Iraqi JMS

Published by College of Medicine, Al-Nahrain University
P-ISSN 1681-6579
E-ISSN 2224-4719
Email: iraqijms@colmed.nahrainuniv.edu.iq
http://www.colmed-alnahrain.edu.iq
http://www.iraqijms.net\
Iraqi JMS 2025; Vol. 23(1)

Evaluation of Intraoperative Somatosensory Evoked Potentials During Spine Surgery for Scoliosis

Amrah M. Khudhur[1] *PhD*, **Ali F. Al-Hashimi**[2] *PhD,* **Mohammed U. Umara**[3] *MSc*

[1]Dept. of Physiology, College of Medicine, Tikrit University, Tikrit, Iraq, [2]Dept. of Physiology, College of Medicine, Al-Nahrain University, Baghdad, Iraq, [3]Dept. of Neurophysiology, Erbil Teaching Hospital, Erbil, Iraq

Abstract

Background In scoliosis surgery, intraoperative somatosensory evoked potential (SSEP) monitoring has reduced the incidence of postoperative neurologic deficits. Many intraoperative environmental and systemic factors affect the amplitude and latency of SSEP waves during surgery.

Objective To assess the role played by SSEP during spinal surgery in preventing postoperative neurologic deficits.

Methods Pre-, intra- and postoperative tibial SSEP recorded in 51 patients with scoliosis undergoing surgical correction were analyzed. Recorded parameters include the P37 and N45 latencies and amplitudes.

Results The intraoperative tibial SSEP latencies were significantly prolonged and intraoperative amplitudes were significantly reduced in comparison to baseline recordings. There was highly significant increase in the mean latency of alarm readings of tibial P37 and N45 waves from baseline. Likewise, there was statistically highly significant decrement in the mean amplitude of the alarm readings of tibial P37 and N45 wave from baseline. Pre- and postoperative latencies and amplitudes were compared; the differences were not significant.

Conclusion The intraoperative SSEP neuromonitoring is valuable in the prevention of neurological injury during surgical procedures.

Keywords Intraoperative monitoring, somatosensory evoked potential, scoliosis, total intravenous anesthesia

Citation Khudhur AM, Al-Hashimi AF, Umara MU. Evaluation of intraoperative somatosensory evoked potentials during spine surgery for scoliosis. Iraqi JMS. 2025; 23(1): 83-91. doi: 10.22578/IJMS.23.1.10

List of abbreviations: EMG = Electromyography, IOM = Intraoperative monitoring, SSEP = Somatosensory evoked potential, Tc-MEP = Transcranial motor evoked potential, TIVA = Total intravenous anesthesia

Introduction

Scoliosis is a three-dimensional anatomical deformity of the spine, mainly including variations in alignment of the sagittal plane, deviations in coronal plane, and vertebral rotation in the axial plane. It is a relatively common problem in the general community [(1)].

Intraoperative monitoring (IOM) is a routine method to ensure integrity of spinal tracts during scoliosis surgery. Somatosensory evoked potential (SSEP) monitoring is widely used in operations with highly risks of spinal cord damage [(2)].

SSEP is the monitoring of the dorsal column integrity. It is the most common used technique in spinal deformity surgeries. monitoring SSEP provides information concerning the integrity of sensory pathway from the periphery to the primary sensory cortex [3].

Use of SSEP monitoring is highly effective at reducing the rate of neurologic injuries, as being able to detect surgical injury at the time of operation which is continuously monitored and can be performed on patients who are neurologically compromised [4,5].

The most important advantages of SSEP are widely available, easy implementation, safe test, has no contraindications, not affected by neuromuscular blockade and generally better resistance to anesthetics than MEP, provides continuous monitoring throughout the surgery, with firm warning criteria and excellent specificity (reaching 100%), and can be combined with other monitoring techniques [6,7].

While the main disadvantages are the ability to assess only the functional integrity of spinal cord dorsal columns and inability to detect motor changes, and the fact that SSEP recording requires signal averaging which results in a time delay until data interpretation can generate a response to the surgeon, so delay in the detection of a signal change up to 16 minutes [8].

There is no doubt that the degree to which different types of neurological deficits affect individuals varies, but reducing the risk of any measurable or noticeable deficit as much as possible must be the goal of intraoperative neurophysiological monitoring [9,10].

The aim of the present work was to assess the role played by SSEP during spinal surgery in preventing immediate and permanent postoperative neurologic deficits.

