

Intraoperative Neurophysiology Monitoring and Anesthesia in Patients Undergoing Deformity Correction and Posterior Spinal Fusion Surgery (PSF) for Adolescent Idiopathic Scoliosis

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ABSTRACT

Adolescent idiopathic scoliosis (AIS), often requiring posterior spinal fusion (PSF), presents significant surgical challenges due to its complex three-dimensional deformity. Intraoperative neurophysiological monitoring (IONM) has become essential in safeguarding neural integrity during corrective spinal procedures. This case-based review discusses the integration of IONM modalities, motor evoked potentials (MEPs), somatosensory evoked potentials (SSEPs), and electromyography (EMG), in a patient undergoing deformity correction for thoracic scoliosis. The success of IONM is closely tied to anesthetic technique, as agents like propofol and dexmedetomidine must be carefully titrated to preserve signal integrity. Anesthetic-induced suppression of evoked potentials remains a key consideration, highlighting the importance of interdisciplinary collaboration among surgeons, anesthesiologists, and neurophysiologists. Alarm criteria were established to promptly detect and address potential neural compromise. This case emphasizes the role of IONM not only in enhancing surgical safety but also in guiding intraoperative decisions. With proper execution, IONM minimizes neurological risks and contributes to improved outcomes in complex spinal deformity surgeries. Its efficacy depends on protocol fidelity, careful anesthetic selection, and robust intra-team communication.

KEYWORDS

IONM, PSF, AIS, Evoked Potentials, Anesthetic Management

INTRODUCTION

Scoliosis is identified by curves greater than 10 degrees as seen on posteroanterior radiographs. This condition forms a complex curve that results in deformities across all three planes due to the spine's self-rotating movement. Idiopathic scoliosis accounts for approximately 80% of structural coronal deformities (Horton WA, 2013). The diagnosis of idiopathic scoliosis is typically made by excluding other known causes. It is categorized into three subgroups based on age: infantile (ages 0-3), juvenile (ages 4-9), and adolescent/adult (ages 10 to maturity). The incidence of curves of 10 degrees or more ranges from 1% to 3%, but for curves exceeding 30 degrees, which generally require treatment, the incidence drops to 0.15% to 0.3%. The female-to-male ratio for curves of 10 degrees and above is 1.4:1, and it increases to 5:1 for curves over 30 degrees (Herring & Tachdjian, 2002).

In general, curves exceeding 45 to 50 degrees should be treated surgically. Research has shown that curves greater than 50 degrees tend to continue progressing even after full skeletal maturity is reached (Maruyama & Takeshita, 2008). Delaying surgical treatment is not advisable, as it increases the risk of complications and leads to greater intraoperative blood loss when addressing more severe curves. Fusion surgery posterior instrumentation in the surgical treatment of scoliosis was first introduced by Paul Harrington, who aimed to correct spinal curves by using rods to apply distraction from the concave side. The second generation of instrumentation, developed by Cotrel and Dubousset, employed rod rotation maneuvers to achieve curve correction. With modern advancements, the spine can now be securely attached to rods using pedicle screws or hybrid systems (Cheng., et al, 2005).

The primary objectives of intraoperative neurophysiological monitoring (IONM) are to safeguard neurological function during surgery, enhance surgical outcomes and detect potential neurological damage before it becomes irreversible. These criteria can be legitimately triggered by surgical manipulation, but anesthesia can also significantly influence the accuracy of neurophysiological measurements, potentially activating these warnings. Additionally, various technical issues may cause changes in neurophysiological signals. Consequently, the effectiveness of neurophysiological monitoring relies on strong collaboration between the surgeon, anesthesiologist, and clinical neurophysiologist. It is essential for the anesthesiologist to develop experience in working closely with the clinical neurophysiologist and surgeons so that this team can operate with mutual trust and effective communication. This trust is crucial for optimizing the surgical outcome when IONM is employed (ElBardissi & Sundt, 2012).

CASE REPORT

An 18-years-old patient came to outpatient clinic complaining about her chronic backpain since several years ago. Examination revealed a scoliotic spine and the patient was scheduled for surgery.

