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Comparison of multimodal intraoperative neurophysiological monitoring efficacy in early childhood and school aged children undergoing spinal surgery

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ABSTRACT

Objective: The aim of this study was to compare the performance of multimodal intraoperative neurophysiological monitoring (MIONM) in children below and over 6 years of age.
Methods: 43 children, diagnosed with spinal pathologies were divided into two cohorts according to their age and enrolled in the study. Those under the age of 6 consisted group A, whereas those between the age of 6 and 11 consisted group B. All patients underwent spinal surgical procedures according to their diagnosis. A standard anesthesia protocol was given to both groups. Baseline somatosensory evoked potentials (SSEPs) and transcranial electrical motor evoked potentials (tcMEPs) were recorded and evaluated at specific time points for each patient.
Results: Except for the SSEPs in three cases, tcMEPs and SSEPs were recorded for all patients. There was no false-negative whereas 9 false positive recordings due to physiological conditions that all recovered intraoperatively. In 10 patients, MIOMN recorded more than %50 decrement, in which 8 had the kyphosis component. The tcMEPs fully recovered by the end of the operation except for the patient with post-tuberculosis kyphosis. There was no statistically significant difference in the mean threshold values with regard to transcranial stimulus intensity for the tcMEPs between the two groups.
Conclusion: Compared to school aged children, both SSEPs, tcMEPs recordings are feasible and MIONM is effective for early childhood patients undergoing spinal surgery.
Level of evidence: Level III, Diagnostic Study.

Introduction

Spinal surgery is a complex procedure that is associated with various risks. The Scoliosis Research Society (SRS) Morbidity and Mortality Committee reported that the annual rate of new neurological complications was 0.95% between 2004 and 2007.[1]

Multimodal intraoperative neurophysiological monitoring (MIONM) has emerged for the real-time evaluation of neurological status in order to prevent these complications. The ascending sensory tracts can be assessed via somatosensory evoked potentials (SSEP) whereas transcranial motor evoked potentials (tcMEP) primarily evaluate the descending motor tracts.[2] Both techniques are combined in MIONM so as to maximize the advantages.[3] Success in obtaining reliable MEP is known to be influenced by lesion location, type and duration of anesthetic agent used, existing spinal chord, cranial anomalies, preoperative motor deficit, patients physiological status and age. Among these variables, one of the most important determinant is concluded to be the age of the child.[4,5] Although advances in electrophysical monitoring techniques and anesthetic agents have led to an improvement in the reliability of MEP monitoring, the reliability of MEP signals in children younger than 11 years of age is still a concern. Studies conclude that success rates decline in children under the age of 6 compared to older ones

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probably due to the incomplete maturation of the corticospinal tract, which leads to changes in the morphology of the waveforms and differences in latencies.[6–9]

The current literature lacks detailed comparison between early childhood and school aged children in terms of intraoperative neurophysiological characteristics, threshold levels, the elicitability of tcMEPs from different myotomes, and the frequency of absence or decrement in amplitude of more than 50% of the baseline values. We consider 6 years to be the critical age for MIONM, thus SSEPs and tcMEPs recordings may not have the desired efficacy. The aim of this study is to elucidate the difference and compare the efficacy of MIONM in early childhood and school-aged children that have underwent surgical procedures due to spinal pathologies.

Materials and methods

Subjects

43 children younger than 11 years of age that underwent spinal surgery between May 2008 and November 2011 were included in the study. Vast majority of all patients were comprised of idiopathic scoliosis (Table 1). MIONM was attempted in all surgical procedures. Children with cardiac pacemakers, cranial anomalies, history of epilepsy and revision cases were excluded. None of the patients had any neurological deficits prior to the surgery. The subjects were divided into two cohorts according to their age. 16 patients mean age 2.7 under the age of six consisted group A and 27 patients mean age 8.2 between 6 and 11 years consisted group B.

