

Utilizing Longer Intramuscular Needle Pair Electrodes: What are we Missing in Our Intraoperative Muscle Recordings?

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Abstract

Objective: This study illustrates the benefit of utilizing longer 18 mm, 25 mm, 37 mm and 50 mm intramuscular needle pair electrodes for recording Transcranial Electrical Motor Evoked Potentials (TCeMEP) in Rectus Femoris (RF) muscle during various surgeries in obese patients, as opposed to the regularly used 13 mm sub-dermal needle electrodes, which can miss Electromyographic (EMG) muscle activity and TCeMEP due to presence of excess adipose tissue. The 37 mm and 50 mm intramuscular needle pair electrodes have increased accuracy and reliability of TCeMEP recording at lower stimulation thresholds.

Methods: We performed a retrospective review of 13 consecutive spinal neurophysiological monitoring cases at two medical centers. Our recording setup included regular 13 mm subdermal needles and 18, 25, 37 and 50 mm long 90-degree intramuscular needle pair hook electrodes placed in right Rectus Femoris muscle. This setup was in addition to Somatosensory Evoked Potentials (SSEP), TCeMEP and EMG from upper and lower extremities. Train of four (TOF) was used as well for monitoring the level of muscle relaxant. We identified thirteen consecutive cases consisted of ten females and three males with age ranging from 22 to 75 years (median: 47 years). The TCeMEP thresholds ranged from 120 - 280 Volts (median: 160V). TCeMEP responses were recordable in all 11 patients with 37 mm hook recordings and one patient with 50 mm hook electrode recording (92.3%). However, TCeMEP were recordable only in one patient with 13 mm subdermal needle recordings (7.7%).

Conclusion: Our muscle recordings with 37 mm and 50 mm length intramuscular needle pairs were much more reliable than 13 mm subdermal in obese patients. These long intramuscular needle pair electrodes are more secure and allow for lower stimulation intensities reducing the risks of excessive TCeMEP stimulation.

Keywords: Transcranial Electrical Motor Evoked Potentials; TCeMEP; Electromyographic; EMG; Neuropathy; Electrodes; Intraoperative Neurophysiological Monitoring; IONM

Introduction

Transcranial Electrical Motor Evoked Potentials (TCeMEP) is one of the routinely performed modality during Intraoperative Neurophysiological Monitoring (IONM). TCeMEP is performed by placing subdermal needle electrodes in the muscles and recording a Compound Muscle Action Potential (CMAP) from the skeletal muscles. TCeMEP helps to evaluate the corticospinal motor pathways in real-time during high-risk spine, brain, brainstem, and peripheral nerves surgeries. TCeMEP also helps identification of intraoperative ischemic changes in the motor cortex, brainstem or peripheral nerves. Early identification of these changes and immediately reported to the surgeon helps the surgeon to make necessary corrective actions intraoperatively and minimizing any post-operative neurological deficits.

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TCeMEP has also been reported as an effective way to monitor for intraoperative detection of a spinal cord injury, and a multimyotomal TCeMEP is highly sensitive and specific in showing injury to the spinal nerve root [1]. The femoral nerve along with other vital structures are at risk of being injured during spinal surgeries. Previous studies have shown monitoring of the lower extremity muscles during spinal surgeries can be used to identify and preserve the nerve roots. The femoral nerve is part of the lumbar plexus which is formed by the L2-L4 nerve roots and emerges to innervate the quadriceps, iliacus, sartorius, and pectineus muscles [2]. Therefore monitoring of the femoral nerve can be used to predict the preservation of quadriceps muscles function and postoperative outcomes.

It is challenging to record TCeMEP in patients under anesthesia and requires specific anesthetic regimen [3]. The dipole electric fields generated by CMAP in response to transcranial stimulation attenuate exponentially with distance from the generator muscle. One of the common reasons for the signal attenuation is the amount of the extra adipose tissue around the recorded muscle [4]. To improve the accuracy and reliability of TCeMEP recordings in patients with high Body Mass Index (BMI) we decided to utilize longer intramuscular needle pair electrodes for recording TCeMEP responses. The longer needles yield more robust and polyphasic TCeMEP responses than the regular shorter subdermal needles. These longer needles are insulated except for the exposed tips part. They are available in 30-degree or 90-degree angles. They can reach muscles in ranges from 4.5 mm to 50 mm. These longer needles, when placed intramuscularly, are more secure due to their depth.