The patient underwent several physical examinations and supporting tests in preparation for surgery. A Chest X-ray dated August 23, 2024 examination revealed the following: Dextroscoliosis Thoracalis (a type of scoliosis where the spine curves to the right in the thoracic region) with Cobb angle 61%, pulmonary radiological findings still appear normal, and normal heart size.

The blood tests showed normal result with Blood Gas Analysis result HCO₃ 26.5, Base Excess 2.2, pCO₂ 37.4, pO₂ 96.0 and pH 7.45. Overall, these results suggest that the patient had a slight alkalosis with a compensatory respiratory response (restrictive type respiratory problem).

For the surgical planning, the patient would be positioned prone (face down). Therefore, the patient was planned to undergo general anesthesia and endotracheal tube placement.

The surgical procedure involved a team including orthopaedic surgeons, anesthesiologists, and neurologists to monitor the patient's condition directly with IONM. The patient, who had an IV line in place, was premedicated with Dexamethasone 5 mg and Ondansetron 4 mg. Preoxygenation/

denitrogenation was performed for 3-5 minutes. The patient was then administered Fentanyl 200 mcg, Propofol 60 mg, and Atracurium 30 mg. Once the effects of these medications were established, an endotracheal tube of size 7.0 was inserted to a depth of 19 cm from the lip.

The patient was positioned prone on the operating table following intubation with the endotracheal tube. The anesthesiology team ensured that the airway remained patent and that the patient was in an optimal position for the surgery. Once the patient was positioned for surgery, the neurology team placed IONM leads on the head, chest, hips, thighs, and legs to directly monitor any potential effects of the spinal surgery. During the surgery, the patient's hemodynamics were continuously monitored and maintained in a stable condition by the anesthesiology team. IONM was overseen by the orthopaedic and neurology teams. The patient was also provided with 2 litres Oxygen (O₂) and Air (Airbar) per minute. The level of anesthesia during the surgery was maintained with a syringe pump delivering Propofol 100 - 200 mcg/kg body weight per minute and Dexmedetomidine 0.2 - 0.7 mcg/kg body weight per hour.

The surgery lasted approximately 2 hours. After the procedure, the patient was transferred to the intensive care unit. During the transfer, the patient's hemodynamics were monitored to ensure stability. The vital signs on the monitor showed blood pressure at 99/59 mmHg, pulse at 78 bpm, and SpO₂ at 100%. The patient's urine output was greater than 0.5 mL/kg body weight per hour.

Postoperative medications administered include: Ringer's Lactate (RL) 60 mL/hour, Paracetamol 1 gram every 8 hours, Omeprazole 40 mg every 12 hours, Cefazolin 1 gram every 12 hours, Mecobalamin 500 mg every 12 hours, Fentanyl (via syringe pump) 3 mcg/hour.

DISCUSSION

IONM of the functional integrity of spinal cord pathways is essential for detecting and preventing surgically induced injuries. The available IONM techniques can be broadly categorized into monitoring and mapping methods. Monitoring modalities, such as motor evoked potentials (MEPs), Electromyography (EMG), and somatosensory evoked potentials (SSEPs), are employed to continuously assess the functional integrity of spinal tracts especially in spine deformity surgery (Sala., et al, 2022).

(a) Motor Evoked Potentials (MEPs)

Motor evoked potentials (MEPs) were bilaterally recorded as compound muscle action potentials (CMAPs) from the tibialis anterior (TA) and abductor hallucis (AH) muscles in the lower extremities, with the rectus femoris muscle added to the protocol in 2013. In the upper extremities, recordings were taken from the abductor digiti minimi (ADM) muscle. Bilateral ADM responses served as controls to distinguish between surgical and non-surgical loss of limb responses and to identify potential brachial plexus compromise due to patient positioning. MEPs were periodically elicited by delivering an anodal pulse train consisting of 4–7 pulses, each of 0.5 ms duration, with an interstimulus interval of 2–4 ms, at amplitudes ranging from 200–500 Volt (for fixed voltage systems) or 150–220 mA (for fixed current systems) using two corkscrew electrodes positioned over the motor cortex at C1 and C2 (**Figure 1**). The stimulus strength was optimized to produce consistent and reproducible responses. For patients with grade IV and V spondylolisthesis included in this series, MEP recordings from the anal sphincter and gastrocnemius muscles were added to the multimodal monitoring technique to effectively monitor the sacral nerve roots (Huang., et al, 2019).

