Volume 8, Issue 1

Canadian IONM News

Official Newsletter of CANM

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CANM
CANADIAN ASSOCIATION OF NEUROPHYSIOLOGICAL MONITORING

Message from the PRESIDENT

Dear IONM professionals,

Another new year is upon us which prompts me to leave a friendly reminder for us to renew our CANM memberships! This year membership renewal is made easy by using the CANM website. A number of improvements have been made to the website and I encourage members and non-members alike to check it out. Please help support your professional organization by joining CANM.

To continue my gentle prompting, I also would remind readers to mark the 2019 CANM Symposium on their calendars (September 20 and 21). This year the meeting is being hosted in beautiful Winnipeg, Manitoba home to the NHL Winnipeg Jets, The Canadian Human Rights Museum and the windiest corner in Canada, Portage and Main. September is a beautiful time of year in Winnipeg and visitors will be rewarded with kilometers of river pathways and an abundance of patios to keep hydrated! We also hope that the academic program will prove to be in the tradition of excellence established by previous CANM symposia.

I am heading into the final year of my tenure as CANM President and I feel that our association has accomplished a great deal but at the same time much still remains to be addressed. This no doubt represents a state of dynamic equilibrium common to many organizations. I do know that the strength of CANM depends on all its members. If you are a former member we would love to have you back or to keep in touch through attendance at the Symposium. We may not agree on every issue but resolution or acceptance only comes through dialogue. Through this dialogue an exchange of ideas and experience can be nurtured and professional growth facilitated. Everyone's ideas and experiences are valuable. As Canadian IONM practitioners we probably have much more in common than not.

I hope to see many of you in Winnipeg this September.

Until then,

Marshall Wilkinson BSc (Hon), MSc, PhD
President, CANM & Neurophysiologist
Section of Neurosurgery
Health Sciences Centre, Winnipeg, MB

Winnipeg 2019 20-21 SEPT

The intraoperative neurophysiology team at the Health Sciences Centre in Winnipeg, Manitoba would like to invite our colleagues to the CANM Symposium September 20 and 21, 2019. Just north of the geographic centre of North America, Winnipeg is equidistant to almost everywhere and we hope this proximity encourages an enthusiastic attendance for the meeting. The CANM symposium has established a reputation for being an openly interactive forum that has been well received by both Canadian and American IONM practitioners. We have endeavoured to create a program that will continue with this tradition.

This year's program includes contributions from local experts as well as members of our community from the rest of Canada and the US. Included in the program is the always popular IONM Case Presentations. We thank all of our speakers for contributing to the symposium agenda. Of note, we are pleased to have Dr. Stan Skinner from Abbott Northwestern Hospital as our keynote speaker this year. We would also like to thank our corporate sponsors and the Section of Neurosurgery for their generous financial support for the meeting.

For those that wish to take in some local attractions I recommend a visit to The Forks National Historic site. The Forks is only minutes away from the Symposium hotel by taxi or a 15 minute walk. The site is formed by the confluence of the Red and Assiniboine Rivers and was a special meeting area for Indigenous peoples of the past and continues to be so to this day. The Forks also has shopping and restaurants for those seeking to satisfy their consumptive urges! The Canadian Museum of Human Rights is also at The Forks and is highly recommended.

The Forks National Historic Site. Image courtesy of Tourism Winnipeg.

A final thank you goes out to Karissa Rosen, Kristine Pederson and Jeremy Spence for their ongoing investment of time and energy to make the symposium possible.

On behalf of the local symposium organizing committee and CANM **bienvenue a Winnipeg tout le monde!**

Marshall Wilkinson BSc (Hon.), MSc, PhD
President, CANM

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YEAR 1 **September 2019 to August 2020**

1	Clinical Sciences for IONM	SEP - DEC
2	Basic Principles of IONM	JAN - APR
3	IONM Modalities I	APR - JUL

YEAR 2 **September 2020 to August 2021**

4	IONM Modalities II	SEP - DEC
5	Considerations for IONM	JAN - APR
6	Advanced Topics in IONM	MAY - AUG

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A strategy to avoid false negative MEP results during cerebral aneurysm surgery

Marshall Wilkinson[1,2], Karissa Rosen[2], Kristine Pederson[2] and Jeremy Spence[2]

[1]President CANM
[2]Section of Neurosurgery
Health Sciences Centre
Winnipeg, MB

In 2017 an article was published in the Journal of Neurosurgery (1) describing a case series of surgical clippings for cerebral aneurysms with the patients awake and locally anesthetized. The author's rationale for the awake procedure was that neurophysiological monitoring techniques were often inadequate in detecting developing ischemia. In their report they used clinical assessment of the patient's neurologic status plus neuromonitoring using EEG, SEP and MEP. During clipping maneuvers they observed 6 incidences of clinically manifest ischemia (motor weakness) where in 3 of these patients there were no MEP changes despite hemiparesis detected with physical examination. To these authors their evidence confirmed their hypothesis that false negatives were an unfortunate drawback to relying on neurophysiological monitoring with patients under general anesthesia and that physical assessment under local was one way to avoid ischemic events during aneurysm clipping. They did not, however, provide an explanation for why the neuromonitoring failed to detect the ischemia. Upon studying their data it was, however, obvious to us what had happened in their study. We outlined our explanation in a Letter to the Editor (2). In short EEG and SEP can easily miss ischemic changes occurring in the motor cortex or internal capsule. MEPs, if performed diligently, should detect ischemic loci in the motor pathway. Why did Abdulrauf *et al.*, (1) fail to detect the developing ischemia neurophysiologically? The most likely answer was that stimulation of the motor pathway was occurring below the ischemic area thereby producing false negative MEPs.

False negative MEP have been described in the literature (3,4) but no one (until recently) has offered a strategy to limit the likelihood of committing this grievous monitoring error. We have noted the importance of measuring MEPs from ipsilateral muscles (usually intrinsic hand muscles) as an indication that stimulation is occurring too deep along the motor pathway (2). Recently, Chen *et al.*, (5) described these ipsilateral MEP as "crossover" responses in a report of 3 brain tumor cases. Chen *et al.*, proposed using a different stimulation montage to minimize so-called "crossover" responses as one method to mitigate false negative MEPs. The key finding of Chen *et al.*, is that when a stable MEP was lost in one patient during the surgery the MEP could be "restored' by increasing the stimulus intensity but only when the "crossover" response also was activated. In other words, the ipsilateral and contralateral MEP responses were being elicited at levels below the level of the brain lesion; a dreaded false negative response. This is critical evidence that validates the ipsilateral hand response as an indicator of distal motor pathway stimulation. Chen *et al.*, (5) also advocated "near-threshold stimulation" to minimize distal motor tract activation.

