Spinal Cord Motor Evoked Potential Monitoring During Scoliosis Surgery and Perioperative Somatosensory Evoked Potentials Outcomes

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ABSTRACT

Background: MEP is the most appropriate technique to assess the functional integrity of the whole motor pathway, particularly during scoliosis surgery. Objectives: The object of this prospective study is to assess the impact of preoperative clinical, electrophysiological (EMG, NCV, SSEPs) studies and intra-operative recording of MEPs using multi-pulse transcranial electrical stimulation on the outcome of 15 operations adolescent idiopathic scoliosis. Methods: The selected 15 cases had diverse grades of scoliosis severity according to Lenke classification of adolescent idiopathic scoliosis (AIS). All patients were under the age of 18 years old (14.3±2.46), 10 females and 5 males. Preoperative clinical, routine laboratory, electrophysiological studies and intra-operative recording were done for all patients who met all study criteria. Post-operative and electrophysiological assessments were carried out for all cases. Patients with a history of epilepsy or skull fracture were excluded. Results: Post-operative follow up for all cases was continued for 6-month and revealed nonexistence of new motor deficits either clinically or electro-physiologically. This is owing to that the cases had normal preoperative studies (n=15) as well as intraoperative MEPs. Apart from considerable intra-operative transient MEP changes in two patients, no new EPs or clinical deficits were documented. Regarding post-operative SSEP, it remained unaltered and even it demonstrated better recovery in 7 patients, on top no complications were raised. Conclusion: All patients who had reproducible MEPs (100%) during the whole surgery procedures via APB, ADM, AH and TA recordings had had excellent clinical and electrophysiological outcomes. (Egypt J. Neurol. Psychiat. Neurosurg., 2009, 46(2): 345-350)

Key words: Adolescent idiopathic scoliosis, Motor evoked potential

INTRODUCTION

Trans-cranial electrical motor evoked potential (tce-MEPs) is widely acknowledged as one of the most appropriate techniques that assess the functional integrity of the whole descending motor pathways and detect spinal cord dysfunction during reversible stage of neuronal ischemia.¹²

The motor pathways are considered as the most vulnerable spinal cord areas to ischemic injury. Consequently, the need for intra-operative monitoring (IOM) in scoliosis surgery is justified by the risk of spinal cord compromise during insertion of pedicle screws, instrumentation and rod tightening, particularly in healthy young subjects with no preoperative deficits.³⁴

Intra-operative recording of sufficiently reproducible tce-MEP responses is influenced by anesthetics that depress synaptic conduction in motor pathways as well hypotension during surgery that lead to diminished blood loss.⁵⁶

By definition, adolescent idiopathic scoliosis (AIS) is a complex deformity of the spine, where the frontal, sagittal and horizontal planes exhibit displacement. So, Successful spinal cord monitoring
requires a team that includes spine surgeon, anesthetist and neurophysiologist in close alliance. This prospective study was aiming to assess the role of pre and postoperative SSEPs as well intra-operative tce-MEPs monitoring in prediction of spinal ischemia or injury during scoliosis surgery using hypotensive anesthesia technique. All patients had been followed up postoperatively for 6 months to assess surgical outcomes.

PATIENTS AND METHODS

This prospective study was accomplished at Sebea Military Hospital-Tripoli-Libya from Feb-2006 to Oct-2008 and enrolled fifteen AIS patients under 18 years old (14.3±2.46), 10 females and 5 males. All patients underwent intra-operative tce-MEPs (Medtronic Sofamor Danek USA) using hypotensive spine surgery technique (arterial catheter allowed continuous measurements of hemodynamical variables (heart rate (HR), mean arterial blood pressure (MAP)). All patients were followed up for 6 months.

Careful history taking, clinical examination and routine laboratory tests were elicited (complete blood count, urea, creatinine, fasting blood sugar, potassium, sodium, calcium, phosphorous, liver-function tests and ESR). Plain x-ray of the whole spine was done and analyzed for each patient. Magnetic resonance imaging (MRI) of the whole spinal cord was done for each patient. Table (1) shows Lenke's classification for all patients according to plain x-ray and MRI results. All enrolled patients had AIS type which was confirmed by clinical and spinal MRI investigations.

Enrolled patients had no medical conditions contraindicating transcranial electrical stimulation (e.g. Pacemaker, Implanted neurostimulator, Cochlear implant, Insulin pump, Aneurysm clip, Any metal or other implant in the patient’s head, Skull defects, History of strokes or seizure).

All patients were subjected to preoperative SSEPs (both tibial nerves recording 1-2 days prior to operation and median nerves as internal control), and NCV & EMG. The postoperative tibial and median SSEP was achieved within 5 days, as well two points 3 and 6-month SSEPs postoperatively were done. Tibial nerve SSEP latencies were P40, N50, P60 and N 75 but median nerve were N 20, P25 and N35. SSEP recordings of the tibial and median nerves were elicited by electrical stimulation (square-wave stimulation of 200 µs at a frequency of 3 Hz) at the ankle and wrist respectively (using surface electrodes; proximally placed cathodes, the respectively anode places 2 cm distally) using topas 4-channel EMG/NCV/EP system, trolley-based (Schwarzer, GmbH Bärmannstrasse 38 D-81245 München, Germany). Stimulation was chosen 2 to 3 times above the sensory threshold to induce reproducible SSEP responses.