Methods

The present study is a cross-sectional study, conducted at Hospitals in Erbil governorate for the periods extended from March 2021 to May 2022. All selected subjects were enlightened about the electrophysiological examination and an informed consent for participation in the study was provided. The study was approved by the Institute Review Board of the College of Medicine, Al-Nahrain University. The study included 51 patients (23 males and 28 females) aging (12-33 years), mean height (161.45±4.17 cm) with documented diagnosis of scoliosis by a senior neurosurgeon and/ or an orthopedic surgeon.

Patients were admitted for correction of scoliosis, collected and referred from neurosurgery and orthopedic surgery units at the Medical Consultation Office of Erbil Teaching Hospital.

Scoliosis patients should meet the following inclusion criteria; all patients with scoliosis undergoing spinal deformity correction, patients had normal neurological examinations, and of age group 12-33 years. The exclusion criteria include patients with neurodegenerative disorders, with neurological diseases, and with spinal kyphotic deformity.

All patients were subjected to SSEP study of tibial nerves, spinal imaging (routine X-ray and magnetic resonance imaging "MRI"), electromyography (EMG) study will be made at time of admission for the patients.

Pre- and postoperative SSEP recordings beside intraoperative SSEP recordings were performed for 51 patients with scoliosis who underwent scoliosis correction surgery. Preoperative SSEP performed few days (1-2 days or same day of operation) preoperatively. The postoperative SSEP examination was performed, 3-7 days after the surgery, before discharge. The MEE-2000 system performing the comprehensive monitoring was used. The system's 32-channel ultra-quiet amplifier collects SSEP. The results are displayed in a format to facilitate rapid interpretations, using Nihon Kohden's (Japan) remote viewing software.

For the tibial nerve stimulation surface electrodes were used where the cathode is placed bilaterally between the medial malleolus and the Achilles tendon, just proximal to the malleolus; the anode is placed 2-3 cm distal over the tibial nerve as it courses around the medial malleolus. The tibial nerves were stimulated with a series of square-wave pulse stimulation (duration of stimulus = 0.2

msec; frequency = 4.7 Hz; intensity = 30 mA). The Data are measured to determine SSEP latency and amplitude of P37 and N45. In intraoperative SSEP recording, crock screw stainless-steel needles are placed quickly, though they must be secured with tape or surgical staples to prevent dislodging. Scalp electrode locations for recording are based on (10-20) international of EEG electrode placement. The active electrode is placed with its center at vertex (Cz, the intersection of the nasion-inion and tragus-tragus lines) flat on top of the head; Cz (for right and left tibial nerve stimulation) at midline central; while the reference electrode is placed at Fz at (midline frontal) (in front of Cz by 20% of the nasion-inion line); according to the international (10-20) system.

Recording filters are chosen between 30 Hz and 3kHz to optimize noise rejection, while retaining the principal evoked potentials characteristics in a typical surgical setting. Also, to decrease the ordinary background fluctuation in SSEP due to minor change in anesthetics depth. Cortical (P37) and (N45) SSEP waves recorded on the scalp were elicited on both sides by electric stimulation of the tibial nerves at the ankle. SSEP is done to the patients preoperatively to obtain values considered as baseline values. Then, many intraoperative readings were obtained from the time the patient was positioned, to the time patient was awakened from the anesthesia. the recording parameters were maintained throughout the surgical procedure. during each step, many of the SSEP amplitude and latency readings were obtained, then means of SSEP amplitudes and latencies were obtained, in which signal changes during the procedures were recorded and compared to the obtained preoperative SSEP values.

Alarm criteria as an intraoperative alarm were defined as a persistent (over at least 10 min) of unilateral and/or bilateral 50% reduction in primary somatosensory cortical amplitude (SSEP) or a prolongation of response latency by >10% from baseline readings to be significant [11,12].

Statistical analysis

Data were analyzed by using software package for social science (SPSS) version (23). Data presented as tables and figures. Data compared by using the means, difference in means and paired t test. For the non-parametric measures, we used the Wilcoxon Signed Ranks Test. The P value of <0.05 was defined as significant.

Results

Fifty-one patients diagnosed with scoliosis were enrolled in this study. The mean age of patients was (18±2.92 years) comprising (23) males and (28) females, female to male ratio 1.22:1.

