Post tetanic facilitation of TcMEP neuromonitoring with partial Neuromuscular Blockade and Total Intravenous Anesthesia (Propofol - Dexmedetomidine) in Adolescent Idiopathic Scoliosis Surgery

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Abstract:
Background: Adolescent idiopathic scoliosis (AIS) is a common spinal deformity characterized by three-dimensional spinal curvature, affecting primarily adolescents between the ages of 10 and 18. While the exact etiology remains unclear, the condition can progress to significant spinal deformity, necessitating surgical intervention. Surgical correction of spinal deformity poses a risk of neurological injury, emphasizing the importance of intraoperative neurophysiological monitoring (IONM) to safeguard against potential complications. IONM techniques, such as somatosensory evoked potentials (SSEPs) and motor evoked potentials (MEPs), are employed to assess the integrity of the spinal cord during surgery. Anesthetic agents and neuromuscular blocking agents can significantly impact the quality of IONM signals. While inhalational anesthetics are generally avoided due to their adverse effects on neurophysiological monitoring, total intravenous anesthesia (TIVA) using a combination of agents like propofol and dexmedetomidine offers a suitable alternative. The judicious use of neuromuscular blocking agents, such as rocuronium, can facilitate surgical procedures while minimizing interference with IONM signals. By carefully selecting and utilizing MEP facilitation techniques; post tetanic facilitated can optimize recorded signals and minimize the risk of neurological injury during spinal surgery for AIS.
Methods: A prospective, double-blind clinical trial was conducted at Cairo University Hospitals from December 2021 to December 2022, after obtaining ethical approval and informed consent from participants' parents or guardians. Thirty patients undergoing spinal surgery were evaluated using conventional MEP technique and post-tetanic facilitated MEP technique. Both the anesthesiologist and neurophysiologist were blinded to the MEP technique used. Five responses were recorded until surgeon started first instrumentation; after which an antidote of the neuromuscular blocking agent was administered and TcMEP were recorded normally. Results: Our study demonstrated elicitable and consistent TcMEP in all surgeries. Our findings align with those of Chae et al. (2024), who demonstrated that despite MEP amplitude reduction, MEP monitoring remained feasible, suggesting that continuous infusion can be compatible with neurophysiological monitoring. Similarly, Kim et al. (2013) investigated the impact of different levels of neuromuscular blockade on MEP parameters. They found that even with partial neuromuscular blockade, MEP amplitude was significantly reduced compared to no blockade. However, MEP monitoring remained possible, suggesting that partial blockade does not preclude its use (Kim et al. 2013). Zhang et al. (2022) further supported these findings, demonstrating that low-dose continuous rocuronium infusion (0.6-0.9 mg/kg/h) had minimal impact on MEP amplitude. Only the highest dose (1.2 mg/kg/h) caused a significant reduction in MEP amplitude at a specific time point (Zhang et al. 2022).
In contrast to our study, Jian et al. (2022) reported that a TOF ratio of 26-50% was optimal for MEP monitoring during scoliosis surgery using cis-atracurium. This discrepancy may be attributed to differences in the sensitivity of muscle groups to neuromuscular blocking agents and the specific agents used (Jian et al. 2022). TcMEP amplitudes showed significant augmentation with post tetanic facilitation compared to unconditioned conventional recordings ($p < .001$). A statistically positive correlation was also found between recordings in each muscle for the two techniques. **Conclusion:** Consistent TcMEP recordings can be acquired with partial neuromuscular blocking agent. Post-tetanic MEP techniques can significantly augment MEP amplitudes recorded intraoperatively.
Keywords: transcranial motor evoked potentials – spine surgery monitoring - partial neuromuscular blockade- post-tetanic facilitation.

Introduction:

Maintaining spinal cord integrity during surgical correction of spinal deformities is paramount. Intraoperative neurophysiological monitoring (IONM) techniques, such as SSEPs, MEPs, and EMG, provide real-time assessment of neural function. However, anesthetic agents, particularly neuromuscular blocking agents, can significantly compromise the quality of IONM signals (Sahinovic et al. 2021).