Our group has been studying the approach of measuring the thresholds of ipsilateral and contralateral responses and to target MEP acquisition at levels of stimulation well away from these crossover levels of stimulation. Additionally, we do these assessments using 2 MEP stimulation montages: C3-C4/C4-C3 (transcranial) and C4-Cz/C3-Cz (hemicranial).

Although preliminary we have been studying MEP activation thresholds prior to temporary or permanent clipping of cerebral aneurysms. Our protocol consists of bilateral hand MEPs plus a contralateral foot MEP measurement. Using transcranial and hemicranial stimulus montages we determine the activation thresholds for each muscle using a 75 µs pulse duration, 5 pulse train with an ISI of 1.7 - 3 ms. We used Cadwell workstations and constant voltage stimulators for MEP acquisition. We will report the data in mA of current delivered. So far the following threshold relationships have been observed between contralateral and ipsilateral hand using transcranial and hemicranial stimulation prior to aneurysm clipping in 15 patients. Predictably transcranial stimulation results in lower activation thresholds for contralateral and ipsilateral hand MEP compared to hemicranial stimulation. This is summarized in Table I. The threshold for contralateral hand MEP was 202.8 ± 15 mA (mean ± SEM) versus 451 ± 51.3 mA for ipsilateral hand activation following transcranial stimulation ($p < 0.01$, t-test, $n = 15$). Pragmatically this indicates that, on average, stimulation currents in excess of 451 mA increase the risk of distal corticospinal tract stimulation. By knowing the approximate level of stimulation that results in a "crossover" response in each patient, practitioners can minimize the risk of false negative MEP when monitoring. Alternatively, our data suggest that stimulation currents 55% greater than the contralateral hand threshold will increase the likelihood of producing false negative MEPs.

This relationship appears to hold when using the hemicranial stimulation montage. In this instance mean contralateral hand MEP thresholds were 300 ± 23 mA versus 650 ± 52 mA for ipsilateral hand responses ($p < 0.01$); a 54% difference. Equally important is that we have noted that patient movement from motor tract stimulation is less or absent using the hemicranial versus transcranial stimulation montage. This can be enormously advantageous during critical portions of an operation as it allows the neuromonitorist to acquire MEPs *ad libitum*.

The issue becomes less straight forward if obtaining upper and lower limb MEPs are a primary monitoring goal. In the transcranial stimulus configuration, the mean contralateral foot MEP activation threshold was found to be 339 ± 24 mA, bringing the stimulation intensity much closer to the mean ipsilateral hand threshold (451 ± 51 mA). While the mean values were not significantly different ($p = 0.23$, Mann-Whitney Rank Sum test) closer inspection of the data is instructive. In 4/15 patients stimulated transcranially, the mean threshold for contralateral foot MEP was identical or nearly identical to the ipsilateral hand response. Moreover, in an additional 2 patients lower limb MEPs were not obtainable even at stimulation intensities exceeding the ipsilateral hand threshold. In other words, foot MEPs were not reliably obtained about 40% of the time because of the risk of distal CST activation. This was a surprisingly high proportion of the lower limb MEP results and should be a significant motivator to find solutions, not only for our group, but for the neuromonitoring community as a whole.

When the hemicranial stimulus montage data were examined, the mean ipsilateral hand threshold was 650 ± 52 mA compared to 542 ± 43 mA for contralateral foot MEP activation. Like the transcranial results, these thresholds were not significantly different ($p = 0.08$, t-test). Also similar to the transcranial data was that the threshold for contralateral foot MEP was virtually identical to the ipsilateral hand threshold in 4 /15 patients. We also observed failure to obtain foot MEP in 2 patients. Note that MEP failures were seen in different patients depending on the stimulation montage. These preliminary data suggest that stimulation montages other than what we examined may need to be assessed in an effort to improve the ability to reliably obtain lower limb MEPs. We agree with Chen and colleagues (5) that monitorists should prepare to use at least 2 stimulation montages to maximize our abilities to make successful MEP recordings as required for each case. The configuration of these stimulation montages will depend on the goals for the neurophysiological monitoring.

Because our data is preliminary we note that the transcranial and hemicranial statistical comparisons above were under powered and thus should be viewed with caution. Nevertheless, our data strongly suggest that when lower limb MEPs are required for IONM, practitioners should be restrained with stimulation intensities and to rigorously watch for even the slightest indication of distal CST activation (ipsilateral hand MEP responses). For recording contralateral lower limb responses, acquisition obtained near the activation threshold may be one way to minimize the chance of distal CST stimulation. Recording large MEP response amplitudes is not necessarily a desired result because of the need for focal stimulation. As suggested by Chen *et al.*, (5) other stimulation montages may also be worth investigating.

These preliminary data represent an on-going study at our institution in which we are also acquiring data on facial MEP as part of our protocol for safe cerebral aneurysm monitoring. These results can also extend to cases involving IONM for other supratentorial pathologies.

Table I. Summary of MEP stimulation thresholds using transcranial (C3-C4/C4-C3) and hemicranial (C3-Cz/C4-Cz) montages in 15 patients. Data are mean ± SEM of the total stimulation current delivered.

	Transcranial stimulation montage stimulus intensity (mA)	Hemicranial stimulation montage stimulus intensity (mA)
Contralateral hand	202.8 ± 15	300 ± 23
Ipsilateral hand	451 ± 51.3	650 ± 51.7
Contralateral foot	339.2 ± 23.8	542.2 ± 43

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This section is devoted to celebrating the accomplishments of members of our Canadian IONM community and recognizing them for their contributions and achievements no matter how big or small. Please join us in congratulating the following CANM Superstars.

Are YOU a CANM Superstar?
Do you KNOW a CANM Superstar?

CANM Superstars are members of the Canadian IONM community who we would like to recognize for their contributions, but we need your help! Please send us the accomplishments that should be celebrated in the next issue of Canadian IONM News by submission to **info@canm.ca**

Samdaye Chan
Regina, SK

After 44 years of a rewarding and fulfilling career path that included IONM, Samdaye announced her retirement effective February 12, 2019. On behalf of the IONM community, we extend our appreciation for her service and send best wishes as she enters this next stage in life.