Comparison between baseline preoperative and intraoperative SSEP readings

A comparison of the mean tibial SSEP baseline readings with the mean of the intraoperative readings are presented in table (1). From the table, the median of the percent changes between baseline and the intraoperative SSEP latencies as well as the p values proves the presence of a statistically significant increment in the tibial SSEPs latencies at both sides (P <0.001). The table, further, demonstrates a comparison of the mean tibial SSEP amplitude baseline readings with the mean of the intraoperative readings. In this table, it is clear that the median of the percent changes between the baseline and the mean intraoperative SSEP amplitudes, as well as the P values proves the presence of a significant decrement at both sides (P <0.001).

Table 1. Comparison between baseline preoperative and intraoperative SSEP readings

Studied parameters		Preoperative (Baseline) readings Mean ±SD	Mean of Intraoperative readings Mean ±SD	% change median (IQR)**	P value
RT Tibial N45	Latency msec	46.21±0.64	49.7±2.5	6.82 (5.53_7.81)	<0.001*
	Amplitude µV	4.14±0.64	3.61±0.87	-10.24 (-20.88_ -6.04)	<0.001*
RT Tibial P37	Latency msec	38.32±0.69	40.98±2.36	5.55(4.36_7.4)	<0.001*
	amplitude µV	4.03±0.47	3.4±0.76	-10.46 (-22.74_ -5.98)	<0.001*
LT Tibial N45	Latency msec	46.22±0.59	49.63±2.5	6.42(5.42_7.6)	<0.001*
	amplitude µV	4.2±0.51	3.64±0.73	-12.55 (-22.02_ -3.79)	<0.001*
LT Tibial P37	Latency msec	38.44±0.65	41.25±2.5	5.3(3.37_7.49)	<0.001*
	amplitude µV	4.01±0.58	3.39±0.77	-13.63 (-22.5_ -4.83)	<0.001*

*Significant, Wilcoxon Signed Ranks Test, ** IQR = Interquartile range, msec= millisecond, µV= microvolt

Comparison between baseline preoperative and postoperative SSEP Readings

A comparison of pre- to postoperative tibial SSEP parameters of the Rt. and Lt. tibial nerves of the studied scoliosis patients are presented in table (2). In this table, postoperative mean tibial SSEP latencies although showed an increment as compared with preoperative baseline SSEP latencies, the differences were not significant (P >0.05). In a same manner, the postoperative mean tibial SSEP showed decreased amplitudes as compared with preoperative data; yet, the differences were not significant (P >0.05).

Table 2. Comparison between baseline preoperative and postoperative SSEP readings

Studied Parameters		Preoperative (Baseline) readings Mean ±SD	Postoperative readings Mean ±SD	% change median (IQR)*	P value
RT Tibial N45	Latency msec	46.21±0.64	46.79±1.64	1.09 (0.45_2.58)	>0.05
	Amplitude µV	4.14±0.64	4.06±0.73	-8.35 (-18.8_-4.9)	>0.05
RT Tibial P37	Latency msec	38.32±0.69	38.78±1.8	1.28 (0.94_3.11)	>0.05
	amplitude µV	4.03±0.47	3.91±0.58	-9.2 (-18.5 _ -2.6)	>0.05
LT Tibial N45	Latency msec	46.22±0.59	46.79±2.88	1.14 (0.56_2.34)	>0.05
	amplitude µv	4.2±0.51	4.05±0.65	-10.9 (-21.6_-3.99)	>0.05
LT Tibial P37	Latency msec	38.44±0.65	39.15±3.11	2.02 (0.8_3.5)	>0.05
	amplitude µV	4.01±0.58	3.8±0.7	-11.1 (-19.2_-6.1)	>0.05

* IQR = interquartile range, msec= millisecond, µV= microvolt, Wilcoxon Signed Ranks Test

Results of SSEP alarm parameters

The results of the SSEP Alarm data (latency and amplitude of the N45 and P37 SSEP waves) of the Rt. and Lt. tibial nerves of the studied scoliosis patients are presented in table (3). The table, in addition, demonstrates a comparison of the mean tibial preoperative (baseline) SSEP reading with the mean of the alarm tibial SSEP readings. Results revealed statistically highly significant increase in the mean latency of the alarm readings of Rt. and Lt. Tibial N45 wave (>10%) from baseline (46.23±0.65, 46.23±0.61 msec) to (54±1.58, 53.99±1.54 msec) respectively, P <0.001. Likewise, there was statistically highly significant decrement in the mean amplitude of the alarm readings of Rt. and Lt. tibial N45 wave (>50%) from baseline (4.05±0.61, 4.23±0.51 µv) to (1.8±0.42, 1.89±0.36 µv) respectively, P <0.001.