While TIVA without neuromuscular blockade offers optimal conditions for IONM, it may increase the risk of intraoperative movement. A balanced approach involving low-dose neuromuscular blocker infusion, preferably with rocuronium, and TIVA can provide adequate anesthesia and maintain acceptable IONM signal quality(Kakimoto et al. 2005).

Recent advancements in tcMEP stimulation techniques, including facilitation strategies, offer promising solutions to mitigate the anesthetic challenge to reliable MEP recordings. These strategies, such as high-frequency tetanic stimulation of peripheral nerves, enhance MEP responses by modulating central nervous system pathways. Understanding the interaction between anesthetic agents and these facilitation mechanisms can further optimize IONM during complex spinal surgeries (Phoowanakulchai and Kawaguchi 2024).

Patients and methods:

Study Design and Participants

This prospective analytical study enrolled 30 patients undergoing spinal deformity correction surgery at a tertiary university hospital between December 2021 and December 2022. Each patient underwent TIVA with partial neuromuscular block. MEP recording techniques: conventional MEP, and post-tetanic stimulation.

Objective

The primary objective of this study was to investigate the impact of partial neuromuscular block and preconditioning tetanic stimulation technique on MEP amplitudes during spinal surgery.

Inclusion and Exclusion Criteria

Patients included in the study were diagnosed with adolescent idiopathic scoliosis and were scheduled for spinal deformity correction surgery. The age range of participants was 10 to 18 years.

Inclusion Criteria:

- Adolescent idiopathic scoliosis (AIS) patients aged 10-18 years
- American Society of Anesthesiologists (ASA) physical status I or II
- Body mass index (BMI) < 30 kg/m²
- Cobb angle > 45 degrees
- Scheduled for elective spinal deformity correction surgery

Exclusion Criteria:

- Inability to undergo MEP monitoring due to central or peripheral nervous system disorders (e.g., cerebral palsy, myasthenia gravis, acute spinal cord injury, neurologic shock)
- Congenital scoliosis
- Severe cardiac conditions
- Implanted pacemaker
- Epilepsy
- Increased intracranial pressure
- Difficult airway

- Allergy to study medications

Preoperative Preparation:

- Detailed medical history and physical examination
- Laboratory tests: Complete blood count, coagulation profile, liver function tests, kidney function tests
- Imaging studies: Chest X-ray, Cobb angle measurement, pulmonary function tests (PFTs), echocardiography
- NPO status according to ASA guidelines
- Preoperative sedation with intravenous midazolam (0.03 mg/kg) and oxygen administration

Ethical Considerations

The study protocol was approved by the Institutional Ethical Research Committee (Code MD-67-2021). Written informed consent was obtained from all participants or their legal guardians after a detailed explanation of the study procedures, potential risks, and benefits.

Procedure:

Preoperative Evaluation

All patients underwent a comprehensive preoperative evaluation, including:

- Detailed medical and family history, focusing on neurological and genetic disorders
- Thorough neurological examination assessing cranial nerves, motor function, reflexes, sensory system, coordination, and gait
- Physical examination to identify systemic medical conditions

Neurophysiological Monitoring

- Transcranial Electrical Motor Evoked Potentials (TcMEP):
  - Cranial stimulation: Electrodes were placed 2 cm anterior and 3 cm lateral to Cz.
  - Peripheral stimulation: Electrodes were placed over the right posterior tibial nerve.
  - Recording: Muscle activity was recorded from the tibialis anterior and abductor hallucis muscles of both legs.
- Stimulation Parameters:
  - Number of pulses: 5
  - Interstimulus interval: 2 ms
  - Intensity: 200 mA
  - Stimulus duration: 500 µs
  - Filters: 50-1000 Hz
  - Epoch time: 100 ms

Preconditioning Technique:

- Post-Tetanic Facilitation: A 10-second train of 50 Hz stimuli was delivered to the right posterior tibial nerve prior to conventional MEP recording.

Data Acquisition:

- Baseline TcMEP amplitude recordings were obtained before surgical incision.
- Subsequent recordings were performed at intervals during the surgery.

Anesthesia Considerations:

- Spectral edge frequency (SEF95) was monitored to assess anesthesia depth and avoid confounding factors.