This study illustrates the benefit of utilizing longer 37 mm and 50 mm intramuscular needle pair electrodes for recording Transcranial Electrical Motor Evoked Potentials (TCeMEP) in Rectus Femoris (RF) muscle during various surgeries in obese patients, as opposed to the regularly used subdermal 13 mm needle electrodes. The regularly used 13 mm subdermal needle electrodes can miss Electromyographic (EMG) muscle activity and TCeMEP due to the presence of excess adipose tissue in patients with higher BMI. The 37 mm and 50 mm intramuscular needle pair electrodes increased accuracy and reliability of TCeMEP recording at lower stimulation thresholds.

Case Study

Methods

Patient's history

We performed a retrospective review of 13 spinal neurophysiological monitoring cases at two medical centers. The patients consisted of ten females and three males with ages ranging from 22 to 75 years (mean: 47 years). The primary diagnosis for these patients is listed in table 1.

Diagnosis	Number of patients
Spinal stenosis	3
Spinal tumor	3
Spondylolisthesis	3
Scoliosis	1
Kyphosis	1
Spinal Fracture	1
Ankylosing spondylitis	1
Total	13

Table 1: Patients preoperative diagnosis.

Anesthesia

An appropriate anesthesia protocol is required when utilizing multimodality IONM to avoid any inhibitory effects on the signals. A Total Intravenous Anesthesia (TIVA) with no neuromuscular blocking agent is highly recommended when recording intraoperative TCeMEP [3]. TIVA with propofol and remifentanyl infusion was administered to all patients with only a short-acting neuromuscular blocking agent

for intubation [5]. The level of muscle relaxation was recorded by Train of Four (TOF) monitoring technique by stimulating the posterior tibial nerves at medial malleolus and recording from the corresponding abductor hallucis (AH) muscles in the feet [6]. The vital signs monitoring was done at a regular interval during the surgical procedure including the Mean Arterial Pressure (MAP), temperature and carbon dioxide (CO₂) levels.

Intraoperative Neurophysiological Monitoring (IONM)

This study was performed to illustrate the benefit of utilizing longer intramuscular needle pair electrodes (Figure 1) for recording TCeMEP in Rectus Femoris (RF) muscle during various surgeries in obese patients, as opposed to the regularly used 13 mm subdermal needle electrodes, which can miss TCeMEP and EMG muscle activity due to presence of excess adipose tissue.

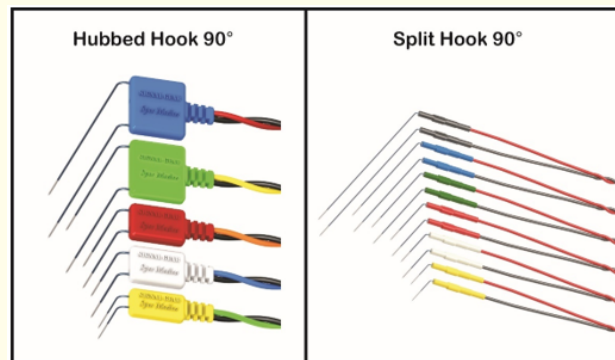


Figure 1: 90-degree hook electrodes (Left: Hubbed, Right: Split). Blue: 50 mm, Green: 37 mm, Red: 25 mm, White: 18 mm and Yellow: 13 mm long intramuscular needle pair electrodes (Reprinted with permission from Signal Gear LLC, USA).

We decided to record TCeMEP from RF because of the relatively high amount of adipose tissue around the quadriceps muscles (adipose). Our recording setup included 18 mm, 25 mm, 37 mm and 50 mm long 90-degree intramuscular needle pair electrodes (Signal Gear LLC, Prosperity, SC, USA) in addition to the regular subdermal 13mm electrodes placed in right RF muscle (Figures 2 and 3). This setup was in addition to Somatosensory Evoked Potentials (SSEP), TCeMEP and EMG from all four extremities muscles. A 32-channel Medtronic NIM-Eclipse (Medtronic, Inc., Minneapolis, MN, USA) and Cadwell Cascade Pro (Cadwell Industries Inc, Kennewick, WA, USA) IONM systems were utilized for neuromonitoring during these procedures.

