*CASE REPORT*

# Intraoperative Neurophysiological Monitoring (IONM) During Peripheral Nerve Hand Surgeries

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## ABSTRACT

Intraoperative Neurophysiological Monitoring (IONM) plays a crucial role in peripheral nerve surgeries by providing real-time feedback on the functional integrity of nerves during surgical procedures. IONM helps identify the nerves and minimize the risk of nerve damage, a significant concern in hand surgeries due to the complex network of nerves involved. By continuously monitoring the electrical activity of nerves, surgeons can make informed decisions, thereby improving surgical outcomes and reducing postoperative complications. IONM techniques commonly used in these surgeries include electromyography (EMG), motor evoked potentials (MEPs), and somatosensory evoked potentials (SSEPs). These techniques allow for identifying and protecting critical nerve structures, particularly in delicate or high-risk procedures. Integrating IONM in peripheral nerve surgeries enhances the surgical intervention's precision and significantly improves patient safety and recovery.



## CASE PRESENTATION

A 34-year-old male patient suffered a crushing injury to his right hand two years ago, resulting in compartment syndrome. Compartment syndrome occurs when increased pressure within a tightly bound myofascial space leads to decreased perfusion, tissue ischemia, and eventual necrosis [1-4]. Following the initial injury, Carpal tunnel and proximal forearm release surgeries were performed. Still, despite these interventions, the patient reported a complete lack of sensation in the right palm, index, and middle fingers, indicating significant distal median nerve dysfunction. However, according to the preoperative assessment information obtained from the patient's chart, some motor function was observed in the fingers during an assessment.

The median nerve is one of the five terminal branches of the brachial plexus and receives contributions from the C5 to T1 anterior rami. The median nerve is a mixed sensory and motor nerve. Therefore, it provides motor innervation to the flexor muscles of the forearm and hand while providing sensory innervation to the dorsal aspect (nail bed) of the distal first two digits of the hand, the palmar aspect of the thumb, index, middle, and half of the ring finger [5,6].

The patient's hand was injured while operating the machinery at work. The surgery was performed at the wrist, where the previous carpal tunnel and proximal forearm release surgeries were performed. The surgeon planned to identify and preserve the sensory fibers of the median nerve for nerve grafting, a reconstruction surgery in which a nerve graft and its extra neural support tissue are attached between the damaged ends of a nerve. The graft acts as a conduit facilitating the regeneration of proximal axons towards the distal nerve stump to restore end-organ function. The graft also provides viable Schwann cells that aid axonal regeneration [7,8].

As part of the surgical plan, a multimodality Intraoperative Neurophysiological Monitoring (IONM) protocol was employed to monitor the neural function and integrity of the hand's nerves and surrounding structures. IONM protocol was designed to provide accurate interventions during surgery and improve patient outcomes by altering the surgery course based on IONM data [9]. The IONM protocol included the following:

- **Dermatomal Sensory Evoked Potentials** (DSEP) were used to assess irregularities within the somatosensory tract by recording cerebral responses elicited from cutaneous stimulation of areas of known dermatomal innervation [10]. The surgery was performed in the carpal tunnel area of the right wrist, which made it impossible to place median or ulnar nerve stimulation there. In this case, DSEP was conducted by placing adhesive surface electrodes distal to the surgical site at the palmar surface of the right middle finger, corresponding to the C7 dermatome (Figure 1). The stimulation parameters were 200 microseconds pulse width and 2.66-3.79 Hz stimulation repetition rate. The recording subdermal needle electrodes were placed on the scalp according to the international 10-20 system at FPz, CP3, and CP4. Subdermal needle electrodes were also placed at Cv5 ($5^{th}$ cervical vertebra), left and right Erb's point. The recording setup included a 30 Hz high-pass filter and a low-pass filter of 500 Hz for cortical and 1500 Hz for subcortical and peripheral responses. The recording sweep was 7.5 ms/division (Figure 2).

