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Improving successful rate of transcranial electrical motor-evoked potentials monitoring during spinal surgery in young children

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Abstract

Introduction This prospective study was to investigate the successful rate of intraoperative motor evoked potentials (MEP) monitoring for children (<12 years old) with congenital scoliosis.

Materials and methods A consecutive series of 27 young children (7 girls and 20 boys; from 1 to 11 years old) between September 2007 and November 2009, were enrolled to this study. 12 patients received general anesthesia based on TIVA, induced with propofol 2–4 mg/kg and fentanyl 3–5 µg/kg followed by a continuous infusion of propofol (20–150 µg/kg/min, at mean of 71.7 µg/kg/min). The other 15 patients received combined inhalation and intravenous anesthesia, induced with sevoflurane and fentanyl 3–5 µg/kg and maintained by sevoflurane (0.5–1%). The maintenance of anaesthesia management was performed with stable physiological parameters during surgery.

Results Intraoperative MEP monitoring was successfully performed in all patients, while SEP was successfully performed in 26 of 27 patients. There was no significant difference of successful rates between SEP and MEP monitoring ($P > 0.05$). As well, no difference in MEP successful rates was observed in two groups with different anesthetic

techniques. No wake-up test and no post-operative neurological deficits occurred in this series of patients.

Conclusion Low dose anesthesia by either TIVA with propofol or sevoflurane-based mixture anesthesia protocol can help the intraoperative spinal cord monitoring to successfully elicit MEP and perform reliable monitoring for patients below 12 years of age.

Keywords Intraoperative spinal cord monitoring · Motor evoked potentials (MEP) · Somatosensory evoked potentials (SEP) · Total intravenous anesthesia (TIVA) · Congenital scoliosis

Introduction

Spine surgery carries a significant risk of neurological impairment to the spinal cord. The incidence of intraoperative neurological sequelae has been reported to be 0.25–3.2% for scoliosis surgery [1–3]. Within those neurological impairments, paralysis and other severe motor function deficits are the most feared complications in the spinal surgery. Intraoperative multimodality spinal cord monitoring has been used to assess functional integrity of the spinal cord, to allow the early detection and reversal of such neurologic complications. In combination with somatosensory evoked potentials, motor evoked potentials (MEP) monitoring is widely utilized in operations with significant risks of spinal cord damage [4]. However, the major drawback of MEP monitoring is the lower successful rate to perform continuous monitoring in comparison with SEP [5]. Even though the recent advances in both anesthetic and electrophysical monitoring techniques have led to an improvement in the reliability of MEP monitoring [6–12], it is still difficult to record reliable MEP signals,

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especially in children. The success rate for lower extremity MEP was reported from 66% [13, 14] in spinal surgery, 81% in congenital scoliosis [15], and even worse in neurologically normal children [13, 14].

In this prospective study, combined monitoring of motor and somatosensory evoked potentials was performed in children with congenital scoliosis under low dose anesthesia either total intravenous protocol (TIVA) or sevoflurane-based protocol. The successful rate of MEP monitoring was reported in a consecutive series of congenital scoliosis children under 11 years of age.

Materials and methods

Patients

Combined intraoperative monitoring of MEP and SEP was performed in a consecutive series of 27 young children patients (7 girls and 20 boys; age ranged from 1 to 11 years), who were undergoing elective spinal surgery between September 2007 and November 2009. All patients were diagnosed as congenital scoliosis with/without semi-vertebral deformity. With approved by local ethic committee, informed consent was given to all patients or their legal guardians for participating in this study.