Moreover, (Table 3) illustrates a statistically highly significant increase in the mean latency of alarm readings of Rt. and Lt. Tibial P37 wave (>10%) from baseline (38.33±0.71, 38.46±0.66 msec) to (45.77±1.47, 45.96±1.68 msec) respectively, P <0.001. Besides, highly significant decrement in the mean amplitude of alarm readings of Rt. and Lt. tibial P37 (>50%) was noticed from baseline readings (4.05±0.47, 3.97±0.58 µv) to (1.81±0.34, 1.76±0.4 µv) respectively, P <0.001.

On the other hand, (Table 3) demonstrates, also, a comparison of mean of intraoperative readings of the SSEP parameters with the alarm tibial SSEP readings. Results of the alarm readings of Rt. and Lt. tibial mean N45 and P37 waves latencies were statistically highly significantly higher than their corresponding mean latencies in the intraoperative readings (54±1.58, 53.99±1.54 msec) compared to (48.88±1.06, 48.81±1.11 msec) for N45 wave respectively, and (45.77±1.47, 45.96±1.68 msec) versus (40.37±1.7, 40.34±0.97 msec) msec for P37 wave respectively, P <0.001.

Whereas, a highly significant decrement in the mean amplitude of the alarm readings of Rt. and Lt. tibial N45 and P37 waves were shown as compared to intraoperative results (1.8±0.42, 1.89±0.36) versus (3.61±0.59, 3.6±0.56 µv) for N45wave respectively, and (3.6±0.56, 3.47±0.66 µv) versus (1.81±0.34, 1.76±0.4 µv) µv for P37 wave respectively, P <0.001.

Table 3. Comparison between baseline preoperative and postoperative SSEP readings

Measurement		Baseline reading Mean ±SD	Alarm readings Mean ±SD	P value **	Intraoperative readings Mean ±SD	P value ***
RT Tibial N45	Latency msec	46.23±0.65	54±1.58	<0.001*	48.88±1.06	<0.001*
	amplitude µV	4.05±0.61	1.8±0.42	<0.001*	3.61±0.59	<0.001*
LT Tibial N45	Latency msec	46.23±0.61	53.99±1.54	<0.001*	48.81±1.11	<0.001*
	amplitude µV	4.23±0.51	1.89±0.36	<0.001*	3.77±0.54	<0.001
RT Tibial P37	Latency msec	38.33±0.71	45.77±1.47	<0.001*	40.37±1.7	<0.001*
	amplitude µV	4.05±0.47	1.81±0.34	<0.001*	3.6±0.56	<0.001*
LT Tibial P37	Latency msec	38.46±0.66	45.96±1.68	<0.001*	40.34±0.97	<0.001*
	amplitude µV	3.97±0.58	1.76±0.4	<0.001*	3.47±0.66	<0.001*

*Significant, ** Compare preoperative (Baseline) readings to Alarm readings, *** compare intraoperative readings to Alarm readings, msec= millisecond, µV= microvolt

The sensitivity and specificity of the studied SSEP parameters

Statistical classification of the patient depending on the intraoperative and postoperative SSEP readings, presented as true positive 49 cases, true negative 2 cases and there were no false negative or false positive cases.

The sensitivity was 100%, specificity 100%, false positive rate 0%, and false negative was 0%. The accuracy was 100%, positive predictive value was 100%, and negative predictive value was 100%, (Table 4).

Table 4. the sensitivity, specificity, positive predictive and negative predictive values of SSEP

Sensitivity	Specificity	False Positive	False negative	Accuracy	PPV	NPV
100%	100%	0 %	0 %	100%	100 %	100 %

PPV; positive predictive value, NPV; negative predictive value

Discussion

SSEP is the continuous detection of any alteration in the monitored dorsal column function, thus allowing for a prompt intervention that will reduce any transient or permanent neurological damage and improve the surgical outcome as well as the overall quality of the medical treatment [13,14].

According to results of the current study, a comparison of the mean tibial SSEP baseline readings with the mean of the intraoperative readings prove the presence of a statistically significant increment in the tibial SSEP latencies and a significant decrement in the tibial SSEP amplitudes at both sides. These finding attributed to the SSEP is affected by many environmental and physiological factors in the operation room, including: anesthetics, positioning of the patient, mean arterial pressure, anemia, changes in $PaCO_2$, decreases in PaO_2 and temperature. These findings are in agreement with several study groups [5,14]. Hence, optimal conditions for SSEP of scoliosis surgery include; the use of total intravenous anesthesia (TIVA) to maintain an adequate depth of anesthesia, as well as awareness of the effects of neuromuscular blocking agents [15]. When mean arterial pressure (MAP) is maintained at or higher than 80 mm Hg and the body temperature is preserved as much as possible, there are usually no deleterious changes in the SSEP, and SSEP parameters would be maintained within normal variability [11].