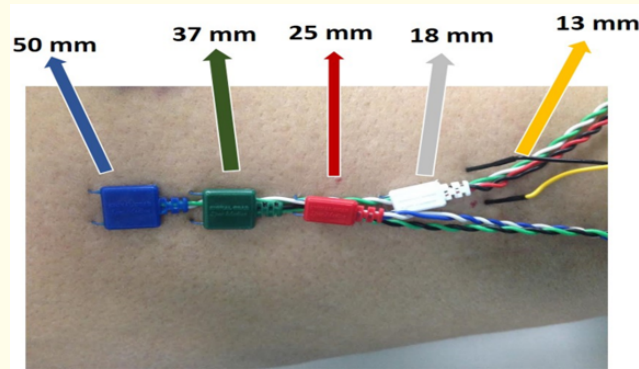


Figure 2: All electrodes placed on the right Rectus Femoris muscle. Left: Head; Right: Foot (Patient # 3).

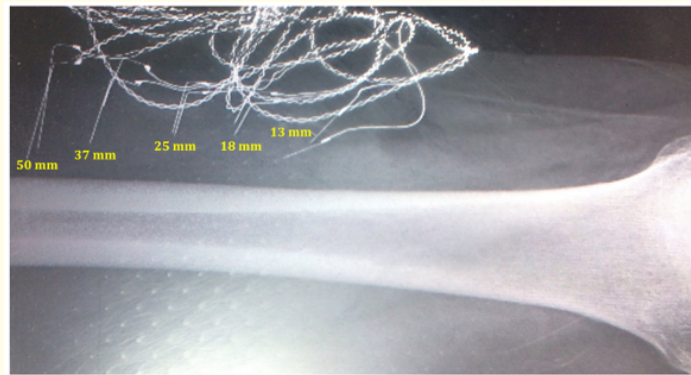


Figure 3: Post-operative X-ray of right thigh showing femur, muscles, adipose tissues and electrodes (50 mm, 37 mm, 25 mm, 18 mm and 13 mm in length). All electrodes placed on the right Rectus Femoris muscle. Left: Hip; Right: Knee joint (Patient # 10).

Corkscrew electrodes were placed on the patient’s scalp at C1, C2, C3, and C4 for TCeMEP stimulation. A train stimulation of six to seven square-wave pulses with 75 μ sec pulse duration and 120 to 280 volts (median 160 V) intensities were utilized. EMG and TCeMEP data was recorded by placing 13mm subdermal needle electrodes in abductor pollicis brevis and abductor digitiminimi (upper extremities) and adductor brevis, rectus femoris, tibialis anterior, gastrocnemius, abductor hallucis (lower extremities) and anal sphincter muscles. The recording sweep was set at 10 ms per division for TCeMEP in all four extremities. The filter settings used for TCeMEP recordings were 10 Hz for low-frequency and 5.0 kHz for high-frequency (Figures 4-6). The alarm criteria for TCeMEP data interpretation was a combination decrease in amplitude (70% or more), morphology change and/or change in the stimulation threshold (100 Volts or more) [7,8].

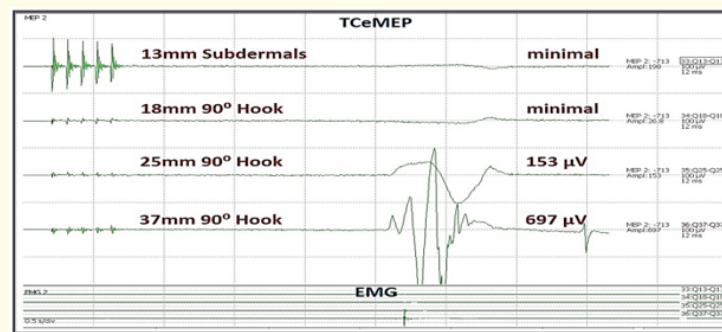


Figure 4: TCeMEP average data comparison between 13 mm subdermal, 18 mm, 25 mm and 37 mm long intramuscular hook electrodes (Patient # 2). Maximum amplitude responses were recorded with 37mm electrodes with minimum stimulation artifact.