Anesthesia

A propofol bolus of 2 mg/kg was administered after the initiation of a remifentanil infusion of 0.2 μg/kg/min, and 100% oxygen (O_2) was delivered via a facemask or laryngeal mask. Following the baseline recordings, 0.5 mg/kg of atracurium besilate, a short-acting myorelaxant, was administered and the patient was intubated. The anesthesia was continued with total intravenous anesthesia (TIVA) with respect to the cardiovascular parameters (remifentanil 0.1–0.2 μg/kg/min and propofol 6–8 mg/kg/h), and the induction of bolus doses of remifentanil and propofol was avoided. Mechanical ventilation with air-oxygen mixtures was performed with respect to the end-tidal CO_2 level, which was maintained between 30 and 35 mmHg. Normotensive anesthesia was performed to maintain the systolic blood pressure between 100 and 130 mmHg. In case of hypotension, which would inhibit the eliciting potentials, the doses of propofol and remifentanil were decreased to 2–4 mg/kg/h and 0.05–0.1 mg/kg/h, respectively. An infusion of ketamine hydrochloride (0.025 mg/kg/h) was also added for the maintenance of the anesthesia.

Monitoring equipment

The Nicolet Endeavor CR™ (Viasys Healthcare, Nicolet Biomedical, Madison, Wisconsin, USA) system was used for MIONM, and the tcMEPs and SSEPs were recorded. In addition, pedicle screw/hole stimulation, free-run electromyography, direct nerve root stimulation and F-waves were also monitored.[10]

Table 1
Diagnosis of the 43 patients and their distribution according to age.

Diagnosis	Age <6 yr	Age 6–11 yr	N
Congenital scoliosis	5	2	7
Idiophatic scoliosis		13	13
Kyphosis (Traumatic, post-tuberculosis, idiopathic)		3	3
Tethered cord	4	3	7
Tethered cord + Diastematomyelia	4	2	6
Diastematomyelia	3	4	7

Evoked potentials

Intraoperative monitoring was accomplished in multimodal manner including SSEPs, tcMEPs, direct nerve root stimulation.

SSEPs

The SSEPs were recorded from the scalp on C3′-FPz and C4′-FPz montages via corkscrew electrodes or subdermal needle electrodes by stimulating the median or ulnar nerves bilaterally with self-adhesive surface electrodes. In the lower extremities, the bilateral tibial nerves were stimulated by surface electrodes, and the SSEPs were recorded from inion-FPz and FZ′-FPz via corkscrew electrodes. The filter settings were adjusted to between 100 and 300 Hz. The stimulus frequency was 1.7 Hz and the duration was 500 μs for the tibial nerve and 300 μs for the median nerve. Furthermore, the stimulus strength ranged from 25 to 60 mA for the tibial and median nerves.[11]

tcMEPs

The tcMEPs were recorded by subdermal needle electrodes from either the abductor pollicis brevis or more commonly from the bilateral abductor digiti quinti due to the intra-arterial interventions to the radial artery at the wrist. In the lower extremities, the tcMEPs were recorded from bilateral iliopsoas (IP), adductor magnus (AddM), vastus lateralis (VL), tibialis anterior (TA), and abductor hallucis muscles (AHL) that involved the L1-S2 myotomes. In addition, the bilateral external anal sphincter muscles were monitored as needed to prevent injury to the lower spinal cord, especially for tethered cord syndrome. Corkscrew electrodes from M3-Mz6 and M4-Mz6 for the left and right motor cortex were respectively applied to the stimuli. The duration of the stimulus was 1000 μs, and the maximum intensity was 400 V. The frequency of the stimuli, including the five consecutive train stimuli, was 250 Hz and the filters were set to 30 and 500 Hz. The number of train stimuli was increased to 10 when five consecutive trains of 400 V elicited no tcMEPs. A threshold level of stimulus intensity was determined when satisfying tcMEP recordings were obtained from at least the muscles that were essential for the relevant surgical procedure.[10]

Direct nerve root stimulation

The tissues suspected to be of nervous structures were stimulated by a bipolar stimulator, and the motor responses were recorded. The stimulus duration was 0.1 ms, and the maximum stimulus intensity was 20 mA.

Assessment of the patients

All cases were evaluated the day before the surgery by the anesthesia and neurophysiological monitoring staff, and written informed consent was obtained from the parents of all patients for both the surgical procedure and MIONM application.

Recording of tcMEPs and SSEPs

Recording was repeated regularly four times during the surgery The regular time points were as follows: after the induction of anesthesia (first baseline), immediately after the beginning of the

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