David Houlden
Toronto, ON

Retirement hasn't slowed Dave down. He continues to advance the important work he started on Visual Evoked Potentials (VEPs).

Gilaad Levy
Sunnybrook HSC, Toronto, ON

Gil has recently joined the IONM team at Sunnybrook Health Sciences in Toronto.

Samuel Strantzas
Sunnybrook HSC, Toronto, ON

Sam was an invited speaker at the Canadian Paediatric Spine Society session on February 27, 2019 during the Canadian Spine Society meeting at the Fairmont Royal York in Toronto.

Michael Vandenberk
SickKids, Toronto, ON

Mike has recently joined the IONM team at SickKids in Toronto.

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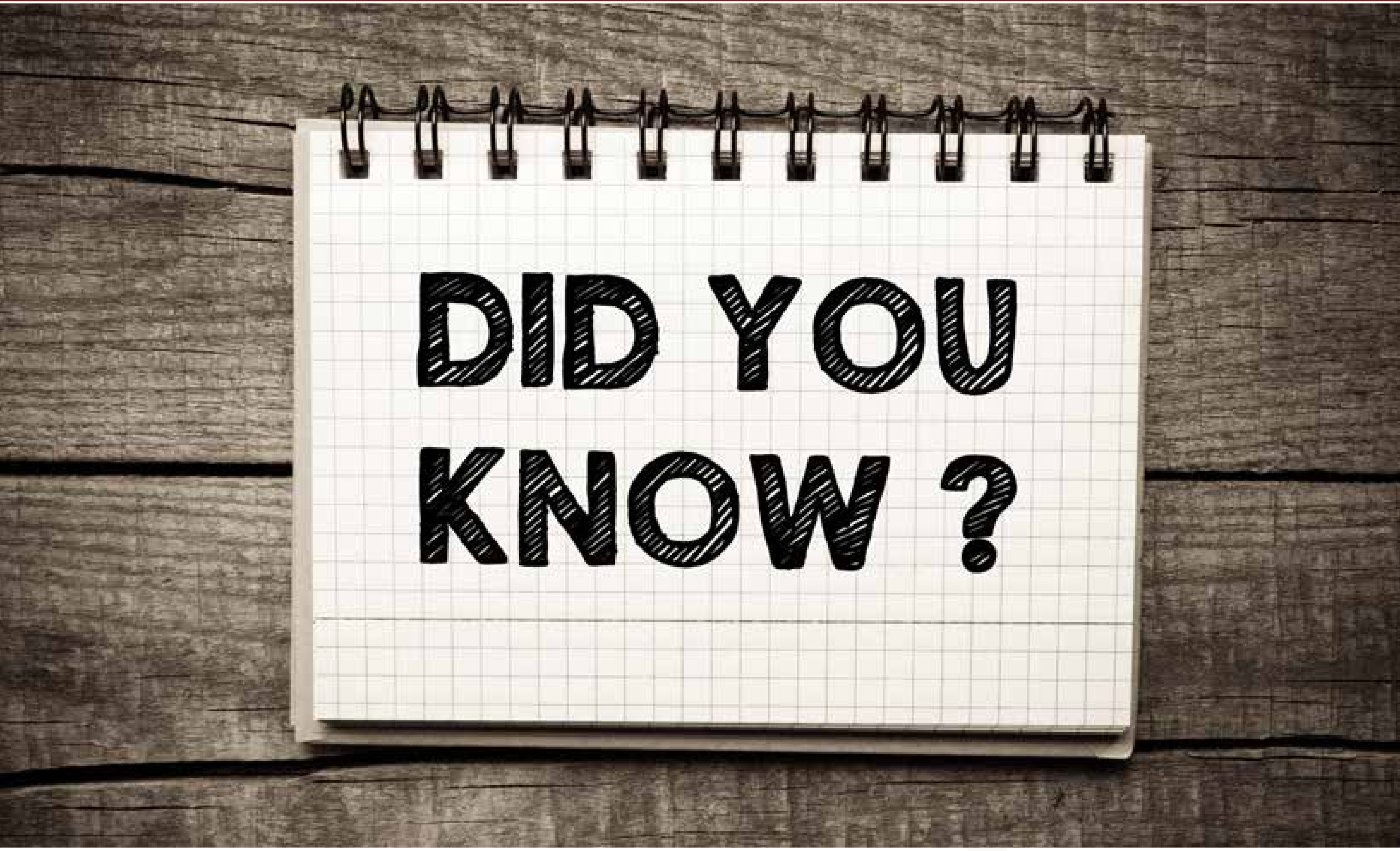

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The Detection of Femoral Nerve Compression by Transcranial Motor Evoked Potentials – A Series of 3 Case Reports

Ly Hoang, BSc, CNIM
UCSF Medical Center

Introduction

Patient positioning during surgery is an important step that should be given considerable thought, especially given the length of the anticipated procedure under general anesthesia. Improper positioning of the upper and lower extremities during surgical procedures can lead to peripheral nerve injuries, one of the most common perioperative complications and a common cause of anesthesia-related litigation. It is therefore important that the nerves be protected from undue pressure, otherwise serious injury may ensue. Analyses of ASA closed-claims concluded that anesthesia-related nerve injury (ulnar nerve 28%, brachial plexus 20%, lumbosacral nerve 16%, and spinal cord 13%) accounted for 15-16% of total claims making it the third most common cause of anesthesia-related litigation (Lalkhen and Bhatia, 2012).

In the prone position, the patient's head is often placed in a padded cushion and chest rolls used to allow for proper diaphragm movement. Arms are either placed at the patient's side or flexed at the elbow and shoulder and placed on arm boards parallel to the head. Padding such as foam is used to cushion the arms. Pillows and/or folded blankets are usually placed beneath the patient's legs to reduce pressure on the feet. *See Figure A.*

Figure A – Example of prone positioning.