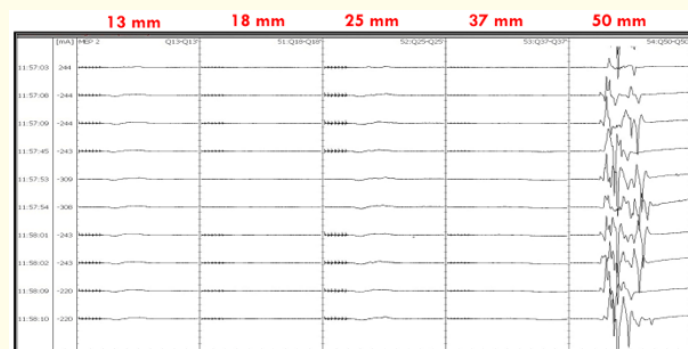


Figure 5: TCeMEP stack data comparison between 13 mm subdermal, 18 mm, 25 mm, 37 mm and 50 mm long intramuscular hook electrodes (Patient # 4). Only 50 mm length electrodes recorded TCeMEP responses with minimum stimulation artifact.

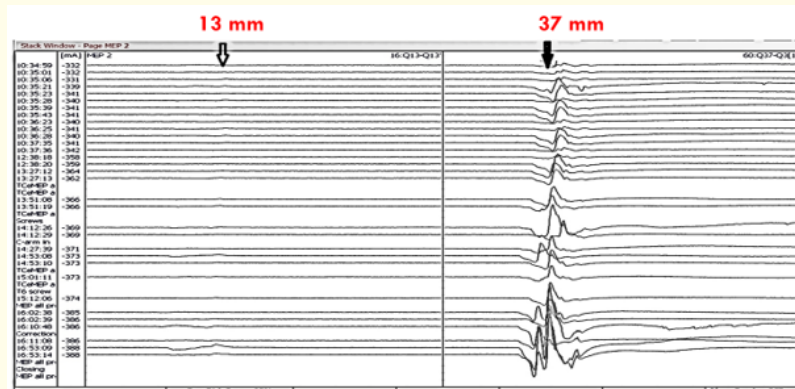


Figure 6: TCEMEP stack data comparison between 13 mm subdermal and 37 mm long 90-degree hook intramuscular hook electrodes (Patient # 7). Only 37 mm length electrodes recorded TCEMEP responses with minimum stimulation artifact.

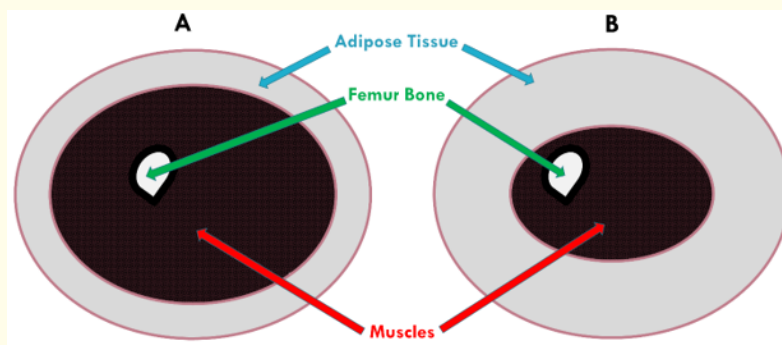


Figure 7: Schematic diagram showing a cross section of the thigh with adipose tissue surrounding the muscles and femur. (A) patient with a lower BMI and less surrounding adipose tissue. (B) patient with a higher BMI and excess surrounding adipose tissue.

Results

We identified thirteen cases. The patients consisted of ten females (76.9%) and three males (23.1%) with age ranging from 22 to 75 years (median: 47 years). Three patients had spinal stenosis, three patients had a spinal tumor; three patients had a spondylolisthesis, one of each patient had scoliosis, kyphosis, spinal fracture, and one ankylosing spondylitis (Table 1). The TCEMEP thresholds ranged from 120 - 280 Volts (median: 160V). A total of 124 TCEMEP responses were recorded in all 13 patients. The TCEMEP responses were present in 11 patients with 37 mm hook recordings and one patient with 50 mm hook electrode recordings (92.3%). On the other hand, TCEMEP were recordable from RF muscle only in one patient with 13 mm subdermal needle recordings (7.7%). The 37 mm and 50 mm intramuscular needle pair electrodes increased accuracy and reliability of TCEMEP recording at lower stimulation thresholds.