Statistical analysis:

Data were coded and entered using the statistical package R studio version 1.0.143. Data were summarized using mean ± standard deviation in quantitative data. Median and interquartile range (IQR) were added to express the data which were not normal. Comparisons between readings using conventional and post-tetanic facilitation from the same muscle were done using paired non-parametrical Wilcoxon signed rank test. P-values less than 0.05 were considered as statistically significant.

Results:

This study was conducted on 30 patients neurologically free and undergoing spine deformity surgery (pedicle screw fixation) with conventional MEP responses, and post tetanic facilitation MEP from January 2021 to June 2023. The study included 12 males (40%) and 18 females (60%); with their ages ranged between 11 and 35 years with mean of 17.4 ± 6.38. (**Table 1**)

Table 1: Demographic data

Variables		Patients (n=30)
Age (Years)	Range	11 to 35 yrs
	Mean± SD	17.4 ± 6.38
Gender	Males	12 (40%)
N (%)	Females	18 (60%)

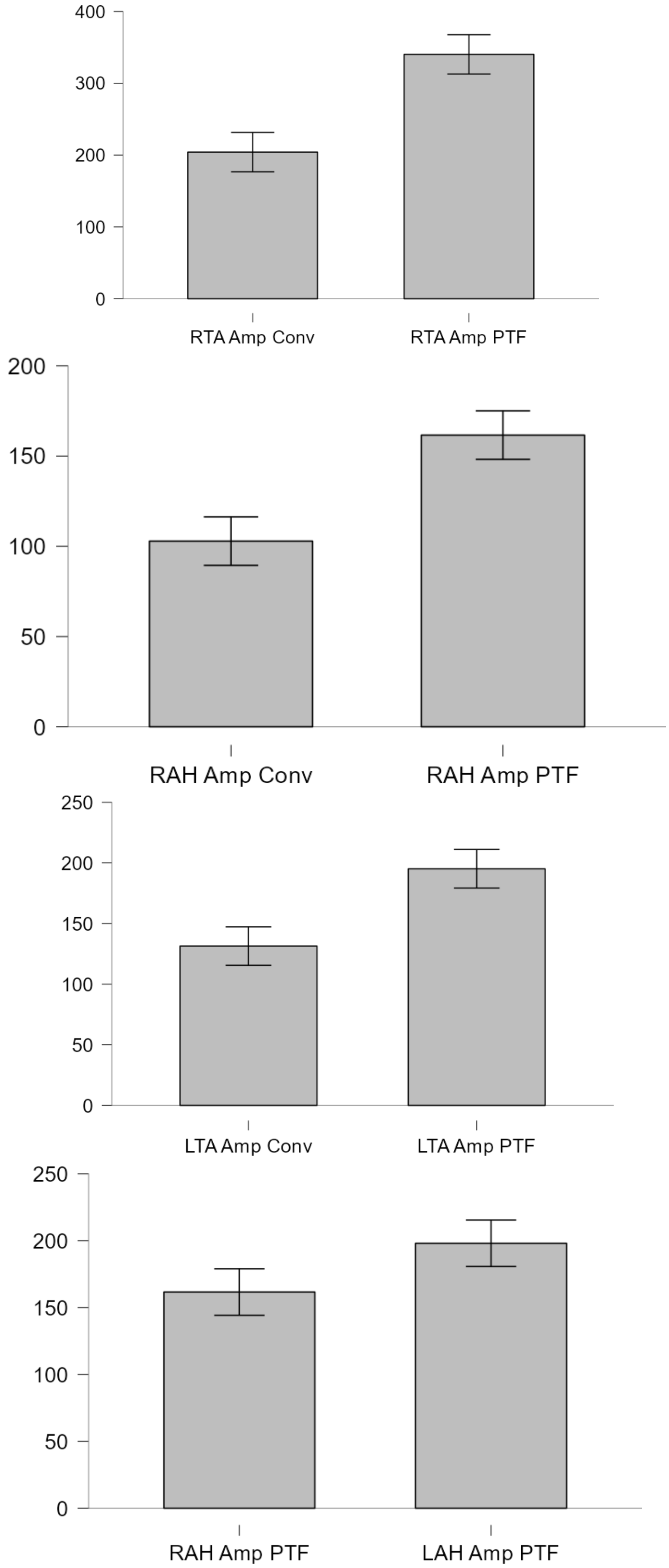
<u>MEP amplitudes (µV)</u>

Reproducible MEPs were acquired in all patients. In addition, post tetanic facilitation technique showed significantly better amplitude in all sampled muscles. **(Table 4), (figures1-4)**