Intraoperative neurophysiological monitoring (IONM) is often used during spine surgery to monitor the central and/or peripheral nervous system, and therefore has the added benefit of preventing complications such as peripheral nerve injuries, especially for prolonged prone spine surgeries. IONM practitioners will often monitor somatosensory evoked potentials (SSEPs), transcranial motor evoked potentials (TcMEPs), and/or free-

The mechanism of injury usually occurs due to stretch, compression, or direct nerve trauma. Brachial plexus and ulnar injuries are well documented in the literature as one of the most common peripheral nerve injuries during spine surgery. There are many documented examples of IONM being able to detect improper positioning of the upper extremities in prone spine procedures. However, there is very little documentation of IONM being able to detect peripheral nerve injury in the lower extremities, particularly of the femoral nerve.

The femoral nerve is the largest nerve of the lumbar plexus and supplies the anterior compartment of the thigh *(Figure B)*. It arises from the nerve roots L2-L4. The motor component helps to flex the hip joint (iliacus,pectineus, sartorius) and extend the knee (quadriceps: rectus femoris, vastus lateralis, vastus intermedius, vastus medialis). The sensory division supplies cutaneous branches to the anteromedial thigh and the medial side of the leg and foot.

From the lumbar plexus in the abdomen, the femoral nerve descends behind the inguinal ligament into the thigh and enters the femoral triangle, just lateral to the femoral artery *(Figure C)*. 'The femoral triangle is an anatomical region of the upper third of the thigh. It is a subfascial space which appears as a triangular depression below the inguinal ligament when the thigh is flexed, abducted and laterally rotated' (Moore, Keith L, Clinically oriented anatomy, 7th ed). The borders of the femoral triangle are the inguinal ligament, the sartorius muscle, and the adductor longus muscle.

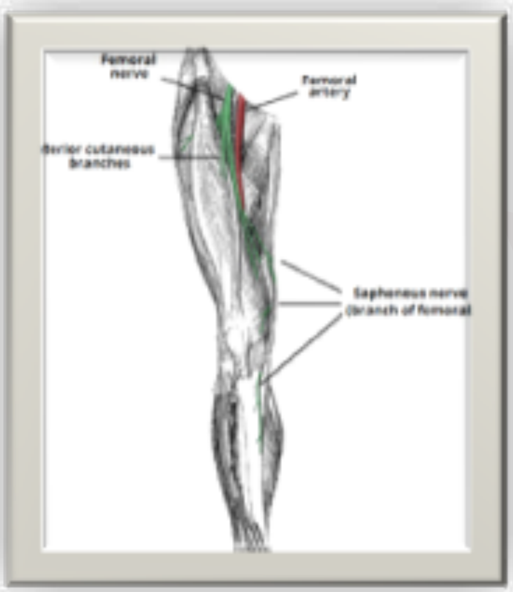


Figure B – Femoral Nerve.

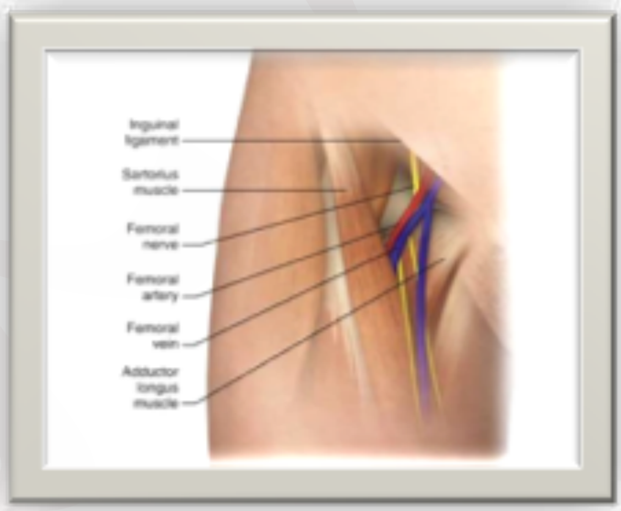


Figure C – Femoral Triangle.

Femoral nerve dysfunction can therefore lead to weakness in hip flexion and knee extension as well as sensation to the anterior thigh and lower leg.

During spine surgery in the prone position, caution must be taken with placement of the bolsters so to as not place undue pressure on the femoral nerve. The surgical team will usually place the bolsters on the anterior superior iliac spine (ASIS) *(Figure D)*.

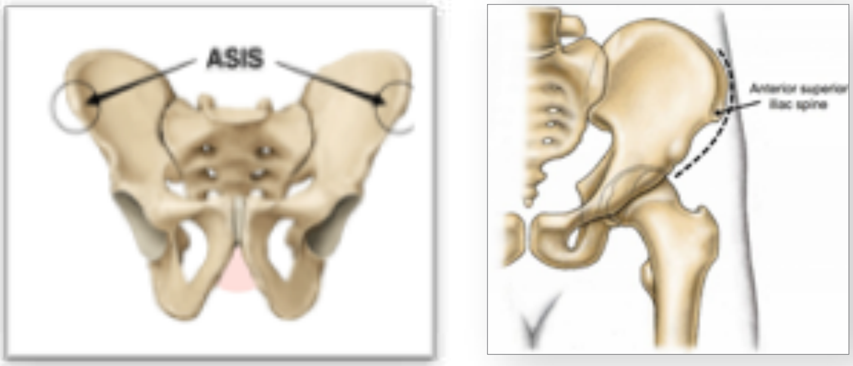


Figure D – Anterior superior iliac spine (ASIS).

However, femoral nerve compression can occur and will be discussed in the following case reports. In each of the examples listed below, neuromonitoring consisted of SSEPs, TcMEPs, and free-running EMG on a Cadwell system (Kennewick, Washington). Transcranial motor evoked potentials were able to detect compression of the femoral nerve which in most of the cases, allowed for a timely surgical intervention which led to reversal of the change and likely prevented injury to the nerve, and hence no patient suffered postoperative weakness.

Case Study 1

Patient A

Height: 155cm (5'1) **Weight:** 54 kg (120 lbs) **BMI:** 22.69 kg/m2

Patient A is a 38 year old male with a diagnosis of severe kyphosis due to ankylosing spondylitis. He has grossly 5/5 strength in the bilateral lower extremities and sensation is intact to light touch in the bilateral L2-S1 distributions. Due to his severe deformity, he has difficulty breathing and can only ambulate short distances before experiencing increasing back pain and shortness of breath.