(b) Electromyography (EMG)

Electromyography (EMG) is the measurement of electrical activity in muscles. Subdermal needle electrodes were placed in the thenar-hypothenar muscles of the upper extremity, as well as in the rectus

abdominis, adductors, quadriceps, tibialis anterior, gastrocnemius, and abductor hallucis muscles (foot) in the lower extremity. Both spontaneous EMG (s-EMG) and triggered EMG (t-EMG) were recorded for all muscle groups. Low-frequency filters were set to 10 Hz and high-frequency filters to 5 kHz for both s-EMG and t-EMG. The display rate for s-EMG was set to 300 milliseconds per division, and for t-EMG, it was set to 10 milliseconds per division (**Figure 2**). s-EMG is particularly useful for detecting abnormal activity that could place a nerve root at risk (Drake, 2009).

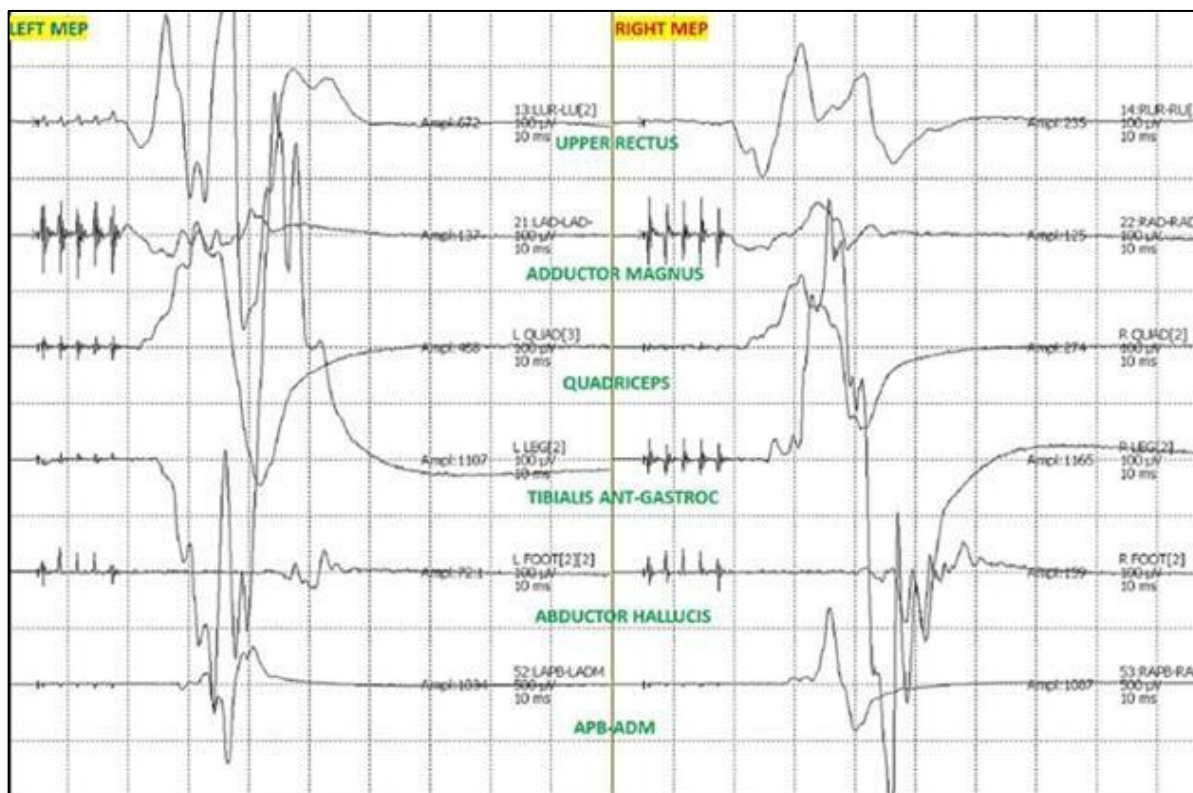


Figure 1. Transcranial electrical Motor Evoked Potentials (TCeMEP); ANT: Anterior, APB: Abductor Pollicis Brevis, ADM: Abductor Digiti minimi.