Informed written consent was obtained in all patients to participate in this institutionally approved study.

Anesthesia was induced using propofol total intravenous anesthetic regimen 2 mg/kg (75-300 mcg/kg/min-TIVA) and sufentanil 1.5 mg/kg. Intubations of the trachea were facilitated with IV Mivacurium 0.1 mg/kg.

Muscle relaxation was monitored via electromyographically at the Abductor digiti minimi and Tibialis anterior muscles. Once the single twitch response amplitude improved to 25% of control, muscle relaxation was reserved with Mivacurium using a simple on-off closed-loop IV infusion system.

At least 15 min after the induction of anesthesia, three transcranial electrical stimulation responses were randomly recorded before skin incision.

Stimulating low impedance MEP 22 mm needle electrodes were implanted anterior to C3-C4 (International 10–20 system). Stimulation output was increased from 50 mA in steps of 5 mA until a reproducible MEP was elicited and then the intensity was increased and fixed at 10% above this threshold intensity to obtain a supramaximal MEP response. Each stimulator was capable of delivering a maximum output of 100 mA (200 mA in total) (Medtronic Sofamor Danek USA).

Filter settings and input impedance of stimulating and recording electrodes were set according to manufacture instructions. Peak to peak amplitudes (between the two largest peaks opposite in polarity) and onset latency were utilized for all MEP responses.
MEP recordings were obtained with electrode twisted pair 22 mm disposable subdermal needles (Medtronic Sofamor Danek USA) in the Abductor pollicis brevis (APB), Abductor digiti minimi (ADM), Abductor hallucis (AH) and Tibialis anterior (TA) bilaterally because the optimal spinal cord evaluation should include above and below the areas of concern.

Within each patient, 10 consecutive baseline MEPs obtained before insertion of pedicle screws. During insertion of pedicle screws and instrumentation, a 50% reduction of MEP amplitude or 10% prolongation of latency was brought to the surgeon’s attention.

MEPs were recorded from upper arm (Arm controls facilitate differentiation between systemic alterations and focal neurologic compromise) and leg following this protocol 1. Constant voltage stimuli were delivered through a bipolar surface stimulator, 2. The anode was positioned over the desired scalp location and the cathode 2.5 cm anterior to the anode, 3. Low impedances were maintained, and 4. The stimulus intensity was over the theoretical motor representation area.

All patients were kept normothermic with a warming blanket. Hypotensive anesthesia was maintained throughout the operation.

Statistical analysis of data is given as mean±SD. Continuous data were analyzed by the independent t test, as appropriate. P value of less than 0.05 was regarded as statistically significant (Medtronic Sofamor Danek USA).

### RESULTS

Nine patients had main thoracic curve (type 1), 3 cases had double thoracic curve (type 2), two patients had double major and one case had thoracolumbar/lumber curve (type 5) (table 1). The mean and SD of Cobb angle in all enrolled patients were 55±10° with no outlier cases. Fifteen patients had asymptomatic AIS that were discovered accidentally, or during the course of school screen or during a medical check-up for cosmetic purpose.

MEPs were successfully elicited from all patients with ADM; APB; AH; TA recordings bilaterally (table 2). There was also no significant difference between all extremities MEP amplitudes (table 2) (P >0.5). Apart from two patients, none of other patients had MEP amplitude or latency changes exceeding our set limits so as to require immediate surgical attention during and after pedicle screw insertion and spinal instrumentation. There is no difference between pre and postoperative results of SSEPs of all enrolled patients.

There were no postoperative complaints of seizures, headache, infection or skin burns; all patients had normal neurologial examination. Apart from considerable intra-operative transient MEP changes in two patients, no new EPs or clinical deficits were documented. Regarding post-operative SSEP, it remained unaltered and even it demonstrated better recovery in 7 patients, on top no complications were raised.

<table>
<thead>
<tr>
<th>Type</th>
<th>Proximal Thoracic</th>
<th>Main Thoracic</th>
<th>Thoracolumbar/Lumber</th>
<th>Curve Type</th>
<th>Patients' No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Non-structure</td>
<td>Structure</td>
<td>Non-structure</td>
<td>Main Thoracic (MT)</td>
<td>9</td>
</tr>
<tr>
<td>I</td>
<td>Structure</td>
<td>Structure</td>
<td>Non-structure</td>
<td>Double Thoracic (DT)</td>
<td>3</td>
</tr>
<tr>
<td>III</td>
<td>Non-structure</td>
<td>Structure</td>
<td>Structure</td>
<td>Double Major (DM)</td>
<td>2</td>
</tr>
<tr>
<td>V</td>
<td>Non-structure</td>
<td>Non-structure</td>
<td>Structure</td>
<td>Thoracolumbar/Lumber (TL/L)</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2. Summary of MEP results in AH and TA muscles.