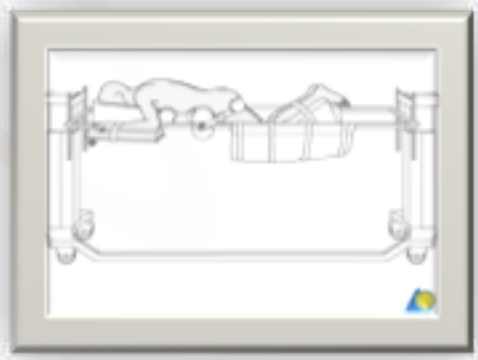


Figure E – Prone positioning on Jackson Table with sling for lower extremities.

Patient A underwent a T10-S1 posterior spine fusion, with an L1 pedicle subtraction osteotomy (PSO), L3 vertebral column resection and T9 kyphoplasty. Due to the patient's severe kyphotic deformity, the patient was positioned on a Jackson table with the head in a Mayfield and a hip sling for his legs. It took the attending surgeon considerable time to position the patient due to the rigidity of the spine. The operative note stated that the 'Positioning of the patient was EXTREMELY difficult in the setting of severe deformity with ankylosing spondylitis. I had 3 attending physicians assist with the positioning.' The final position was similar to the illustration in *Figure E*.

Pre-positioning and post-positioning baseline SSEPs and TcMEPs were obtained with no significant change *(Figure 1A)*. After exposure, there was a small systemic decrease in the TcMEPs globally, but in particular there was a significant focal change in the left rectus femoris (RF) TcMEP (>90% decrease in amplitude) *(Figure 1B)*. Of particular interest was the preservation of the other left proximals, the iliopsoas and the adductors. The elapsed time from when TcMEPs were first tested with the patient in the prone position, to the time of the drop in the left RF TcMEP, was 97 minutes, of which, 78 minutes was exposure time. The surgeon then proceeded to adjust the left leg by lifting it up and adjusting the position in the hip sling, which resulted in immediate recovery of the left RF TcMEP due to relieving pressure off the femoral nerve (Figure 1C). The surgery proceeded with no further significant neurophysiological intraoperative monitoring events and the patient woke up with no focal neurological deficits.

Figure 1A – Left TcMEP pre-positioning and post-positioning baselines were obtained with no significant change

Figure 1B - After exposure (78 minutes), there was a focal drop in the left rectus femoris TcMEP response

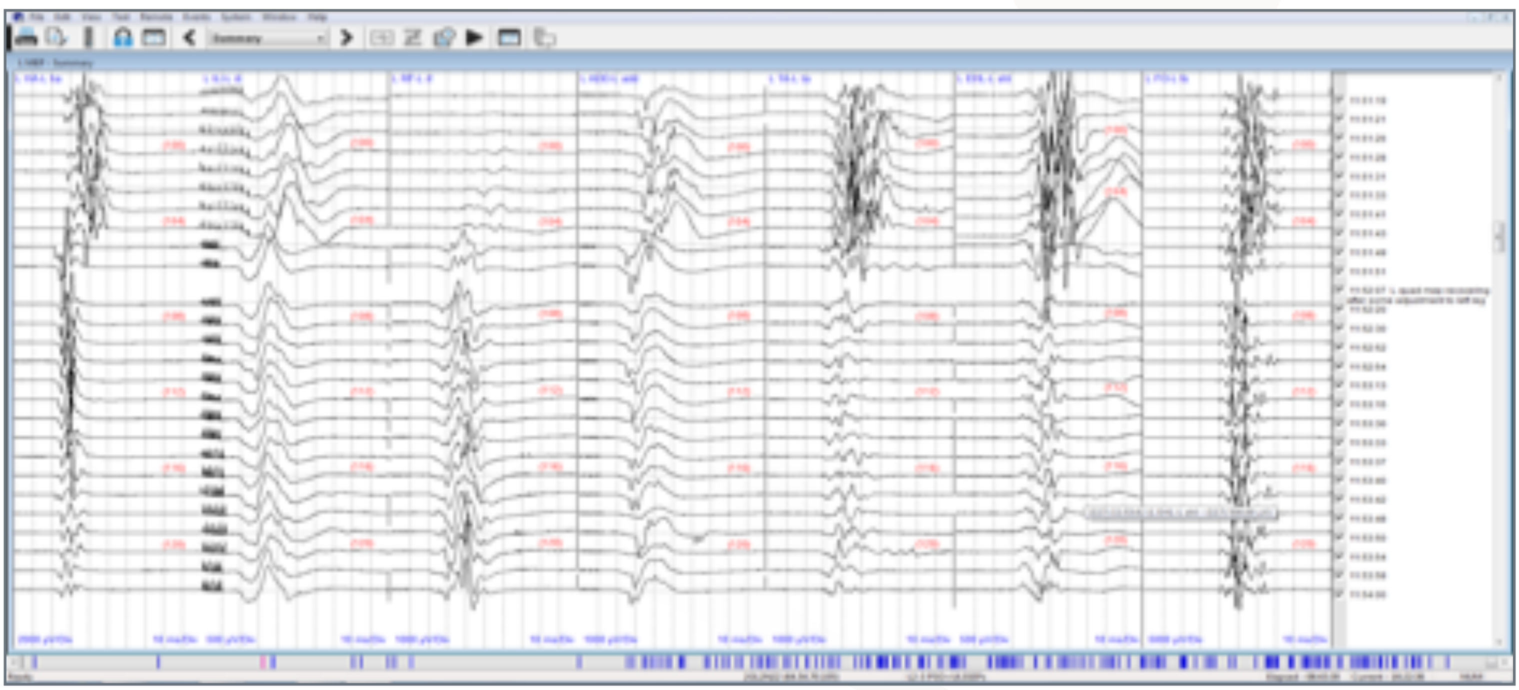


Figure 1C - The surgeon adjusted the left leg to relieve pressure off the femoral nerve which led to an immediate

Case Study 2

Patient B

Height: 179cm (5' 10") **Weight:** 93 kg (205 lb) **BMI** 29.00 kg/m²

Patient B is a 65 year old male with a diagnosis of spondylolisthesis at L5-S1 and lumbar radiculopathy. On motor exam, the patient is 5/5 in all muscle groups tested in the bilateral lower extremities apart from the right gastroc-soleus where he is 4+/5.