Intraoperative SSEP alarms can be due to surgical causes such as direct mechanical trauma due to the incorrect placement of the screws and rods, or the deficits in these cases were thought to have been caused by vascular compromise of dorsal column tract. Several literatures have reported that the incidence of pedicle screw misplacement ranged within 20% to 30%, and 1% of which suffered from neurological damage that could bring about serious consequences such as paralysis [16]; or nonsurgical alarms by ruling out technical issues: The intraoperative environmental and systemic factors such as excessive depth of anesthesia, hypotension, hypothermia, hypovolemia, and nerve compression from limb positioning, which all can affected SSEP [17].

SSEPs, are less susceptible to dose depended effects of anesthetic agents compared to MEP [15]. An additional factor is the mean arterial blood pressure and its effect on spinal cord perfusion pressure. Therefore, when a decrease of amplitude and prolongation of latency of SSEP is noted during a procedure, it is important to raise the mean arterial pressure to at least 80 mm Hg prior to surgical intervention [2]. Lowering the temperature of the limb on which a peripheral nerve is being stimulated electrically below that of normal body temperature or lowering core temperature causes decreased conduction velocity of the somatosensory pathway in the spinal cord and brain and thus, an increase in the latency of the SSEP and reduction of the amplitude [18].

The differences between pre- and postoperative latencies and amplitudes were compared, in order to evaluate the influence of spine surgery upon spinal cord; yet, the differences were not significant. Such findings prove that although there were significant intraoperative changes in latencies and amplitudes of the SSEP waves in scoliosis patients, postoperatively such changes became attenuated so that no significant difference was found, which may point to the significance of neuromonitoring in improving surgical procedures in such patients.

According to the relation between intraoperative and postoperative SSEP readings, the sensitivity and specificity study of SSEP parameters in scoliosis patients was done depending on definitions of Hilibrand and his associates [19]. In the current study, 51 patients who underwent to surgical correction for scoliosis were included, 49 were classified as true positive; who showed an alarm that responded favorably to intervention and had no new post-operative deficit (No. is 46), or an alarm that was irreversible despite all interventional measures and followed by a new postoperative neurologic deficit (No. is 3). The remaining two patients were classified as true negative who had no alarm and the patient awoke neurologically intact, there were no false negative or false positive cases in our results; hence, the validity values for SSEP study of tibial nerves in patients with scoliosis in the current study were highly sensitive and specific with the percentage of 100% for both.

In conclusions, the intraoperative SSEP neuromonitoring is valuable in the prevention of neurological injury during surgical procedures. SSEP monitoring is highly specific to physiologic/mechanical insult and highly sensitive to posterior column of spinal cord.

Acknowledgement

The authors would like to thank all the patients and their families for their kind cooperation, in addition to the members of the Dept. of Physiology, College of Medicine, Al-Nahrain University, and to the staff members of Neurophysiology Units in of Erbil Teaching Hospital, for their assistance.

Author contribution

Dr. Khudhur: conducted the study, collected the data, performed the statistical analysis and drafting the manuscript. Dr. Al-Hashimi and Dr. Umara contributed in the designing, organization and finalization of manuscript.

Conflict of interest

There are no conflicts of interest.

Funding

Self-funded, there was no internal or external funding for this project.

