STUDENTS CORNER

The Science Behind TCeMEPs: Transcranial Electrical Motor Evoked Potentials. Part 2

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ABSTRACT

Transcranial motor evoked potentials (TCeMEPs) are an essential modality for intraoperative neurophysiological monitoring (IONM) that provides immediate feedback on the functional integrity of the corticospinal tract. In Part 1, we discussed how TCeMEPs offer a dynamic, real-time perspective on the motor system during surgery. This article delves into the physiology of TCeMEPs, focusing on waveform analysis, targeting muscles by spinal level, and the clinical significance of signal changes during surgery. Considering intraoperative conditions and indications, we highlight that TCeMEPs are valuable tools for preventing permanent motor injury and enhancing surgical outcomes. A deeper understanding of TCeMEP dynamics promotes collaboration among surgical teams and strengthens the use of neuromonitoring to protect patients further.

INTRODUCTION

Interpreting TCeMEP Waveforms

TCeMEPs are recorded from muscle rather than nerves, following transcranial stimulation of the motor cortex. After delivering a stimulus through electrodes placed on the scalp, compound muscle action potentials (CMAPs) are captured from specific muscles, providing a functional assessment of the descending corticospinal tract. The resulting waveforms are brief bursts of electrical activity, with amplitude and latency characteristics that vary by muscle and individual neuromuscular physiology.

Unlike sensory-evoked potentials, TCeMEPs are not averaged across multiple stimuli; each waveform corresponds to a single stimulus, offering immediate insights. Interpretation primarily focuses on the presence or absence of a response, significant amplitude changes, and the waveform's stability over time. Even under stable anesthesia, minor variations in waveform shape or size can indicate potential compromise of the motor pathway before any clinical symptoms manifest [1].

Target Muscles and Their Cranial and Spinal Levels

Transcranial electrical motor evoked potentials (TCeMEPs) are recorded from multiple muscle groups at various cranial and spinal cord levels to provide a thorough intraoperative assessment [2]. This multi-level monitoring approach enables clinicians to detect potential neurological compromise due to impending injury or perfusion deficits and take timely corrective action to preserve motor function.

Below is a detailed table outlining motor evoked potential (MEP) recording sites, including their muscle, function, innervation, and nerve root levels, spanning cranial muscles, upper limbs, and lower limbs.

Muscle	Region	Primary Function	Innervation	Nerve Root Level
Masseter	Cranial Muscles	Jaw closure, mastication	Trigeminal nerve	CN V
Orbicularis Oculi		Eyelid closure, facial expression	Facial nerve	CN VII
Orbicularis Oris		Lip movement, speech articulation	Facial nerve	CN VII
Mentalis		Chin movement, lower lip protrusion	Facial nerve	CN VII
Soft Palate (Levator Veli Palatini)		Elevation of the soft palate during swallowing and speech	Glossopharyngeal nerve	CN IX
Vocal Cords		Voice modulation, speech production	Vagus nerve	CN X
Sternocleidomastoid		Head rotation, neck flexion	Accessory nerve	CN XI
Tongue (Genioglossus)		Tongue movement, swallowing	Hypoglossal nerve	CN XII
Biceps Brachii	Upper Limb	Forearm flexion, supination	Musculocutaneous nerve	C5–C6
Triceps Brachii		Elbow extension	Radial nerve	C7–C8
Flexor Carpi Radialis		Wrist flexion, radial deviation	Median nerve	C6–C7
Abductor Pollicis Brevis		Thumb abduction	Median nerve	C8–T1
First Dorsal Interosseous		Finger abduction	Ulnar nerve	C8–T1
Vastus Medialis	Lower Limb	Knee extension	Femoral nerve	L2–L4
Tibialis Anterior		Ankle dorsiflexion	Deep peroneal nerve	L4–L5
Gastrocnemius		Ankle plantarflexion	Tibial nerve	S1–S2
Gluteus Maximus		Hip extension	Inferior gluteal nerve	L5–S2
Abductor Hallucis		Toe abduction, foot stabilization	Medial plantar nerve	S1–S2
External Anal Sphincter	Pelvic Muscles	Voluntary control of defecation	Pudendal nerve	S2–S4
External Urinary Sphincter		Voluntary control of urination	Pudendal nerve	S2–S4

Table 1. Common muscles used in TCeMEP monitoring and their corresponding nerve root levels, crucial for clinical and intraoperative neurophysiological monitoring.

By observing the upper and lower limbs separately, one can determine whether the changes in TCeMEPs are systemic (global) or local (focal), thereby affecting intraoperative troubleshooting and decision-making.

What Signal Changes Mean in Practice

Abrupt reduction or loss of TCeMEP signals typically indicates disruption in the corticospinal pathway. It is caused by spinal cord ischemia, mechanical compression, or instrumentation with direct trauma. Systemic conditions such as hypotension or inordinate administration of neuromuscular blockers can also produce signal deterioration [2]. Patterns of signal change are significant: an all-muscle loss may represent an anesthetic or perfusion issue, whereas loss restricted to the lower limbs may reflect local cord compromise at the level of the thoracolumbar junction [3].

When these alterations occur, the neurophysiological monitoring team typically acts promptly and alerts the surgeon. These intraoperative interventions can critically affect the patient's neurological postoperative outcome.

CASE STUDY

The Critical Role of TCeMEPs in Spinal Deformity Correction

A Case in Point

Consider a spinal deformity correction surgery where transcranial electrical motor evoked potentials (TCeMEPs) were reliable at baseline for both upper and lower limbs. All lower limb TCeMEPs disappeared following rod placement, while upper limb signals remained intact. Recognizing this alarming change, the neurophysiologist immediately alerted the surgical team, prompting swift action. The rods were removed, and perfusion pressure was elevated, resulting in the rapid restoration of lower-limb TCeMEPs within minutes. The patient awoke without motor deficits, demonstrating the critical role of real-time neurophysiological monitoring in preventing irreversible injury.

CONCLUSION

TCeMEPs serve as a vital protective mechanism during surgeries that pose risks to motor pathways. Their ability to provide continuous, second-by-second feedback enables surgical teams to act promptly, mitigating potential neurological damage. Mastering waveform interpretation, selecting appropriate target muscles, and adapting to intraoperative changes allows clinicians to leverage TCeMEPs effectively, enhancing surgical outcomes and advancing the standard of care in neurosurgery and spine surgery.

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