



# Neuromuscular blockade used in conjunction with motor evoked potential spinal cord monitoring and blood loss during corrective paediatric scoliosis surgery

Erden Ali\*; Yasmin Mahmoud; Geraldine Edge; Jan Lehovsky

Spinal Deformity Unit, Royal National Orthopaedic Hospital, Brockley Hill, Stanmore, Middlesex, HA7 4LP UK

**\*Corresponding Author(s): Erden Ali**

Spinal Deformity Unit, Royal National Orthopaedic Hospital, Brockley Hill, Stanmore, Middlesex, HA7 4LP UK  
Tel: +44 (0)1223 332100; Email: erden@doctors.org.uk

## Abstract

**Study Design:** A Retrospective Database Study.

**Objective:** To establish whether spinal cord IOM with specific regard to transcranial electrical Motor Evoked Potentials (MEPs) and absent use of associated neuromuscular blocking agents led to increased peri-operative blood loss.

**Summary of Background Data:** Somatosensory-Evoked Potentials (SEPs) and Motor-Evoked Potentials (MEPs) are the commonly used intraoperative monitoring modalities for corrective scoliosis surgery. There is a paucity of evidence within the literature looking at the potential association between their use and subsequent effect on blood loss.

**Methods:** We retrospectively examined 126 paediatric patients who underwent posterior instrumented fusion for scoliosis between 2010 and 2014 with both somatosensory evoked potential (SEP) and MEP monitoring combined or SEP monitoring alone. The same surgeon and anaesthetic team were used in all cases. Patient age, level correction and blood loss were recorded.

**Results:** 79 patients met our selection criteria. Level correction within the SEP and MEP group spanned an average of 12.78 (Range 10-16) versus 13.03 (range 5-18) in the SEP group alone. Within the SEP and MEP monitoring group average blood loss was calculated at 707.30 (Range 200-1400) mls and 740.25mls (Range 250- 1700) in the SEP monitoring alone group. There was no statistical difference between age nor the amount of level correction between the two groups ( $p = 0.25$  and  $p = 0.23$  respectively). Less blood loss occurred in the SEP and MEP group though this was not statistically significant ( $p = 0.84$ ).

**Conclusion:** SEP monitoring and hence continuous perioperative use of muscle relaxation medication did not decrease blood loss during instrumented corrective spinal deformity surgery when age and level correction was accounted for.

Received: Apr 02, 2018

Accepted: Aug 05, 2018

Published Online: Aug 10, 2018

Journal: Journal of Orthopedics and Muscular System

Publisher: MedDocs Publishers LLC

Online edition: <http://meddocsonline.org/>

Copyright: © Ali E (2018). *This Article is distributed under the terms of Creative Commons Attribution 4.0 International License*



**Cite this article:** Ali E, Mahmoud Y, Edge G, Lehovsky J. Neuromuscular blockade used in conjunction with motor evoked potential spinal cord monitoring and blood loss during corrective paediatric scoliosis surgery. *J Orthop Muscular Syst.* 2018; 1: 1002.

## Introduction

Spinal cord monitoring is an essential component of the surgical management of spinal deformity when minimising iatrogenic spinal cord injury. This peri-operative monitoring modality was first utilised during the 1970s with the introduction of somatosensory evoked potential monitoring for corrective scoliosis surgery (Figure 1) [1]. Since the advent of Motor Evoked Potential monitoring (MEP) (Figure 2), it has been used in conjunction with Somatosensory Monitoring (SEP). The protective intra-operative aspects of this modality are well documented with greater sensitivity and specificity of spinal cord damage, with specific regard to corticospinal pathways [2,3]. Prior to the introduction of MEP monitoring, corticospinal tract integrity was primarily assessed utilising the Stagnara wake up test, though this method does not permit continuous assessment and possesses obvious drawbacks. Whilst patients do not feel any pain during this test and have no recollection of its performance due to amnesic effects, it introduces significant surgical delay, lacks the ability of continuous and frequent assessment of neural cord function and permits a significant period of time to have elapsed with regards injury, detection and potential treatment. Its use is dependent on patients possessing cognitive function and no hearing deficits which can prove difficult when taking into account patients who present with paediatric spinal deformity can be complicated by other neurological deficit.