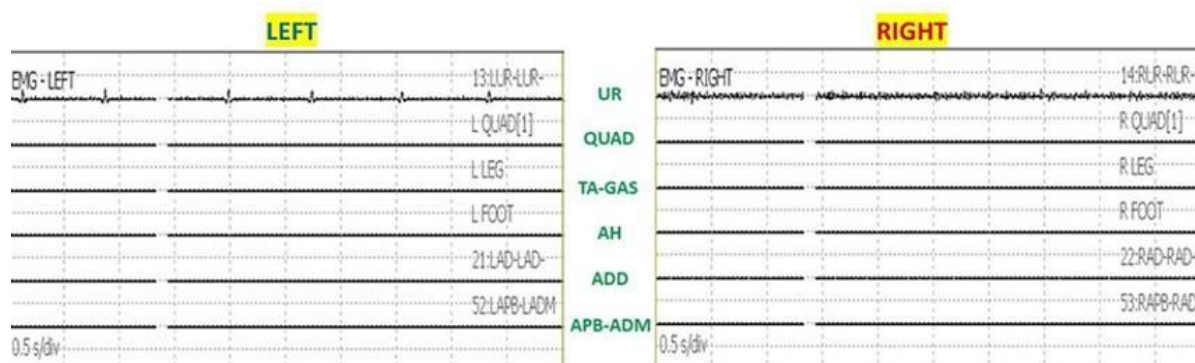


Figure 2. Electromyography (EMG); UR: Upper Rectus Abdominis, QUAD: Quadriceps, TA: Tibialis Anterior, GAS: Gastrocnemius, AH: Abductor Hallucis, ADD: Adductor Magnus, Abductor Pollicis Brevis, ADM: Abductor Digiti minimi.

Different types of EMG signals can be recorded during surgery. Touching a nerve root with an instrument may produce a single, biphasic, or triphasic spike, which generally does not indicate any immediate concern. However, a spike train composed of multiple spikes should be reported to the surgeon immediately, as it may signal nerve stretching, compression, or heating during the procedure. Neurotonic discharge, the most concerning type of EMG activity, usually indicates nerve injury and can correlate with postoperative deficits. Complex spike trains can

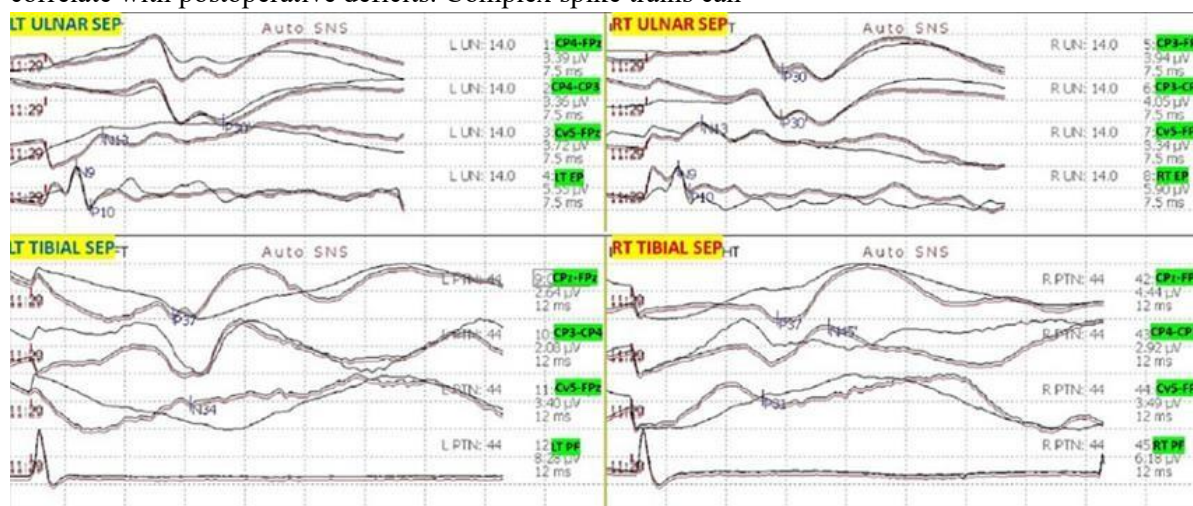


Figure 3. Baseline Somatosensory Evoked Potentials (SSEP); LT: Left, RT: Right. EP: Erb's Point, PF: Popliteal Fossa.

result from the activation of multiple muscle groups, while accidental contact with a nerve during surgery may cause burst EMG activity (Jahangiri., et al, 2014).