- **Somatosensory Evoked Potentials** (SSEP) were utilized. SSEP evaluates the integrity of sensory pathways by recording signals to the somatosensory cortex evoked by electrical stimulation of peripheral nerves [11-13]. SSEP of both upper extremities was recorded bilaterally. Left-hand SSEP was performed by stimulating the left median nerve at the wrist. Meanwhile, right-hand SSEP was performed as DSEP by stimulating the palmar surface of the right middle finger (Figure 2). The stimulation parameters were 200 microseconds pulse width and 2.66-3.79 Hz stimulation repetition rate. The recording subdermal needle electrodes were placed on the scalp according to the international 10-20 system at FPz, CP3, and CP4. Subdermal needle electrodes were also placed at Cv5 (5th cervical vertebra), left and right Erb's point. The recording setup included a 30 Hz high-pass filter and a low-pass filter of 500 Hz for cortical and 1500 Hz for subcortical and peripheral responses. The recording sweep was 7.5 ms/division.

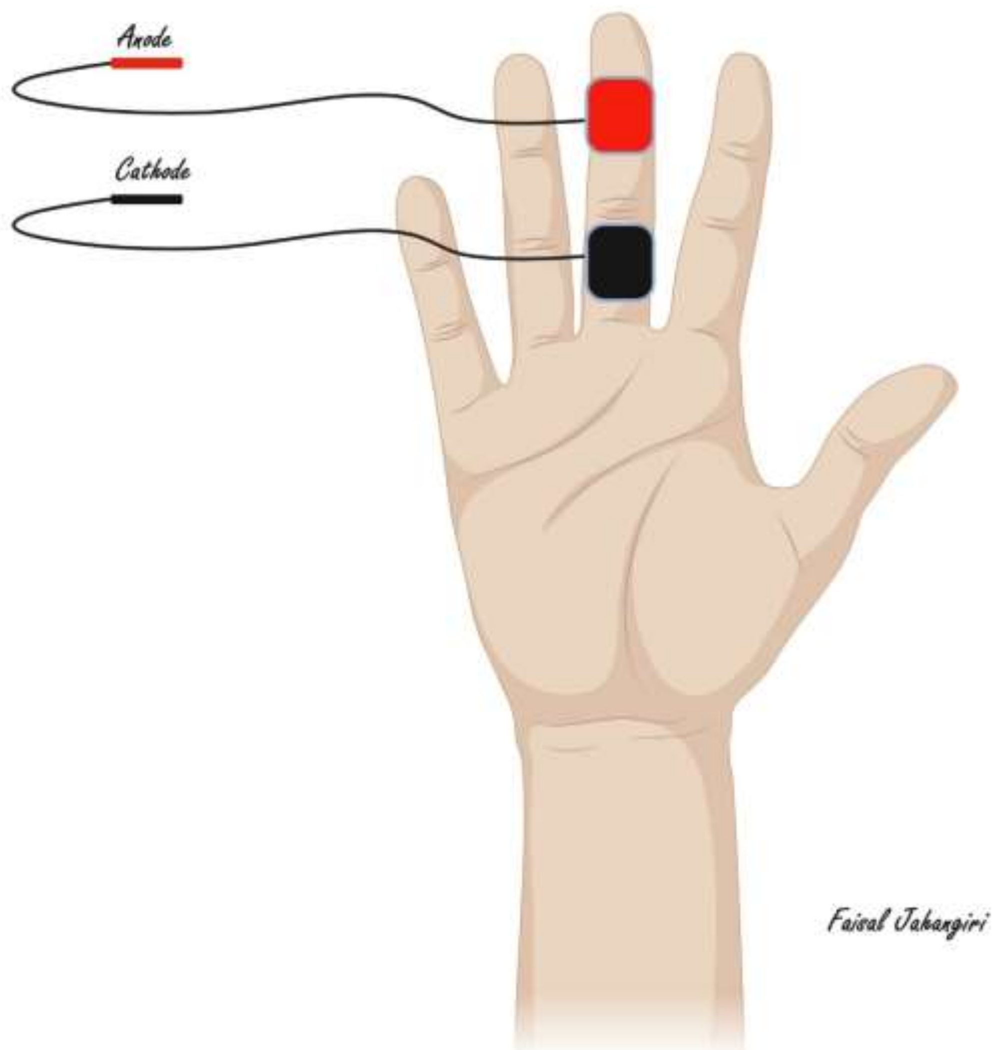


**Figure 1.** Illustration of the placement of the surface adhesive electrode on the middle finger of the right hand for the stimulation of the C7 nerve root. Distal anode (+) and proximal cathode (-).