A stable anaesthetic depth is essential for reliable intra-operative monitoring interpretation. When 60% nitrous oxide and isoflurane less than 0.5 of the Minimum Alveolar Concentration (MAC) are used concurrently, accurate SEP assessment and monitoring is permitted. However, in 60% nitrous oxide, end-tidal isoflurane concentrations larger than 0.87 render MEP monitoring too inconsistent for reliable interpretation [4]. Neuromuscular Blockade (NMB) decreases and may abolish MEP amplitude and hence its use, requires further thought.

Both clinical and experimental data examining the monitoring and subsequent interpretation of intraoperative MEPs have demonstrated that elicited responses are very sensitive to suppression by neuromuscular relaxation. This is due to abolition of myogenic MEP responses [5] and hence neuromuscular blockade cannot be utilised during MEP monitoring. Whilst the benefits of evaluating specific corticospinal tract integrity in this manner are well documented, the consequent effect of the lack of use of neuromuscular blockade on myotomal blood loss has not been examined and a comparison of these factors does not exist within the literature.

## Patients and methods

We retrospectively examined the records of 126 paediatric patients who underwent single stage posterior instrumented fusion for scoliosis from January 2011 to December 2013. A list of patients who had undergone surgical correction prior to implementation of MEP monitoring and those who had undergone correction with MEP monitoring, was obtained from the Neurophysiology Department. Operative notes and anaesthetic charts were examined and blood loss compared between those who had peri-operative SEP and MEP monitoring and those with SEP monitoring alone. All surgery had been undertaken by the same surgeon and anaesthetic team. Those treated with tranexamic acid were excluded from the study as were those without documentation of level correction, blood loss and age. Pre-operatively whole spine Postero-Anterior (PA), lateral and left and right bending radiographs were taken (Figures 3 & 4).

## Surgical technique

Patients were positioned prone on the operating table as per a posterior approach to the spine. A longitudinal midline incision was made permitting surgical access to the relevant surgical vertebral levels. Diathermy of fascia was then performed to the spinous processes with spinous ligament removal and periosteal stripping with a Cobb Elevator. The Universal Spinal System Low Profile Throacolumbar Posterior Fixation System (Synthes, Inc. U.S.A.) was used in all cases. Low profile pedicle screws were inserted accordingly under image intensification with cranial placement of two laminar hooks. Rods were cut to length and inserted with sagittal and rotational reduction, followed by decortication of spinous processes and bilateral facetectomies along the length of the spine (Figure 5). Autologous bone graft with the addition of 20mls demineralised bone matrix. No drain was inserted post-operatively. Closure was performed in layers: 1 Vicryl continuous to fascia and adipose layers, 2/0 Vicryl subcutaneous fat, 3/0 vicryl to skin. A standard dressing was applied (Mepore<sup>®</sup>, Mölnlycke Health Care, UK) with pressure.

## Anaesthetic technique

A uniform anaesthetic regimen was employed for each respective group. Differences existed at induction though this had no effect on spinal cord monitoring data with spinal exposure. Anaesthesia was induced with intravenous 1% propofol in all patients. In patients who had monitoring of SEPs only, intubation was facilitated using fentanyl and vecuronium and anaesthesia was maintained using either sevoflurane or isoflurane in 40% oxygen in air. Further boluses of vecuronium were used as required. In patients who had both MEP and SEP monitoring intubation was facilitated using fentanyl and low dose (0.5mg/kg) vecuronium and anaesthesia was maintained using 2% propofol infusion. In both groups of patients analgesia was achieved using remifentanyl 50mcg/ml infusion. Mean arterial pressure was maintained at 60-70mmHg.

## Neuromuscular monitoring

SEPs were recorded on a Nihon Kohden Neuromaster system (Japan) with subdermal corkscrew electrodes (AMBU<sup>®</sup>, Copenhagen) from the cranial vertex and occipital region following stimulation of the tibial nerves at the ankles. Following stimulation of tibial nerves at the popliteal fossae and ulnar nerves at the wrists, SEPs were monitored from the occiput alone.

Using the same equipment, MEPs were recorded from surface electrodes (AMBU<sup>®</sup>) on quadriceps, tibialis anterior and gastrocnemius muscles with an upper limb control. This upper limb control was the first dorsal interosseous and followed transcranial electrical stimulation using a digitimer stimulator. The following stimulation parameters were used as standard: a train of 4 with an interstimulus interval between peripheral nerves and transcranial magnetic stimuli of 2.0-3.0ms, using 300-600V.

## Statistical analysis

Statistical analysis was performed using JMP version 12.0.1 (SAS Institute Inc, North Carolina, USA).