Anesthesia

All subjects received general anesthesia based on TIVA (Group P) or sevoflurane-based protocol (Group S). In the group P, 12 patients were induced with propofol 2–4 mg/kg and fentanyl 3–5 µg/kg followed by a continuous infusion of propofol (20–150 µg/kg/min, at mean of 71.7 µg/kg/min) in accompany with remifentanyl (0.1–0.5 µg/kg/min, at mean of 0.18 µg/kg/min) or *cis*-atracuronium (0.23–0.67 µg/kg/min, at mean of 0.485 µg/kg/min). The other 15 patients received combined inhalation and intravenous anesthesia (Group S). They were induced with sevoflurane and fentanyl 3–5 µg/kg. In the group S, the patients were maintained by sevoflurane (0.5–1%), usually associated with remifentanyl (8 cases of 15 patients, 0.1–0.3 µg/kg/min, at mean of 0.22 µg/kg/min), or fentanyl (5 cases of 15 patients, intermittent intravenous infusion, 1–2 µg/kg), or propofol (5 cases of 15 patients, intermittent intravenous infusion, 37.5–65 µg/kg/min)/remifentanyl (9 cases of 15 patients, intermittent intravenous infusion, 0.16–0.21 µg/kg/min)/*cis*-atracuronium (2 cases of 15 patients, 0.5 µg/kg/min).

Invasive blood pressure, ECG, end-tidal carbon dioxide concentration, pulse oximetry and temperature were monitored. During surgery, the mean arterial pressure (MAP) was remained at 60–70 mmHg, the body temperature at 36–37.5°C, and the heart rate at 80–100. In addition, the

depth of anesthesia was monitored by electroencephalographic Narcotrend Index (NI) (MT MonitorTechnik GmbH, Bad Bramstedt, Germany), while Narcotrend index was maintained between 36 and 60.

Intraoperative monitoring

Simultaneous motor and somatosensory evoked potential monitoring was performed with a Nicolet Endeavor CR 16 (Nicolet Biomedical Instruments, Madison, WI, USA).

SEP was elicited with 300-µS square-wave electrical pulses presented sequentially to posterior tibial nerve at a rate of 4.7 pulses/s. The stimulation intensity levels ranged from 20 to 40 mA. These levels were selected because they were well within the asymptotic portion of the SEP intensity versus amplitude plot for each patient. SEP was recorded by needle electrodes affixed to Cz and referenced to Fpz (international 10–20 system).

Transcranial electrical MEP was recorded over the tibialis anterior and Gastrocnemius muscle in the lower extremities following a brief high-voltage (300–800 V) anodal electrical stimulus train (pulse width = 50 µS; $N = 5$; interpulse interval = 2 ms). The multipulse stimulus was delivered between two saddle electrodes placed over the motor cortex regions at C3 (anode) and C4 (cathode) (international 10–20 system).

During the operation, SEP and MEP were monitored, and peak-to-peak amplitudes and onset latency were measured. A decrease more than 50% in amplitude or an increase more than 10% in latency was defined as abnormal SEP. Abnormal MEP changes were defined if MEP was measured 50% decrease of amplitude or 2 ms delay of latency.

Data analysis

Successful rates of both MEP and SEP monitoring in two different anesthetic groups were analyzed. The monitoring outcomes were summarized. A λ^2 test of Fisher exact test was used to compare the successful MEP recordings between two different anesthetic groups. $P < 0.05$ was considered statistically significant.

Results

Demographic data and anesthetic regimens for the patients are shown in Table 1. In this study, general anesthesia with TIVA was applied to 12 patients, while sevoflurane-based protocol was applied to 15 patients. Low-dose anesthesia was adjusted according to individual physiological variables intraoperatively. All patients are neurologically intact. The average duration of anesthesia was 4.62 ± 3.2 h (range

Table 1 Demographic and anesthetic dosing data for patient groups

Anesthetic type	Group P	Group S
No. of patients	12	15
Age (years)	6.23 ± 2.87	1.77 ± 0.79
No. of patients (<6 years)	3	15
No. of patients (>6 years)	9	0
Gender (male/female)	9/3	11/4
Mean end-tidal sevo (%)		1.42 ± 1.11
Mean propofol dose (μg/kg/min)	71.7 ± 23.2	17.7 ± 32.17
Mean operation time (h)	5.63 (2.5–8.5)	4.60 (2–8)
Diagnosis		
Congenital Scoliosis (CS) + fused rib	3	7
Semi-vertebral	5	8
CS/neurofibromatosis	4	0

from 2 to 8.5 h). No any post-operative neurological complication presented in these patients.