The patient was consented to undergo an L5-S1 posterior spinal fusion and instrumentation, L5-S1 transforaminal lumbar interbody fusion (TLIF) and an L5 laminectomy. Pre-incision TcMEP baselines were unobtainable due to an insufficient amount of time for the rocuronium to wear off. Reversal could not be given since the surgeon wanted relaxation for at least 45 minutes to facilitate the exposure. Therefore, only SSEPs baselines were obtained and it was discussed with the surgeon that baseline TcMEPs would be attempted after exposure. At the start of instrumentation, the surgeon consented to reversal, adequate TcMEP baselines were obtained and SSEP baselines were re-established. Approximately 20 minutes later, there appeared to be a sudden drop in the left rectus femoris (RF) TcMEP *(Figure 2A)*. What was apparent was the asymmetry between the left and right RF response given there was no weakness in those myotomes. After several TcMEP trials, which showed a definite decrease in the left RF recording (>80% from baseline amplitude), the surgeon was notified of the change. A time of 102 minutes had elapsed since the patient had been on the Jackson table to when the TcMEP change had been detected, of which, 45 minutes was exposure time. Since the surgeon was only working at L5/S1 and the RF represented at least one level proximal to where he was working, it was proposed that the change was likely femoral nerve compression. The response was small post-incision and seemed to deteriorate further despite being on a pure TIVA and attempts to optimize technical parameters (ie. voltage, interstimulus interval (ISI), corkscrew mapping). The surgeon decided to reposition both bolsters more proximally. After completing this maneuver, there was an acute improvement in the left RF TcMEP, the amplitude was, in fact, far bigger than the post-incision baseline. Had a pre-incision baseline been obtained, the post-exposure trials would have likely represented a big asymmetry. The sudden augmentation of the left RF response with adjustment of the bolster strongly advocates femoral nerve compression. The patient had a distended abdomen which, in the prone position, was being pulled down due to gravity, which added more pressure on the bolsters, and likely compressed the femoral nerve on the left side *(Figure 2C)*. The rest of the surgery proceeded without any complications and the patient woke up postoperatively with full strength in all myotomes in the lower extremities.

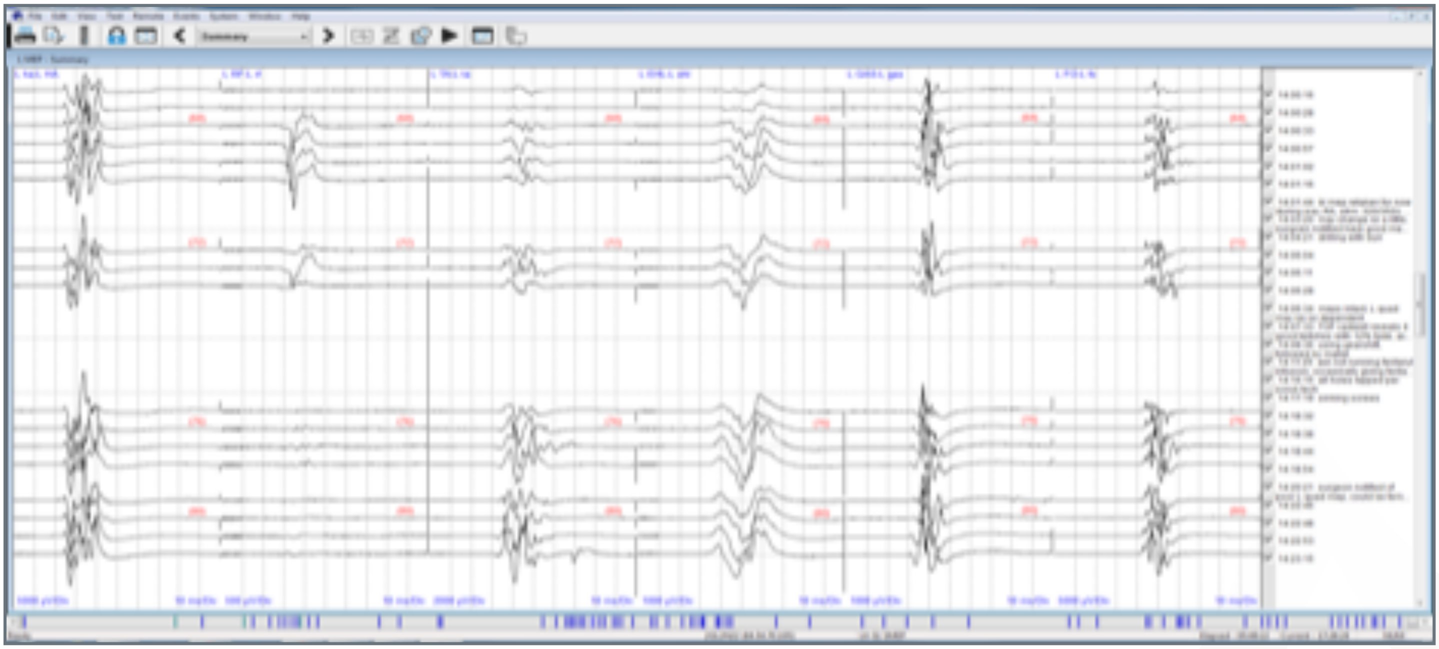


Figure 2A - Post-incision left TcMEP baseline with a sudden decrease in the left RF response shortly after, note that the surgeon was working at L5/S1