Linear regression analysis was used to generate least square means estimates and standard error and a post-hoc analysis of variance was used to compare these. Age, correction level and blood loss were compared between the SEP and MEP monitoring group and the SEP monitored group alone. For all tests the alpha level was set at .05; corresponding to a level of signifi-

cance of  $p < 0.05$ .

## Results

### Somatosensory and motor evoked potential monitoring and absent neuromuscular blockade

In the combined SEP and MEP group 38 patients were included, 36 of these had adolescent idiopathic scoliosis and 2 presented with neuromuscular scoliotic disease. The average age was 14.54 years (range 12-18 years), with the correction spanning an average of 12.78 levels (range 10-16). An average of 707.30mls of blood was lost peri-operatively.

### Somatosensory monitoring and neuromuscular blockade

41 patients were included, 34 of these presented with Adolescent Idiopathic Scoliosis, 6 possessed neuromuscular disease and 1 patient presented with congenital deformity as an aetiology for scoliotic deformity. The average age of these patients was 15.00 years (range 12-18 years) with the correction spanning an average of 13.03 levels (range 5-18). Average blood loss was 740.25mls.

Within both groups, no cases were abandoned peri-operatively for loss of spinal cord monitoring and no neuromuscular complications were encountered post-operatively.

There was no statistical difference between the age of the patients between the SEP and MEP monitoring group and the SEP monitoring alone group ( $p = 0.25$ ). With regards operative level correction, no statistically significant difference existed ( $p = 0.23$ ). With regards to blood loss, whilst less blood loss occurred in the SEP and MEP group when compared with the SEP group alone, this was not statistically significant ( $p = 0.84$ ).

Within the combined SEP and MEP monitoring group, when compared, no statistically significant difference existed between level correction and age ( $p = 0.91$ ) nor age and blood loss ( $p = 0.07$ ) though an older age and heavier weight did indeed correlate with greater blood loss. Within the SEP alone group, no statistically significant difference existed between level correction and age ( $p = 0.90$ ) nor age and blood loss ( $p = 0.09$ ) though, as in the combined SEP and MEP group, an older age did indeed correlate with greater blood loss.

In both groups, level correction was not compared with blood loss as it has long been established that increased level correction does indeed lead to statistically greater blood loss.

## Discussion

Corticospinal tract integrity is not examined by somatosensory evoked potential monitoring. Hence, variations in peri-operative motor evoked potentials provide greater reliability in postoperative motor deficit detection [6]. Evidence exists within the literature of cases where permanent post-operative deficit has occurred in the presence of unchanged SEP monitoring alone and the absence of signal changes within this modality which failed to validate alarm criteria [7].

Corticospinal tract injury and subsequent motor deficit is either via mechanical trauma or ischaemia. Residing within different anatomical regions, corticospinal tracts and dorsal columns retain dissimilar vascular zones. The posterior spinal arteries provide the main vascular supply to dorsal columns whilst it is the anterior spinal artery that is responsible for the majority of supply to anterior horn cells and both anterior and lateral corticospinal tracts. Passing through adjacent vertebral

osseous rings, radiculomedullary arteries may be compressed or stretched during scoliosis surgery resulting in ensuing ischaemic damage or infarction. Such injuries may only modify the anterolateral funiculus, if this occurs, variations in intra-operative spinal cord monitoring will only occur in MEP data and not SEP data.

Blood loss is an obvious concern during paediatric scoliosis surgery, with its determinants being previously investigated within the literature [8]. Whilst many have produced data offering reasons for greater blood loss, the effect of neuromuscular blocking agents and the presumed associated reduction in blood loss is purely anecdotal with some evidence in the literature suggested an advocated avoidance of neuromuscular blocking agent use during intraoperative neurophysiological monitoring [9].

The benefits of combined intraoperative SEP monitoring used in conjunction with MEP measurement are well documented in the prevention of spinal cord injury. Some have shown this combined approach provides a greater sensitivity and improved positive and negative predictive values than single modality techniques [10]. It is not only established injury detection where IOM has been used but imminent iatrogenic spinal cord injury. In a study by Schwartz et al. [11], transcranial motor evoked potential monitoring was seen to be extremely sensitive to alterations in spinal cord blood flow as a result of vascular insult or hypotension. The authors from this study also stated that prompt identification of imminent iatrogenic cord injury was permitted due to earlier detection of variations of MEPs than SEPs.