SEP signals were successfully recorded from 26 out of 27 patients with successful rate of 96%, while MEP signals were successfully recorded from all patients on either tibialis anterior or Gastrocnemius muscle. During each surgery, electrical stimulation intensity for MEP was adjusted along surgical duration to decrease depressant effect of anesthesia on MEP (Fig. 1). Table 2 presented monitoring outcomes of SEP and MEP in this series. In this study, there is no significant difference in successful rates between SEP and MEP monitoring ($P > 0.05$). As well, same successful rate in MEP was found in both two anesthetic techniques. Reliable monitoring was performed by electrophysiological testing, so that no wake-up test was performed in this series of patients.

Discussion

Multimodality monitoring with SEP and MEP has been widely applied in intraoperative spinal cord monitoring. However, transcranial electrical MEP was reported more difficult to be reliably measured than SEP, especially in children. The successful intraoperative MEP technique for children younger than 6 years old has not been well documented and reported so far. This prospective study applied low dose anesthesia and adjustable transcranial electrical stimulation to enhance the successful rate of MEP for intraoperative spinal cord monitoring.

Surgical treatment to adolescent scoliosis was recently reported at a risk of neurologic injury of 0.32% (14 out of 4,369 cases) by the Scoliosis Research Society Morbidity and Mortality Committee [16]. Even though there was no a large scale survey on the risk of neurologic injury during surgery for congenital scoliosis, it was assumed to be higher in younger children than adolescent scoliosis [17]. A recent report of the treatment of early-onset spinal deformity by the vertical expandable prosthetic titanium rib (VEPTR) device indicated that the common use of somatosensory evoked potentials alone without monitoring of motor evoked potentials led to the poor positive predictive value of intraoperative neuromonitoring [17].

In this study, SEP was successfully detected in most of patients, which support the previous report [18]. In contrary, reliable MEP monitoring was difficult to be obtained in very young children. However, the success rate of intraoperative MEP monitoring in this study is much higher than previous reports [14, 19–22]. In a previous study with 341 consecutive orthopedic procedures, the success rate for monitoring upper extremity MEP was 94.8%, while only 66.6% for the lower extremity [13]. The success rate was

Fig. 1 MEP signals along the key operation in surgery

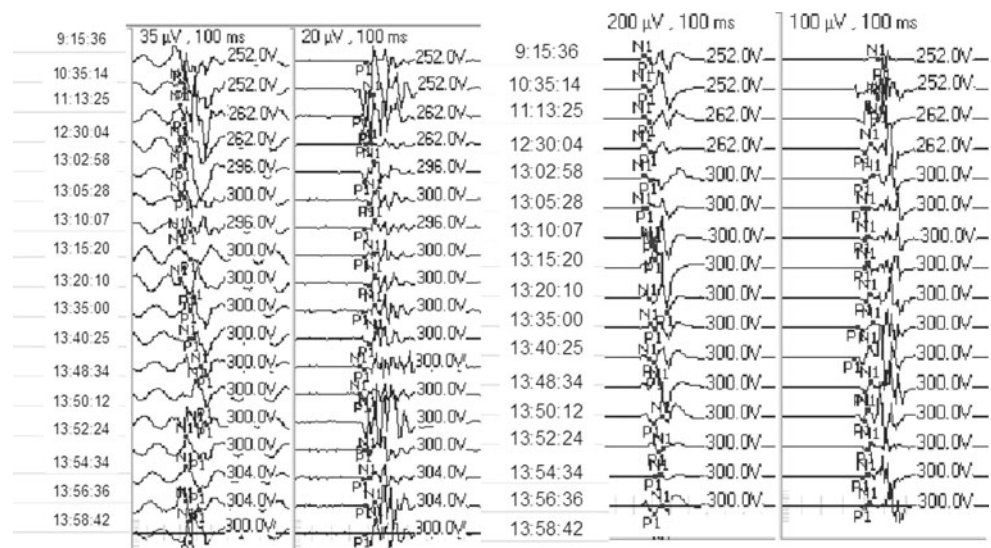


Table 2 Monitoring outcomes in all 28 patients

	Anesthesia types	
	Propofol-based protocol	Sevoflurane-based protocol
SEP monitoring	12	15
Successful cases	11	15
Successful rates	92%	100%
Intermittent loss	None	None
MEP monitoring	12	15
Successful cases	12	15
Successful rates	100%	100%
Intermittent loss	None	None
Wake-up test	None	None
Postoperative and follow-up neurologic outcome	No post-operative neurological complications	No post-operative neurological complications