- **Electromyography** (EMG) of the median and ulnar nerves involves electrically stimulating a nerve and measuring muscle action potentials from myotomes innervated by nerve roots near the stimulated instrument [14]. In the right hand, subdermal needle electrodes were placed in lumbricals, opponens pollicis, abductor pollicis brevis, flexor pollicis brevis, and abductor digitiminimi muscles. The left hand was used as a control with subdermal needle electrodes placed in the abductor pollicis brevis and abductor digitiminimi muscles. A monopolar and a bipolar concentric probe were used for the triggered EMG recordings. The sweep for spontaneous EMG (s-EMG) was set to 300 ms/division; the triggered EMG (t-EMG) was set to 10 milliseconds/division. A 10-5000 Hz bandpass filter was used to record EMG (Figure 3).

- **Transcranial Motor Evoked Potentials** (TCeMEP) were used to monitor motor pathway integrity by recording muscle action potentials evoked by transcranial motor cortex stimulation [15]. TCeMEP of both upper extremities was recorded bilaterally). In the right hand, subdermal needle electrodes were placed in the lumbricals, opponens pollicis, abductor pollicis brevis, flexor pollicis brevis, and abductor digitiminimi muscles. The left hand was used as a control with subdermal needle electrodes placed in the abductor pollicis brevis and abductor digitiminimi muscles. Transcranial stimulation was performed by placing corkscrew electrodes on the scalp at C1, C2, C3, and C4 according to the international 10-20 system. The stimulation was done by 50 and 75 microseconds pulse width, 5-7 pulses, and an interstimulus interval of 2.1-3.7 milliseconds. The sweep for TCeMEP was set to 10 milliseconds/division. A bandpass filter of 10-5000 Hz was used for recording EMG.

The anesthetic regimen utilized involved less than 0.5 MAC of Sevoflurane, with no muscle relaxation administered after intubation.

Baseline SSEP was detected in the left hand but not in the right hand. TCeMEP responses were present in the left hand but absent in the right hand at the baseline. After the patient was exposed and 90 minutes into the procedure, the t-EMG in the right hand was not detectable at 0.5 mA. The stimulation was increased to 4.0 mA, but no response was recorded. The surgeon was consulted to troubleshoot, and the tourniquet was recommended to be removed from the right arm. Fifteen minutes after removing the tourniquet, a t-EMG response was detected at the baseline 0.5 mA threshold (Figure 3). Additionally, right-hand DSEP and TCeMEP from all the right-hand muscles were successfully recorded. T-EMG responses were observed at 0.5 mA through direct monopolar nerve stimulation. The surgeon received real-time feedback throughout the procedure.