Whilst others have demonstrated the importance of intraoperative neurophysiological monitoring for both SEP and MEP monitoring [3,12], recent evidence has established the importance of MEP monitoring. This has been validated on several occasions with pedicle screw placement leading to a loss of MEP data without any changes seen in SEP recordings [13]. This permitted earlier injury prevention and whilst a postoperative motor deficit was seen, early intervention led to a full recovery due to the higher sensitivity of MEP monitoring [14].

These studies underscore the advantage of monitoring the spinal cord motor tracts directly by recording transcranial electric motor evoked potentials in addition to somatosensory evoked potentials. Transcranial electric motor evoked potentials are exquisitely sensitive to altered spinal cord blood flow due to either hypotension or a vascular insult. Moreover, changes in transcranial electric motor evoked potentials are detected earlier than are changes in somatosensory evoked potentials, thereby facilitating more rapid identification of impending spinal cord injury. This however should not suggest that SEP data does not provide adequate monitoring of spinal cord injury with robust meta-analysis showing high sensitivity and specificity in diagnosis of spinal cord injury [15].

Whilst IOM has greatly improved the safety of spinal surgery, episodes of false negative events are documented. An example by Modi et al. [16] demonstrated that post-operative paraplegia can occur without peri-operative changes in MEP activity.

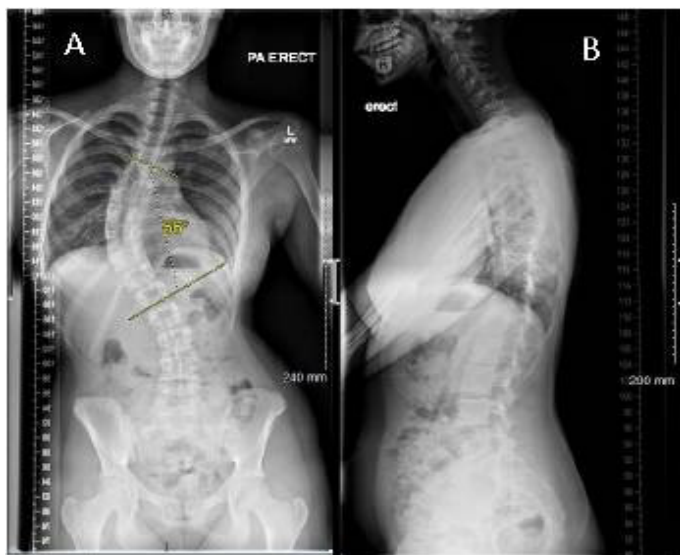
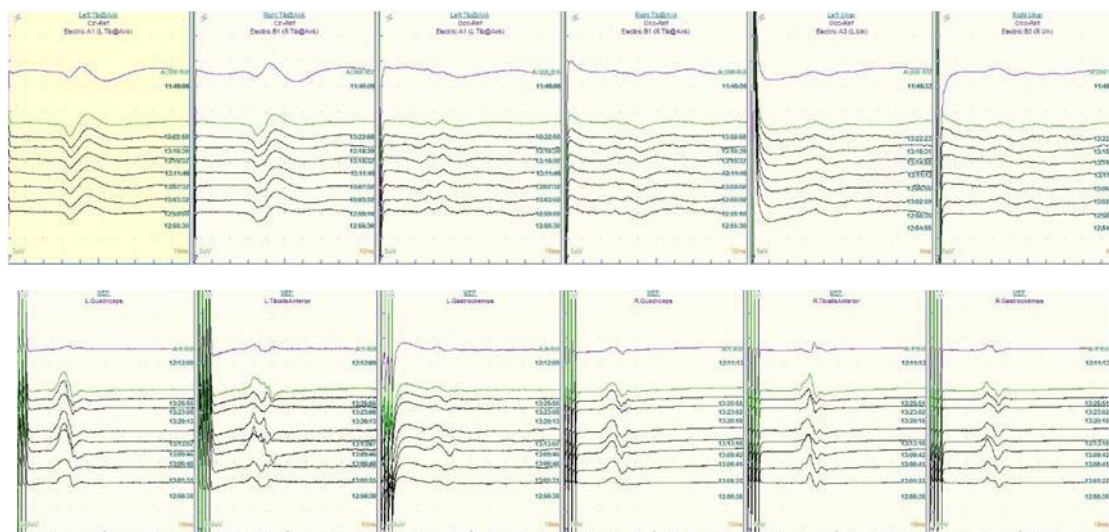
Whilst MEP has become the gold standard for spinal cord monitoring, it does not come without its drawbacks. This modality does permit assessment of the spinal cord throughout the procedure: MEP acquisition is obtained recurrently at intervals and is not a true continuous assessment. They are also more