even worse in neurologically normal children under 7 years and adults over 64 years [22]. The major reason for low successful rate of MEP recordings was assumed as the electrophysiologic maturation of the corticospinal tract is not complete until 11–13 years [22]. The improvement of MEP in children below 7 years by spatial or temporal facilitation [14, 19] may provide negative support to the hypothesis of the corticospinal tract immaturity. In a previous report, low-dose propofol can be effectively used as a supplement to ketamine-based anesthesia during intraoperative monitoring of myogenic MEP [23]. This protocol suggested our assumption that the main problem of low successful MEP monitoring in children is the anesthetic issue. In this study, we applied two kinds of anesthetic techniques with low concentration. The dosage of anesthesia was less than half of previous reported concentration. The results proved that the use of low dose anesthesia could help to improve the successful rate of intraoperative MEP recording.

One of questions regarding low dose anesthesia is the depth of anesthesia. In this study, supplement anesthesia with remifentanyl and midazolam can help to inhibit awareness under low dose propofol or Sevoflurane. We monitored intraoperative hypnotic state by the Narcotrend electroencephalogram and maintained the Narcotrend index between 36 and 60 during surgery. The Narcotrend EEG monitor can provide a computerized analysis of the EEG, calculate the processed EEG results and give a number, a NI ranging from 0 (very deep hypnosis) to 100 (awake). It was reported that electroencephalographic NI could be applied for monitoring anesthetic hypnotic depth in children and performed good prediction probability [24–26]. In addition, Narcotrend index ranging from 20 to 64 was thought to be reasonable general anesthesia depth. The results showed that the combination of multiple anesthetics

could provide satisfactory anesthesia for these patients. Another question regarding low dose anesthetic protocol is the safety of operation, especially the body movement that may bring disastrous consequences for children undergoing surgery. Therefore, the anesthetist should anticipate the changes of stress and stimulus induced by surgery and titrate intraoperative anesthetics to satisfy the need of surgery and neurologic monitoring. In addition, patient physiological variables (e.g. blood pressure, heart rate, airway pressure) and body movement should be closely monitored to achieve stable and smooth anesthesia management. To avoiding possible side effects in younger children due to prolonged propofol [24], the attending anesthesiologists prefer to use sevoflurane in the patient below 3 years of age, thus, the age of patients receiving combined sevoflurane and intravenous anesthesia (Group S) were significantly younger than patients receiving TIVA (Group P). Therefore, the outcome of neurologic monitoring and perioperative morbidities in two groups were not different because of the careful management of anesthesia.

Applying MEP monitoring in children, the possible ‘fade phenomenon’ of anesthetic factor on MEP should be taken big consideration. A previous study proved that a durational-dependent, depressant effect on MEP under anesthesia must be considered as one differentiates anesthetic-related trends from acute changes in MEP responses [25]. This effect of anesthesia would be much serious in children than adults. Therefore, stimulation increase gradually from 50 to 100% of the threshold intensity was performed in this study to amend possible anesthetic fade and avoid false positive findings.

Possible limitation to our study lies partly in small sample size. In the consecutive series of 27 young patients, there was no positive outcome to be able to evaluate the efficacy of intraoperative neurological monitoring.

Conclusion

In summary, MEP was successfully monitored during surgery in patients from 1 to 12 years of age. Either TIVA with propofol or sevoflurane-based mixture anesthesia protocol did not affect the successful recording of MEP, if low dose protocol applied. Although the anesthetic fade significantly inhibited MEP in a manner of durational-dependent, the use of gradually increasing stimulation could overcome this suppression. The proposed methods could help to improve the successful rate of MEP recording for intraoperative multi-modality neurology monitoring.

Conflict of interest None.

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