Somatosensory evoked potentials (SSEP) were used intraoperatively to monitor the function of the brain, brainstem, spinal cord, and peripheral nerves, as well as to ensure adequate blood flow to the central nervous system. For SSEP monitoring of the upper and lower extremities, surface adhesive stimulation electrodes were placed at the wrist (ulnar nerve) and medial malleolus (posterior tibial nerve). Constant current stimulation was applied to the peripheral nerves, with the upper limbs receiving 15-25mA and the lower limbs receiving 40-60mA, using a pulse width of 200-300 microseconds. Low-frequency filters were set to 30 Hz, while high-frequency filters were adjusted to 500 Hz for cortical recordings and 1500 Hz for subcortical and peripheral recordings. The time display was configured to 7.5 milliseconds per division for ulnar nerve SSEP and 12 milliseconds per division for tibial nerve SSEP (**Figure 3**). The SSEP modality was employed to monitor the integrity of the spinal cord's ascending pathways within the dorsal-median column, providing real-time feedback to the surgeon on the condition of these pathways. Subdermal needle electrodes for SSEP recording were placed according to the international 10-10 system at CP3 (C3'), CP4 (C4'), CPz (Cz'), FPz, Cv5, Erb's Point (EPF), and the Popliteal Fossa (PF). The alarm criteria to immediately alert the surgeon were defined as a 10% or greater increase in latency or a 50% decrease in cortical amplitude (Macdonald DB., et al, 2013).

Alarm Criteria were established as follows:

1. Mode 1 (Cortical SSEPs): Action was taken if unilateral or bilateral responses decreased by more than 50% in amplitude, with or without a corresponding increase in latency greater than 10% of reference traces.
2. Mode 2 (Cervical SSEPs): Action was required if unilateral or bilateral responses dropped by more than 50% in amplitude, with or without a corresponding increase in latency greater than 10% of reference traces.

3. Mode 3 (MEPs): If MEP-evoked compound muscle action potential (CMAP) responses in any muscle were lost and remained absent, or if there was a sudden drop in amplitude of MEP traces exceeding 80% of reference traces, these conditions were reported and investigated (Tsirikos., et al, 2020).

Many anesthetic agents can cause dose-dependent suppression of evoked potentials. It is crucial for anesthetists to select an anesthetic regimen that is compatible with the IONM modalities being used. Anesthetists must maintain a stable physiological and anesthetic environment to ensure meaningful interpretation of signal changes and accurate surgical guidance. If true signal changes are detected, anesthetists should be aware of potential non-surgical causes of neural injury and be prepared to act promptly to mitigate further insults and secondary injuries. The use of IONM may introduce risks to the patient, so anesthetists should implement appropriate precautions to safeguard against these risks (Wing-hay & Chun-kwong, 2019).

(a) Volatile agents

Inhalational anesthetic agents cause a dose-dependent decrease in the amplitude and an increase in the latency of evoked responses. For somatosensory evoked potentials (SSEP), these effects are more pronounced on cortical responses compared to subcortical and peripheral responses. Typically, adequate SSEPs can be recorded at less than 1 minimum alveolar concentration of inhalational agents. However, in patients with pre-existing neurological impairments or neuropathy due to systemic diseases, even lower levels of inhalational agents may eliminate potential recordings, making monitoring difficult.

MEPs are affected by even lower concentrations of volatile agents, as these agents more profoundly suppress lower motor neuron excitability. On the other hand, brainstem auditory evoked potentials (BAEPs) and EMG are relatively resistant to the effects of inhalational agents (Lotto., et al, 2004).

(b) Intravenous agents

SSEPs are unaffected by high doses of barbiturates, while motor evoked potentials (MEPs) are sensitive to their effects. Benzodiazepines, used at premedication doses, do not suppress SSEPs or MEPs. Ketamine can enhance both SSEP and MEP responses, which may be advantageous for monitoring when used as an adjunct to anesthesia or analgesia. Etomidate can increase the amplitude of cortical SSEP recordings without affecting peripheral or subcortical evoked potentials. There is limited research on the impact of dexmedetomidine on evoked potentials, but it has been shown that SSEPs and MEPs can be recorded at low clinical doses, though MEP recordings may be lost at higher doses.