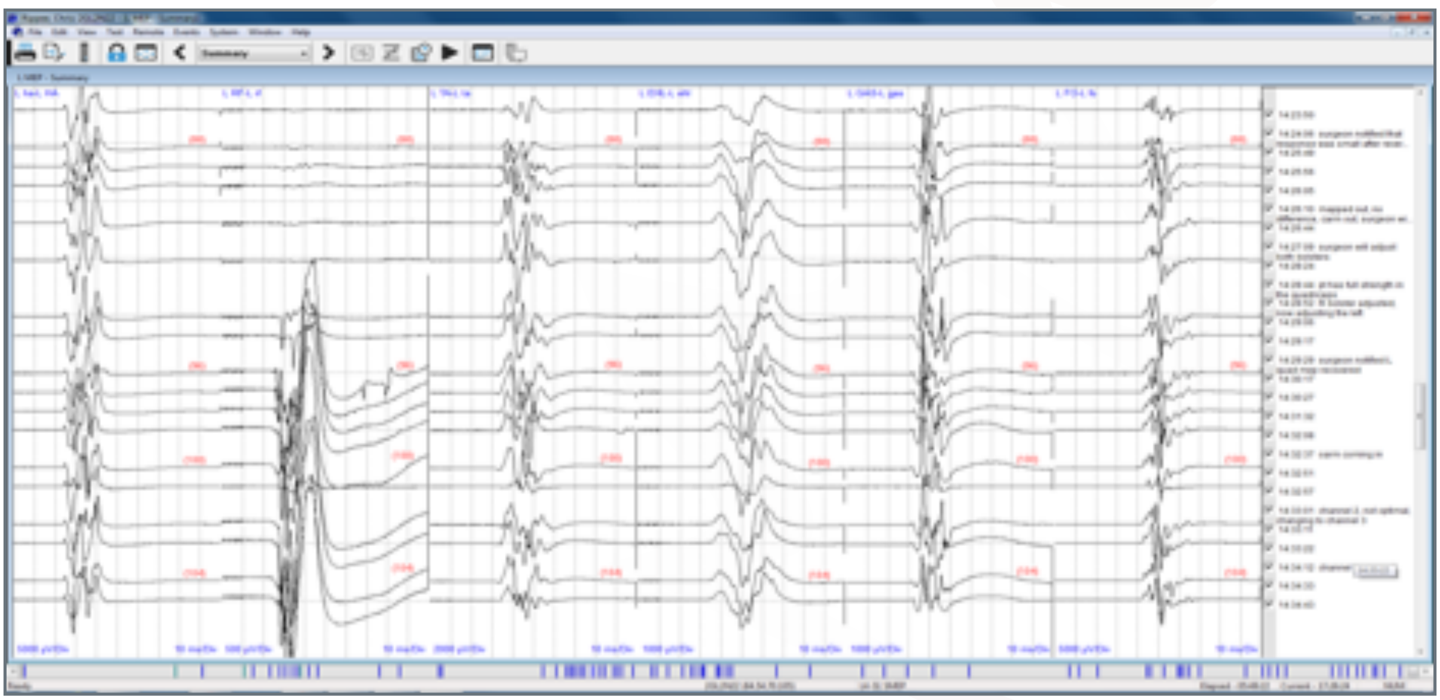
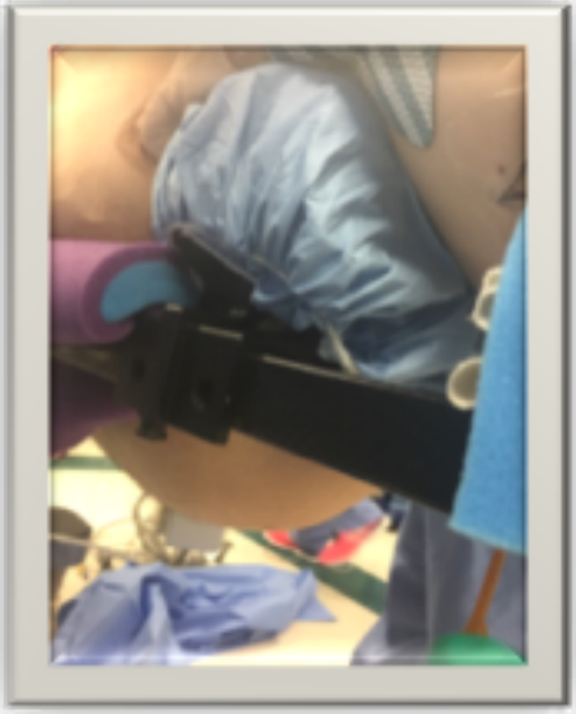


Figure 2B - Adjustment of the bolster resulting in sudden improvement of the left RF TcMEP



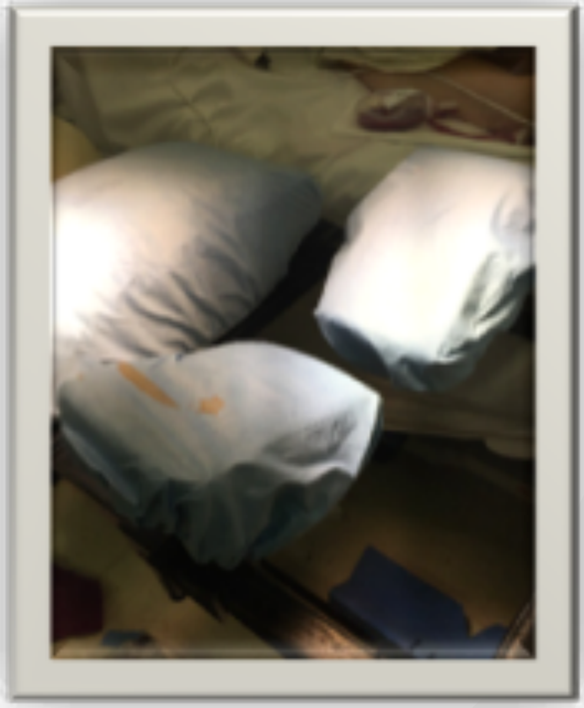


Figure 2C - The weight of the patient's abdomen pulling down on the bolsters

Case Study 3

Patient C

Height: 6 feet (183 cm) **Weight:** 109 kg (240 lbs) **BMI:** 32.55 kg/m2

Patient C is a 67 year old male with Parkinson disease and a history of six prior lumbar surgeries. He presents with debilitating lower back pain and right L5 radiculopathy. He denies leg weakness, hand numbness/clumsiness, gait unsteadiness, recent falls, or numbness in the groin/anus.

Patient C was scheduled to undergo a T10-pelvis posterior spinal fusion and instrumentation with an L3 PSO. Adequate SSEP and TcMEP pre-incision baselines were obtained. Following exposure, there was an immediate decrease in three of the left quadricep TcMEPs, superior rectus femoris, inferior rectus femoris, and vastus medialis (Figure 3A). The adductors were still preserved, as were the other distal lower extremity responses. The decrease was noted 56 minutes from the time the patient was in the prone position (with a 54 minute exposure time). After further optimization of anesthesia and TcMEP parameters, the surgeon was notified of the asymmetry between the left and right quadriceps despite the patient having no weakness in left leg extension. At that time, it was proposed that the asymmetry was positional, in particular femoral nerve compression. The surgical fellow inspected the left bolster and had deemed it in a good place and did not attempt to reposition it. Without surgical intervention, the left quadricep TcMEPs continued to remain decreased (>80%) with no improvement (Figure 3B). The surgeon was notified that monitoring of the proximals on the left side would be less sensitive due to only having the adductors, which is significant since the surgeon was intending to do a PSO at L3. During the case, while closing down the osteotomy, there was a sudden recovery of the left quadricep TcMEPs. The adductors had remained stable at this point. The surgeon was notified of this acute improvement and it was postulated that the correction created significant lordosis such that the patient's left thigh on the bolster shifted distally, hence taking pressure off the left femoral nerve. It is interesting to note that this surgical move inadvertently resulted in immediate improvement of the left quadricep TcMEPs. The rest of the case proceeded with preservation of all responses, including the left quadriceps, and the patient woke up with no new postoperative weakness. What was apparent though, was once the patient was transferred from the Jackson table to the gurney, there was significant bruising over the left upper thigh, representing significant pressure over the femoral triangle.