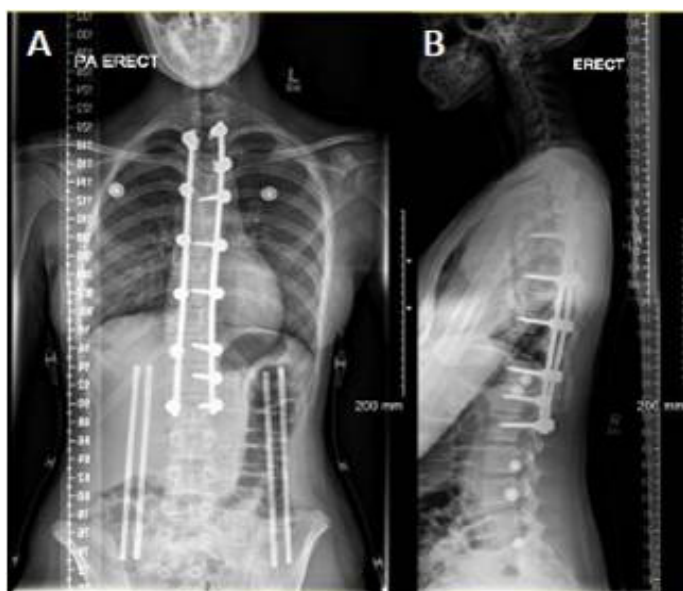
difficult to obtain technically and possess lower success rates when compared to SEPs. Data has shown lower success rates when trying to acquire MEPs with 94.8% and 66.6% success in the upper and lower limbs respectively when measuring motor evoked potentials and 98% and 93% in the upper and lower limbs respectively when looking at SEP data [17]. The same authors established that if MEP signal acquisition is difficult to obtain pre-operatively, the ability to then acquire these signals thereafter can be reduced to a success rate of 39% which can lead to unnecessarily abandoning the procedure itself. Earlier in this document, the anaesthetic regimen that patients within this study underwent was explained and several anaesthetic considerations exist when embarking on intra-operative spinal cord monitoring. When MEP monitoring is undertaken, Total Intra-Venous Anaesthetic (TIVA) is employed using propofol and remifentanyl infusions and nitrous oxide and volatile agents and longer neuromuscular blockade is avoided. This in itself can pose greater difficulty for the surgeon due to continued patient movement from intraoperative MEP stimulation during the procedure. Volatile anaesthetic agents decrease the available pool of motor unit recruitment and hence interfere with MEP recruitment due to inhibition of I wave interneuron generators at the level of the cerebral cortex and anterior horn cells. Peripheral motor response propagation is indirectly responsible for generation of these impulses.

Whilst we examined blood loss within scoliosis corrective surgery, we are aware that chemical measures do exist that can lead to a significant reduction in blood loss [18,19]. None of the patients included within this study were treated with these agents such as tranexamic acid.

Multimodal intraoperative spinal cord monitoring has been shown to increase sensitivity and specificity for detecting changes in neurological status. This has led to immediate intra-operative strategy modification and subsequent prevention of irreversible neurological deficits [20]. Whilst their use has led to dis-satisfaction by some surgeons regarding the specific use of MEP monitoring and hence a lack of neuromuscular blockade and subsequently perceived increased blood loss, our study supports the evidence for a combined approach to intra-operative spinal cord monitoring. With regards to an absence of neuromuscular blockade and linked increase in blood loss when age and level correction have been accounted for, our study did not discover a statistically significant difference in blood loss when those undergoing corrective spinal deformity surgery for scoliosis were monitored using combined MEPs and SEPs and SEPs alone.