Table 4: MEP amplitudes in µV among study participants

Muscle	Technique	Median	IQR	Mean	SD	P-value
RTA n=150	Conventional	121.5	196.25	204.153	190.384	**< .001**
	PTF	221.5	419.75	340.265	334.394	
RAH n=150	Conventional	82	105.25	102.887	107.035	**< .001**
	PTF	124	115.5	161.631	136.146	
LTA n=150	Conventional	67	100.75	131.407	208.537	**< .001**
	PTF	90.5	184.75	195.149	276.82	
LAH n=150	Conventional	114.5	168	123.827	94.106	**0.002**
	PTF	166.5	205	198.08	145.217	

RTA: right tibialis anterior, RAH: right abductor hallucis, LTA: left tibialis anterior, LAH: left abductor hallucis, PTF: post tetanic facilitation MEP.



Figures 1-4 Bar chart of the MEP amplitudes measured in uV.

Discussion:

Expectations of patients undergoing corrective surgery for spinal deformity have been shifting toward the ideal spine shape. In most cases, surgeons can meet those expectations with new surgical techniques, improved spinal implants, perioperative care, safer anesthesia, invention of cell saver, etc. Unfortunately, with more extensive surgeries, the intraoperative risk of spinal cord injury increases. This neurologic injury may occur due to direct mechanical force applied to the spinal cord (implants, instruments, bony structures), or due to indirect ischemic changes (vessel ligation during exposure, cord distraction/compression during corrective manoeuvres) (Biscevic, Sehic, and Krupic 2020).

Safety is the first priority in any spine surgery. The development of new onset postoperative neurological deficits needs to be reduced if at all feasible. Thus, the primary aim of IONM is early detection and possible reversal of potential neurological injury to reduce postoperative neurological deficits (Buhl et al. 2021).

Surgeons should understand the rationale and the clinical basis for IONM , interpret the monitoring alerts, and utilize them for a better surgical outcome. In addition to a surgeon, the neuromonitoring team is composed of clinical neurophysiologist, anesthesiologist, and monitoring technician (Phoowanakulchai and Kawaguchi 2024).

Oh et al., 2019 showed that deep NMB provides lower blood loss compared to no NMB in lumbar spinal surgery. In addition, akinesia intraoperative, is more easily achieved with NMB agents. However, this may compromise the MEP monitoring. Hence, we explored the use of post-tetanic facilitation to augment MEPs during partial neuromuscular block through rocuronium given during induction with dose of (0.6 mg/kg) then maintained with (0.6 mg /kg /h). Our results show that its possible to obtain consistent MEPs with partial neuromuscular block and the usefulness of post-tetanic facilitation in augmenting the elicited responses (Oh et al. 2019).

Conclusion:

Reliable TcMEP monitoring can be achieved despite the use of partial neuromuscular blockade during spine surgery. Post-tetanic MEPs offer a valuable tool for significantly amplifying MEP signals, thereby improving the accuracy and sensitivity of intraoperative neurophysiological monitoring.

Declarations:

Ethics approval and consent to participate: The institutional research ethics committee approved the study in accordance with the code (MD-67-2021). Written informed consent was obtained from each patient's legal guardians. They were made aware of the study's objectives, a thorough explanation of the process, the expected advantages, and any possible hazards. Participation was entirely voluntary. Privacy and data were preserved in accordance with the Helsinki Declaration.

Consent for publication: Not applicable.

Availability of data and material: The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available as they contain information that could compromise the privacy of research participants.

Competing interests: Authors declare no conflict of interest is present.

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Authors' contributions: , Hala ElHabashy, generated ideas, interpreted the data, and revised the manuscript. Basma Bahgat, generated ideas, interpreted the data, and revised the manuscript. Neveen Elfayoumy, wrote and revised the manuscript. Hesham Nafia, collected, analyzed the data, and wrote the manuscript. Aliaa Tawfeek, interpreted the data, and wrote and revised the manuscript. All authors read and approved the final manuscript.

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