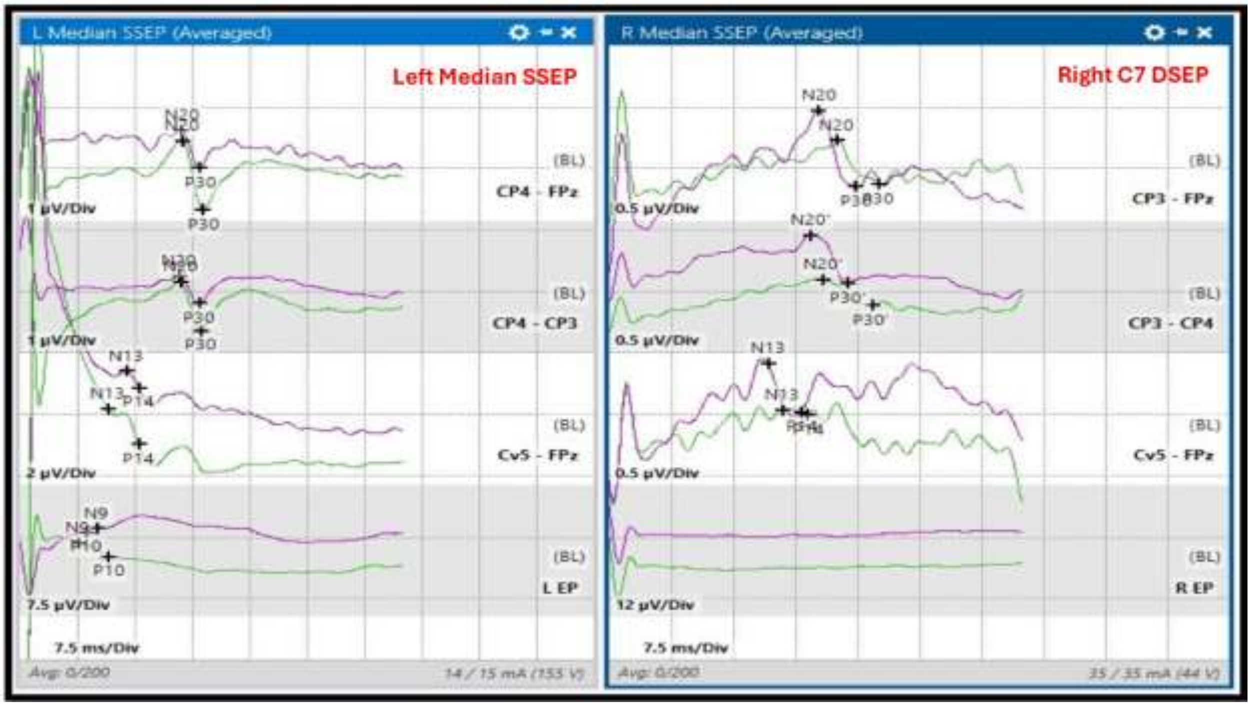


**Figure 2.** Left Median Nerve SSEP and Right C7 Dermatomal SSEP (Median nerve) with cortical (CP4-FPz, CP3-FPz), transcortical (CP4-CP3, CP3-CP4), subcortical (Cv5-FPz) and peripheral responses (Left Erb'-Right Erb's) responses. Baseline responses (Green) and the final trace (Purple). C7= cervical root 7 (middle finger), DSEP= dermatomal SSEP.

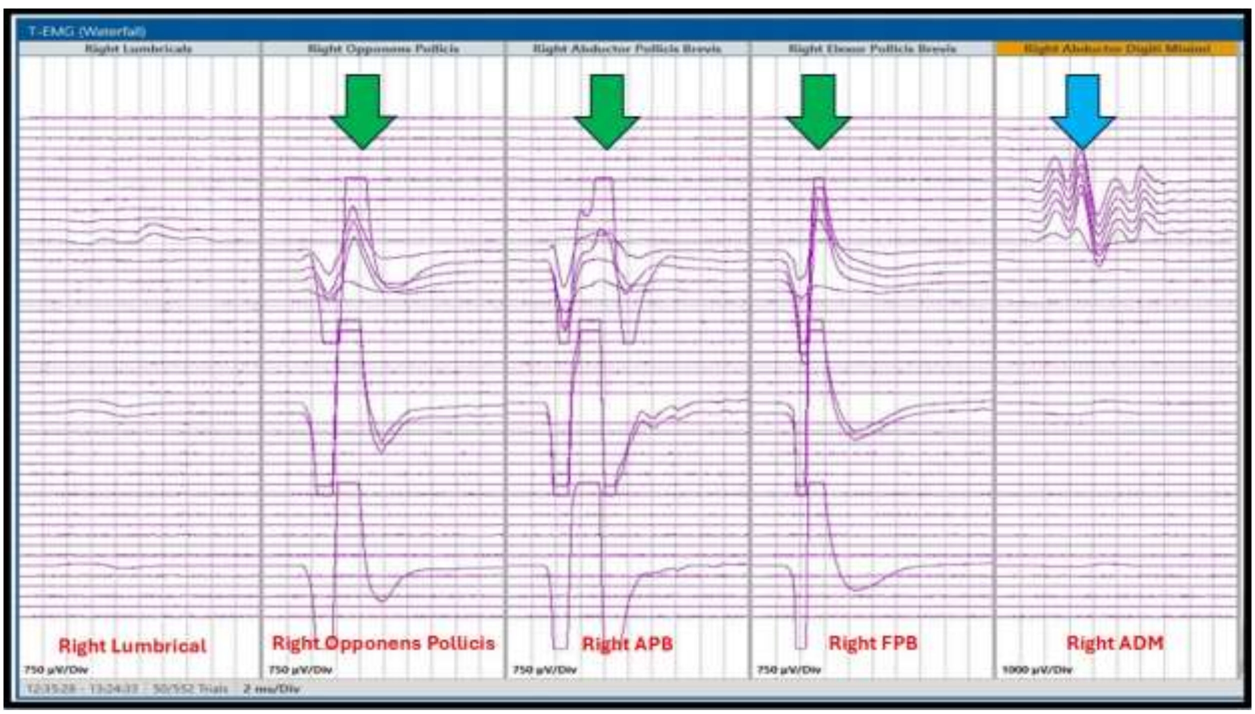


**Figure. 3.** Triggered Electromyography (t-EMG) responses from hand muscles supplied by the median nerve (Green arrows) and ulnar nerve (Blue arrow). Muscle recorded from the right-hand lumbricals, opponens pollicis, APB= abductor pollicis brevis, FPB=flexor pollicis brevis, and ADM=abductor digitiminimi.