References

1. Chen Z, Qiu Y, Zhu Z, et al. Posterior-only hemivertebra resection for congenital cervicothoracic scoliosis: correcting neck tilt and balancing the shoulders. Spine (Phila Pa 1976). 2018; 43(6): 394-401. doi: 10.1097/BRS.0000000000002325. PMID: 28700454.
2. Tsirikos AI, Duckworth AD, Henderson LE, et al. Multimodal intraoperative spinal cord monitoring during spinal deformity surgery: Efficacy, Diagnostic Characteristics, and Algorithm Development. Med Princ Pract. 2020; 29(1): 6-17. doi: 10.1159/000501256.
3. Becker A, Amlong C, Rusy DA. Somatosensory-evoked potentials. In: Koht A, Sloan T, Toleikis J. (eds) Monitoring the nervous system for anesthesiologists and other health care professionals. 2nd ed. Springer; 2017. p. 3-18.
4. Holdefer RN, MacDonald DB, Skinner SA. Somatosensory and motor evoked potentials as biomarkers for post-operative neurological status. Clin Neurophysiol. 2015; 126(5): 857-65. doi: 10.1016/j.clinph.2014.11.009.
5. Baker A, Widrich J. Somatosensory evoked potentials. [Updated 2023 Aug 14]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025.
6. Park JH, Hyun SJ. Intraoperative neurophysiological monitoring in spinal surgery. World J Clin Cases. 2015; 3(9): 765-73. doi: 10.12998/wjcc.v3.i9.765.
7. Biscevic M, Sehic A, Krupic F. Intraoperative neuromonitoring in spine deformity surgery: modalities, advantages, limitations, medicolegal issues - surgeons' views. EFORT Open Rev. 2020; 5(1): 9-16. doi: 10.1302/2058-5241.5.180032.
8. Muzyka IM, Estephan B. Somatosensory evoked potentials. Handb Clin Neurol. 2019; 160: 523-40. doi: 10.1016/B978-0-444-64032-1.00035-7.
9. Singh G. Somatosensory evoked potential monitoring. J Neuroanaesthesiol Crit Care. 2016; 3: 97-104. doi: 10.4103/2348-0548.174745.
10. Nassef M, Splinter W, Lidster N, et al. Intraoperative neurophysiologic monitoring in idiopathic scoliosis surgery: a retrospective observational study of new neurologic deficits. Can J Anaesth. 2021; 68(4): 477-84. English. doi: 10.1007/s12630-020-01898-9.
11. Nagarajan L, Ghosh S, Dillon D, et al. Intraoperative neurophysiology monitoring in scoliosis surgery in children. Clin Neurophysiol Pract. 2019; 4: 11-7. doi: 10.1016/j.cnp.2018.12.002.
12. Halsey MF, Myung KS, Ghag A, et al. Neurophysiological monitoring of spinal cord function during spinal deformity surgery: 2020 SRS neuromonitoring information statement. Spine Deform. 2020; 8(4): 591-6. doi: 10.1007/s43390-020-00140-2.
13. Chui J, Flexman AM. Intraoperative neuromonitoring for scoliosis surgery: Is there an end to justify the means? Can J Anaesth. 2021; 68(4): 454-9. English. doi: 10.1007/s12630-020-01899-8.
14. Kim JH, Lenina S, Mosley G, et al. The efficacy of intraoperative neurophysiological monitoring to detect postoperative neurological deficits in transforaminal lumbar interbody fusion surgery. oper neurosurg (Hagerstown). 2019; 16(1): 71-8. doi: 10.1093/ons/opy061.
15. Hasan MS, Tan JK, Chan CYW, et al. Comparison between effect of desflurane/remifentanil and propofol/remifentanil anesthesia on somatosensory evoked potential monitoring during scoliosis surgery- A randomized controlled trial. J Orthop Surg (Hong Kong). 2018; 26(3): 2309499018789529. doi: 10.1177/2309499018789529.
16. Miller SM, Donegan SW, Voigt N, et al. Transcranial motor-evoked potentials for prediction of postoperative neurologic and motor deficit following surgery for thoracolumbar scoliosis. Orthop Rev (Pavia). 2019; 11(1): 7757. doi: 10.4081/or.2019.7757.

17. Yoshida G, Ando M, Imagama S, et al. Alert timing and corresponding intervention with intraoperative spinal cord monitoring for high-risk spinal surgery. spine (Phila Pa 1976). 2019; 44(8): E470-9. doi: 10.1097/BRS.0000000000002900.
18. Simon M. Somatosensory evoked potentials and phase reversal technique: Identifying the motor cortex. In: Loftus C M, Biller J, Baron EM. (eds) Intraoperative neuromonitoring. McGraw-Hill Education; 2014. p. 165-70.
19. Hilibrand AS, Schwartz DM, Sethuraman V, et al. Comparison of transcranial electric motor and somatosensory evoked potential monitoring during cervical spine surgery. J Bone Joint Surg Am. 2004; 86(6): 1248-53. doi: 10.2106/00004623-200406000-00018.

Correspondence to Amrah M. Saeed
E-mail: amramsaaed@gmail.com

Received Apr. 9th 2023
Accepted Apr. 30th 2023