Statistical data analysis

We analyzed all TCEMEP responses recorded from subdermal and longer intramuscular 90-degree hook electrodes. The Wilcoxon signed-ranks test was used to analyze the TCEMEP data. Data analysis was performed using SPSS version 23 statistical analysis software.

A Wilcoxon Signed-Ranks Test indicated that 37 mm length needle electrodes were statistically significantly higher than 13 mm length needle electrodes with a mean difference of 244.0, $Z = 2.401$, $p < 0.05$. A Wilcoxon Signed-Ranks Test indicated that 25 mm length needle electrodes were statistically significantly higher than 18mm length needle electrodes with a mean difference of 207.3, $Z = 2.578$, $p < 0.05$. A Wilcoxon Signed-Ranks Test indicated that 37mm length electrodes were statistically significantly higher than 18mm length needle electrodes with a mean difference of 207.2, $Z=2.045$, $p < 0.05$.

Discussion

Studies have shown that nerve root injury is associated with substantial decreases in TCeMEP response amplitudes while there are constant stimulation parameters, however, during complex surgeries stimulation voltage adjustments have been used to overcome TCeMEP amplitude decreases and from anesthetic effect. Lyon, *et al.* use two patient examples with both patients undergoing surgery in the L5 region. During these operations, each patient had a 94 - 95% drop in TCeMEP amplitude in the right tibialis anterior which established the warning criteria and the voltage was increased. Post-operatively each patient had a new right foot drop that did not regain function. These examples and the further study did demonstrate that variability in amplitudes and increased in voltage may be specific to nerve root injuries. Several explanations for this include nerve root injuries are frequently partial; a higher voltage may enhance corticospinal tract activation that may lead to conduction through the remaining intact fibers [1]. It should be noted that the lower extremity muscles are innervated by multiple nerve roots which can impact the amplitude measured. It is recommended that longer needles should be used to improve sensitivity and specificity for TCeMEP monitoring during surgeries to ensure accurate readings are being done in the lower extremities rather than only increasing the stimulation voltage.

A recent study from Melachuri, *et al.* looked at 3946 patients who were obese that underwent spinal surgeries. They associated increasing BMI with an increased risk of significant postoperative complications and also stated this could be effected by position and amount of anesthetic [9]. With their population of patients, they identified that women were at a higher risk than men for perioperative complications given that women have a higher body fat percentage at around 25% compared to men at 15% which might lead women to have similar problems to obese or overweight individuals (Figure 7). It has been shown that body habitus can present difficult challenges for intraoperative neuromonitoring. If an individual has little muscle mass may incline peripheral nerve compression, and obesity can increase this risk due to body and limb weight [10]. This is due to the larger amount of adipose tissue or distance from the skin to the target muscle making it difficult to record TCeMEP responses. Kim, *et al.* have also reported obesity as one of the key factors in TCeMEP false positives [11].

In our study, we recorded TCeMEP responses from right rectus femoris muscles with regular subdermal needles as well as longer intramuscular needles. The responses in longer needles were higher amplitude, polyphasic morphology, and lower stimulation intensities. The stimulation artifact was minimal in longer needles compared to the 13 mm subdermal needles. The difference in amplitude was statistically significant between these electrodes in obese patients. The length of 25 mm, 37 mm and 50 mm electrodes is higher than the regularly used 13 mm subdermal needle electrodes. This is beneficial in obese patients for reaching the target muscles being recorded.

Conclusions

In this study, TCeMEP recordings from rectus femoris muscles with longer 37 mm and 50 mm length intramuscular needle pairs were much more reliable than regular 13 mm subdermal needles in obese patients. Longer electrodes can reach the deeper muscles and due to their non-insulate tip much deeper and away from skin produce minimum stimulation artifact. These long intramuscular needle pair electrodes are more secure, have minimal stimulation artifact and allow for lower TCeMEP stimulation intensities, with higher recorded amplitude responses. TCeMEP recordings in general from rectus femoris muscles in proximal lower extremities are more difficult to obtain. Selecting a longer 25 mm, 37 mm or 50 mm intramuscular electrodes for patients according to their BMI could be very beneficial for obtaining a higher amplitude TCeMEP responses.

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