Throughout the neurolysis procedure, reproducible and recordable right DSEPs from the index finger were observed. A few minutes after removing the tourniquet, the surgeon was informed about the presence of DSEP, which remained stable until closing. The amplitude was smaller, and the latency was longer compared to the SSEP responses of the left hand (Figure 3). The DSEP latency in the right finger was a few ms longer than the left-hand median nerve stimulation because of the more distal stimulation site and longer distance between the stimulation and recording sites for the right hand. The amplitude of the right DSEP was also smaller than the left median nerve SSEP because the right-side stimulation was activating fewer nerve fibers compared to the median nerve stimulation at the left wrist.

Both sensory and motor signals improved during the procedure (Figures 4 and 5). Observing the enhanced somatosensory responses, the surgeon opted against resecting the damaged sensory branch or performing a nerve graft. The signal remained stable until the conclusion of the surgery.

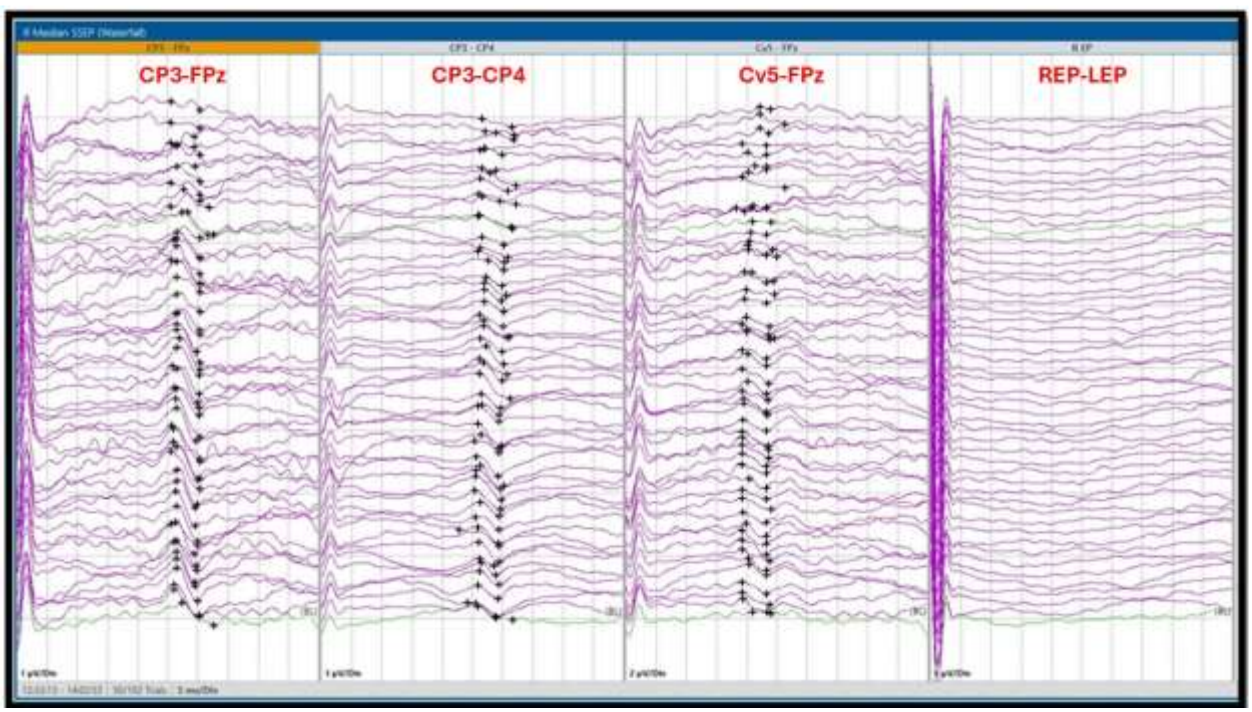


**Figure 4.** Right C7 Dermatomal SSEP (Median nerve) responses in a stack with absent baseline (Red arrow) and reproducible closing responses (Blue arrow). Stack view of cortical (CP3-FPz), transcortical (CP3-CP4), subcortical (Cv5-FPz), and peripheral responses (Right Erb'-Left Erb's) responses.