<table>
<thead>
<tr>
<th>IOM-tec-MEP</th>
<th>ADM</th>
<th>APB</th>
<th>TA</th>
<th>AH</th>
</tr>
</thead>
</table>

347
<table>
<thead>
<tr>
<th>Range (mV)</th>
<th>20-70</th>
<th>25-74</th>
<th>22-78</th>
<th>26-75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean amplitude (mV)</td>
<td>44.76</td>
<td>43.47</td>
<td>46.89</td>
<td>42.69</td>
</tr>
<tr>
<td>SD</td>
<td>16.1</td>
<td>15.4</td>
<td>17.5</td>
<td>16.9</td>
</tr>
</tbody>
</table>

ADM: abductor digit minimi; APB: abductor pollis brevis; AH: abductor hallucis; TA: tibialis anterior; SD: Standard deviation.

Fig. (1): This figure displays the difference between pre and postoperative results of SSEPs of all enrolled patients that revealed insignificant differences at all recording points and also at two-point follow up results (data not shown).
Fig. (2): A, demonstrated plain x-ray of 17 yo boy with Cobb's angle 67º dorsal scoliosis. B picture showed EMG record and C&D pictures showed tce-MEPs during surgery.

DISCUSSION

The current study confirms the safety of tce-MEPs as an alternative to wake up test, only few randomized trials assessing the clinical outcome of combined intraoperative SSEPs and MEPs have been published but pre and post-operative long term outcome assessments of SSEPs in scoliosis surgery still need extensive researches.

A satisfactory recording of MEP was possible in all patients but with interindividual variability of amplitude. In one patient, MEP amplitude showed more than 40% reduction in the four-extremity muscles, with correction of anesthesia protocol, MEP amplitude regained its baseline level.6,10-12

In the second case the amplitude of lower limb muscles revealed more than 50% decrement and with surgical site adjustment via release of correction degree, the amplitude tuned up and at the same time wake-up test (which has many drawbacks such as late diagnostic information, time-consuming procedure and distressing for the patient) was normal.12,13 Fortunately, both patients showed normal clinical and electrophysiological results. The postoperative SSEPs (latency and amplitude) were not significantly changed in comparison to preoperative recordings (p<0.05) that denoted no influence of spine surgery or other invasive interventions on spinal cord function in our patients. IOM was accurate and consistent with short term follow up concerning clinical and electrophysiological assessments.14,15

Besides the relative differences between pre- and postoperative SSEP that showed non significant difference, moderate latency improvement in 7 cases was obtained. Additionally, the perpetuation of spinal cord function can be accepted by SSEP in consecutive follow-up assessments which can be beneficial in particular patients who eventually may develop neurological disorders not related to spine deformity correction.16-18

There was no history of headache, seizure or motor deficit postoperatively; all patients had normal postoperative neurological assessment and electrophysiological results. So, Intra-operative MEP monitoring is useful for improving scoliosis surgery outcomes.19,20

Conclusion

In brief, all patients who had reproducible MEPs (100%) during the whole surgery procedures via APB, ADM, AH and TA recordings had had excellent clinical and electrophysiological outcomes. Although not widely evaluated, pre and postoperative SSEPs could be applied complementary to clinical examinations, as capable tool to predict and confirm the worsening of spinal cord function due to surgical or systemic disorder but not as improvement predictor.

REFERENCES


الملخص العربي

متابعة النخاع الشوكي أثناء عمليات اعوجاج فقرات الظهر عن طريق الاستحثاث الحركي والحسي

خلفية البحث: يعتبر الاستحثاث الحركي للنخاع الشوكي أثناء عمليات الاعوجاج لل الفقرات الظهرية من أهم الطرق للتأكد من

سلامة النخاع الشوكي أثناء العمليات.
الهدف من البحث: طرح سؤال عن أهمية مقارنة الاستعانات الحسية قبل وبعد عمليات الاعوجاج في العمود الفقري والاستماتات الحركي أثناء العمليات الجراحية باستخدام أسلوب خاص في التخدير.

الطريقة البحثية: تم اختيار 15 مريض بعانون من اعوجاج أولوي في الفترات الظهرية وبدراجات مختلفة طبقاً إلى مقياس لتك تقيم الاعوجاج. وتم عمل استمارات حسية قبل العملية ومقارنتها بما بعد العملية بالنسبة للاستماتات الحركي فتم عمله أثناء العملية الجراحية باستخدام طريقة تدخير خاص مثلا هذه الاليات.

النتائج: من خلال هذه الدراسة تم إثبات أن المتابعة باستخدام الاستماتات الحركي أكثر أماناً للمرضي وذلك بالتشخيص المبكر لأي غلطة في التغذية الشريانية للنخاع الشوكي أثناء العمليات الجراحية وقد أظهرت النتائج عن تحسن في الاستماتات الحسية في 7 مرضى فيما بعد العمليات.

الخلاصة البحثية: وقد خلصت هذه الدراسة أنه يجب استخدام الاستماتات الحركي في جميع العمليات الجراحية الخاصة بالنخاع الشوكي وذلك لتفادي الإصابة غير ممكّنة التثبيت للنخاع الشوكي.