Figures





## References

- Nash CL Jr, Lorig RA, Schatzinger LA, Brown RH. Spinal cord monitoring during operative treatment of the spine. *Clin Orthop Relat Res.* 1977; 100-105.
- Gonzalez AA, Jeyanandarajan D, Hansen C, Zada G, Hsieh PC. Intraoperative neurophysiological monitoring during spine surgery: a review. *Neurosurg Focus.* 2009; 27: E6.
- Nuwer MR, Emerson RG, Galloway G, Legatt AD, Lopez J, Minahan R, et al. Evidence-based guideline update: intraoperative spinal monitoring with somatosensory and transcranial electrical motor evoked potentials: report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology and the American Clinical Neurophysiology Society. *Neurology.* 2012; 78: 585-589.
- Pelosi L, Stevenson M, Hobbs GJ, Jardine A, Webb JK. Intraoperative motor evoked potentials to transcranial electrical stimulation during two anaesthetic regimens. *Clin Neurophysiol.* 2001; 112: 1076-1087.
- Yamamoto Y, Kawaguchi M, Hayashi H, Horiuchi T, Inoue S, Nakase H, et al. The effects of the neuromuscular blockade levels on amplitudes of post tetanic motor-evoked potentials and movement in response to transcranial stimulation in patients receiving propofol and fentanyl anesthesia. *Anesth Analg.* 2008; 106: 930-934.
- Hsu B, Cree AK, Lagopoulos J, Cummine JL. Transcranial motor-evoked potentials combined with response recording through compound muscle action potential as the sole modality of spinal cord monitoring in spinal deformity surgery. *Spine (Phila Pa 1976).* 2008; 33: 1100-1106.
- Jones SJ, Buonamassa S, Crockard HA. Two cases of quadriplegia following anterior cervical discectomy, with normal perioperative somatosensory evoked potentials. *J Neurol Neurosurg Psychiatry.* 2003; 74: 273-276.
- Shapiro F, Sethna N. Blood loss in pediatric spine surgery. *Eur Spine J.* 2004; 13: S6-17.
- Sloan TB. Muscle relaxant use during intraoperative neurophysiological monitoring. *J Clin Monit Comput.* 2013; 27: 35-46.
- Hyun SJ, Rhim SC. Combined motor and somatosensory evoked potential monitoring for intramedullary spinal cord tumor surgery: correlation of clinical and neurophysiological data in 17 consecutive procedures. *Br J Neurosurg.* 2009; 23: 393-400.
- Schwartz DM, Auerbach JD, Dormans JP, Flynn J, Drummond DS, Bowe JA, et al. Neurophysiological detection of impending spinal cord injury during scoliosis surgery. *J Bone Joint Surg Am.* 2007; 89: 2440-2449.
- Samdani AF, Bennett JT, Ames RJ, Asghar JK, Orlando G, Pahys JM, et al. Reversible Intraoperative Neurophysiologic Monitoring Alerts in Patients Undergoing Arthrodesis for Adolescent Idiopathic Scoliosis: What Are the Outcomes of Surgery? *J Bone Joint Surg Am.* 2016; 98: 1478-1483.
- Jahangiri FR, Sheryar M, Al Behairy Y. Early detection of pedicle screw-related spinal cord injury by continuous intraoperative neurophysiological monitoring (IONM). *Neurodiagn J.* 2014; 54: 323-337.
- Neira VM, Ghaffari K, Bulusu S, Moroz PJ, Jarvis JG, Barrowman N, et al. Diagnostic Accuracy of Neuromonitoring for Identification of New Neurologic Deficits in Pediatric Spinal Fusion Surgery. *Anesth Analg.* 2016; 123: 1556-1566.
- Thirumala PD, Cheng HL, Loke YK, Kojo Hamilton D, Balzer J, Crammond DJ. Diagnostic accuracy of somatosensory evoked potential monitoring during scoliosis fusion. *J Clin Neurosci.* 2016; 30: 8-14.
- Modi HN, Suh SW, Yang JH, Yoon JY. False-negative transcranial motor-evoked potentials during scoliosis surgery causing paralysis: a case report with literature review. *Spine (Phila Pa 1976).* 2009; 34: E896-900.
- Chen X, Sterio D, Ming X, Para DD, Butusova M, Tong T, et al. Success rate of motor evoked potentials for intraoperative neurophysiological monitoring: effects of age, lesion location, and preoperative neurologic deficits. *J Clin Neurophysiol.* 2007; 24: 281-285.
- Wang M, Zheng XF, Jiang LS. Efficacy and Safety of Antifibrinolytic Agents in Reducing Perioperative Blood Loss and Transfusion Requirements in Scoliosis Surgery: A Systematic Review and Meta-Analysis. *PLoS ONE.* 2015; 10: e0137886.
- McNicol ED, Tzortzopoulou A, Schumann R, Carr DB, Kalra A. Antifibrinolytic agents for reducing blood loss in scoliosis surgery in children. *Cochrane Database Syst Rev.* 2016; 19: 9.
- Feng B, Qiu G, Shen J, Zhang J, Tian Y, Li S, et al. Impact of multimodal intraoperative monitoring during surgery for spine deformity and potential risk factors for neurological monitoring changes. *J Spinal Disord Tech.* 2012; 25: E108-114.