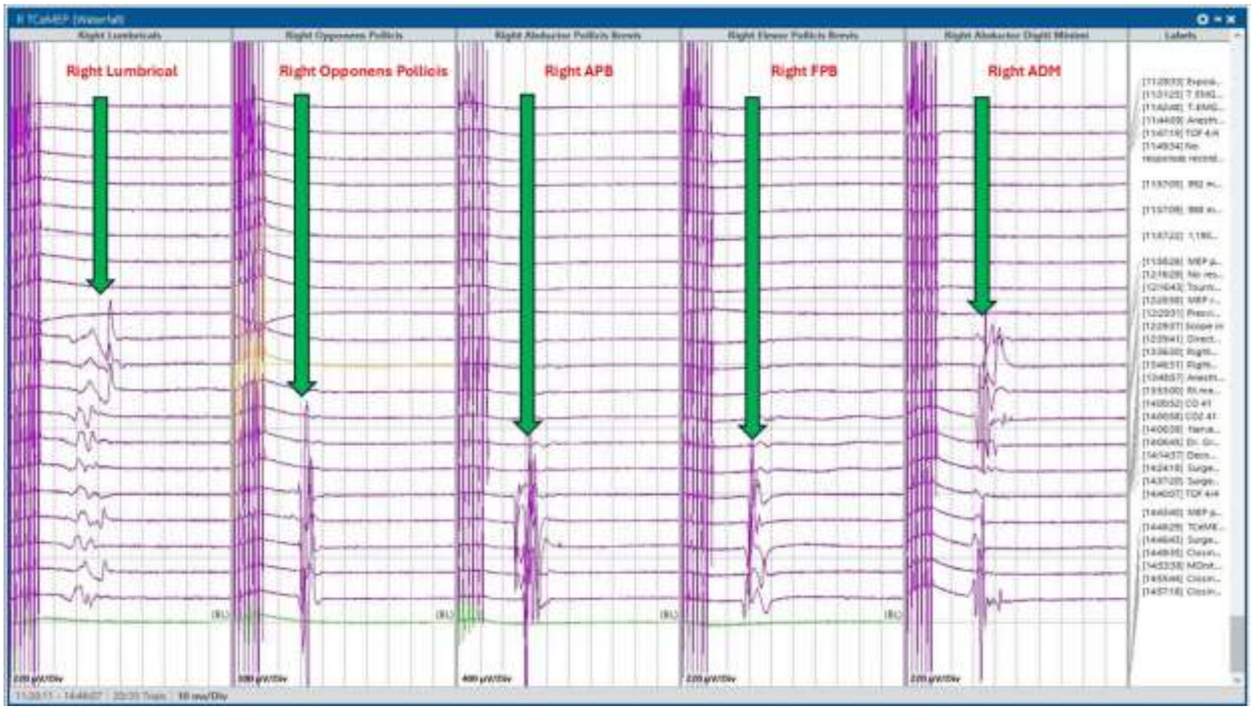


**Figure 5.** Transcranial motor evoked potentials (TCeMEP) responses from the right hand. Muscle recorded from the right-hand lumbricals, opponens pollicis, APB= abductor pollicis brevis, FPB=flexor pollicis brevis, and ADM=abductor digitiminimi. The green arrows show the appearance of late responses after removing the tourniquet.

## CONCLUSION

Throughout the peripheral nerve surgery for this patient, a multimodality intraoperative neurophysiological monitoring (IONM) was employed, incorporating SSEP/DSEP, TCeMEP, s-EMG, and t-EMG to assess neural function. Using DSEP and EMG in neurophysiological monitoring aided the surgeon in making real-time decisions during the procedure. Despite the patient experiencing sensory loss for two years, DSEP/MEP and t-EMG responses were still detectable. Based on the improved DSEP, t-EMG, and TCeMEP responses, the surgeon adjusted the treatment plan by removing the tourniquet with the aim of minimizing potential postoperative neurological deficits and optimizing patient outcomes. Furthermore, the presence of t-EMG helped mitigate potential post-operative neurological deficits. In this surgery, the procedure was performed at the wrist, but dermatomal stimulation at the distal finger site contributed to monitoring the somatosensory pathway. Continuous monitoring of nerve function is recommended during surgeries, posing a risk to peripheral nerves.

## DISCLOSURE STATEMENT

The author reported no potential conflict of interest.

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