Propofol, known for its favorable pharmacokinetic profile and titratability, suppresses both SSEPs and MEPs in a dose-dependent manner. However, this suppression is relatively minor, allowing for adequate measurements at commonly used clinical doses. Consequently, propofol is often considered the anesthetic agent of choice for facilitating IONM, particularly when MEP monitoring is involved. It is important to note that all anesthetic agents require time to equilibrate after dose adjustments. Therefore, altering the dose unnecessarily during critical phases of surgery is undesirable, as it may interfere with the interpretation of IONM signals (Dineen., et al, 2018).

(c) Opioid

Evoked potentials can be recorded even at very high doses of opioids. Consequently, short-acting, potent opioids like remifentanyl are frequently used during surgical procedures involving evoked potentials monitoring. These opioids help to reduce the overall anesthetic requirement while still allowing for effective monitoring of evoked potentials.

CONCLUSION

As spinal deformity correction and posterior spinal fusion (PSF) surgeries become increasingly complex, the integration of intraoperative neurophysiological monitoring (IONM) has become indispensable in ensuring patient safety and optimizing neurological outcomes. IONM provides real-time functional assessment of spinal cord integrity, enabling early detection and prevention of potential intraoperative neural injuries. The use of multimodal techniques, such as motor evoked potentials (MEPs), somatosensory evoked potentials (SSEPs), and electromyography (EMG), allows for comprehensive monitoring of both ascending and descending neural pathways during deformity correction procedures.

The success of IONM, however, depends greatly on multidisciplinary coordination among the surgical, anesthetic, and neurophysiology teams. Anesthesiologists play a pivotal role in maintaining a stable physiological and pharmacological environment conducive to accurate signal interpretation. The choice of anesthetic agents, particularly the use of total intravenous anesthesia (TIVA) with agents like propofol and short-acting opioids, is crucial to minimize interference with neurophysiological signals while maintaining adequate anesthesia depth.

This case reinforces that effective collaboration and communication between the surgeon, anesthesiologist, and neurophysiologist are essential to optimize surgical outcomes, minimize neurological risks, and ensure patient safety. IONM thus represents not merely a monitoring tool, but a critical component of modern spinal surgery that bridges surgical precision, anesthetic management, and neurological protection in achieving optimal functional and clinical results.

CONFLICT OF INTEREST

The author(s) declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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None

PATIENT CONSENT STATEMENT

Verbal consent was obtained from the patient for the case report

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request

GENERATIVE AI STATEMENT

The author(s) declare that no Generative AI was used in the creation of this manuscript

LIST OF ABBREVIATIONS

ADD : Adductor Magnus
ADM : Abductor Digiti Minimi

AH	: Abductor Hallucis
AIS	: Adolescent Idiopathic Scoliosis
ANT	: Anterior
APB	: Abductor Pollicis Brevis
BAEPs	: brainstem auditory evoked potentials
bpm	: Beats per minute
C1	: Cervical spinal nerve 1
C2	: Cervical spinal nerve 2
CMAPs	: Compound muscle action potentials
EMG	: Electromyography
EPF	: Erb's Point
GAS	: Gastrocnemius
Hz	: Hertz
IONM	: Intraoperative neurophysiological Monitoring
IV	: Intravenous
Kg	: Kilogram
kHz	: kilohertz
LT	: Left
mA	: Miliampere
mcg	: Microgram
MEPs	: Motor evoked potentials
mg	: Miligram
mL	: Milliliter
mmHg	: Millimeter of mercury
ms	: Milliseconds
O ₂	: Oxygen
PF	: Popliteal Fossa
PSF	: Posterior Spinal Fusion Surgery
QUAD	: Quadriceps
RL	: Ringer's Lactate
RT	: Right
s-EMG	: spontaneous EMG
SpO ₂	: Peripheral oxygen saturation
SSEPs	: Somatosensory evoked potentials
t-EMG	: triggered EMG
TA	: Tibialis Anterior
TCeMEP	: Transcranial electrical Motor Evoked Potentials
UR	: Upper Rectus Abdominis

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