positioning, gamma-cyclodextrin (sugammadex®) 4–8 mg/kg was administered to reverse neuromuscular blockade and to prevent any interference in the motor evoked muscle responses (Reid et al., 2011). No inhalational agents were ever used for induction or during the surgical procedure.

2.3. IONM recording

All procedures were recorded by the same clinical neurophysiologist and intraoperative neurophysiologic monitoring device (Cadwell Cascade, Cadwell Labs, USA) and followed the standard procedure setup (Valverde Junguito et al., 2007).

2.3.1. Somatosensory evoked potentials (SEPs)

A pair of stimulating surface electrodes (Ambu® Neuroline 72015-K) was applied on the posterior tibial nerve at the ankle and median nerve at the wrist bilaterally. An electrical pulse stimulation of 30 mA, 5.1 Hz frequency, 0.2 ms duration was used. Subdermal corkscrew electrodes (Ambu® Subdermal Corkscrew) were used to record SEPs from the scalp. The SEPs were recorded at C3, C4, Cz and Fpz (10–20 International System) with derivations including C3–Cz, C4–Cz, C3–C4, Cz–Fz and peripheral responses, using a bandpass of 1–300 Hz. Warning criteria were defined as a 50% decrease in amplitude or a 10% increase in latency uni- or bilaterally.

Table 1
Primary indications for surgery.

Diagnosis	%
Degenerative myelopathy	50.7
Disc herniation	24.0
Fracture/luxation	22.7
Tumour	2.7

Table 2
Cervical levels approached.

Level		No. of cases
Single level	C1–C2	0
	C2–C3	1
	C3–C4	6
	C4–C5	11
	C5–C6	17
	C6–C7	18
Multilevel		22

2.3.2. Transcranial motor evoked potentials (TcMEPs)

Stimulation was performed using a multipulse technique based on a train of 7 pulses with an interstimulus interval (ISI) of 4 ms, pulse width of 50 μs, and an intensity between 240 and 400 V, delivered at C1–C2 by corkscrew electrodes (TCS Stimulator, Cadwell Labs, USA). Muscle MEPs were recorded by paired subdermal needle electrodes from the first dorsal interosseus (FDI) in the upper limbs and tibialis anterior (TA) and abductor hallucis (AH) in the lower limbs. Band pass was 10–1500 Hz. An 80% decrease in amplitude or a 10% increase in latency unilaterally or bilaterally or an increase of 100 V stimulation intensity were used to detect the MEPs over the basal threshold as warning criteria.

2.3.3. Free-running electromyography (EMG)

A continuous intraoperative free running EMG was recorded from the upper limbs over both deltoids and biceps to detect C5–C6 radiculopathy using twisted paired stainless-steel subdermal needle electrodes (Ambu® 12 $\times$ 0.40 mm).

2.4. Statistical analysis

Sensitivity and specificity, as well as positive and negative predictive values were calculated. A true positive was defined as the presence of irreversible SEP and/or TcMEP warnings during positioning or during the surgical procedure followed by neurological deficits in the postoperative period. On the other hand, a true negative was defined as the absence of monitoring alerts or the recovery of the potentials after re-positioning and absence of new neurological deficits after surgery. A false positive was defined as the presence of SEP and/or TcMEP warnings during positioning or during the surgical procedure that was not followed by neurological deficits in the postoperative period. A false negative was defined as the absence of warnings during IONM or recovery of SEPs or MEPs after re-positioning but the presence of new neurological deficits after surgery. All analyses were performed on the data using SPSS 18.0 (SPSS Inc., Chicago).

3. Results

Out of seventy-five patients, thirty-nine patients (52%) underwent cervical spinal surgery using an anterior approach while the rest were operated on using a posterior approach. Twelve patients (16%) presented altered TcMEP and SEP recordings at