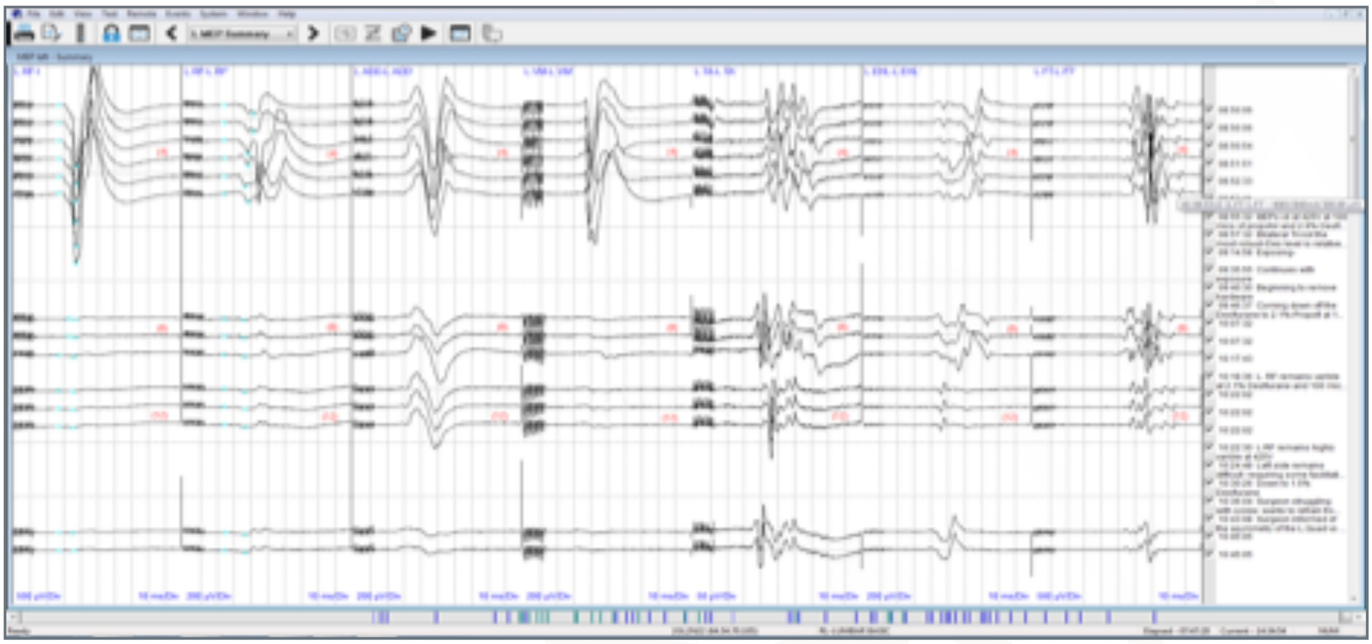


Figure 3A - Acute amplitude drop in the left quadricep TcMEPs following exposure

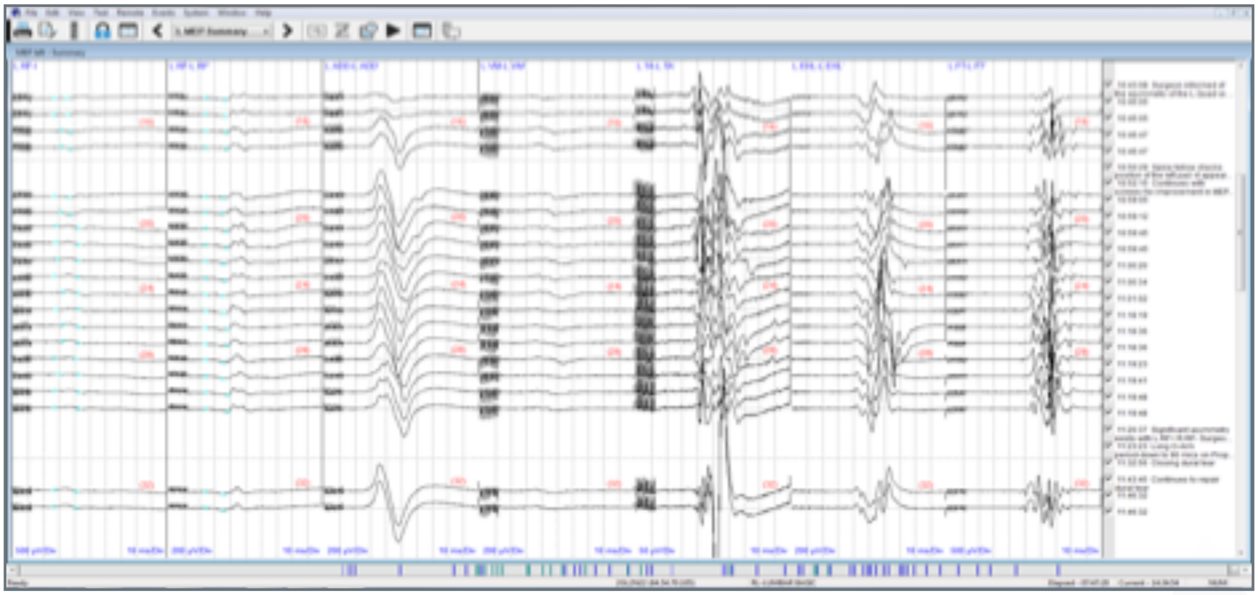


Figure 3B - The left quadricep TcMEPs remain reduced in amplitude with no surgical intervention

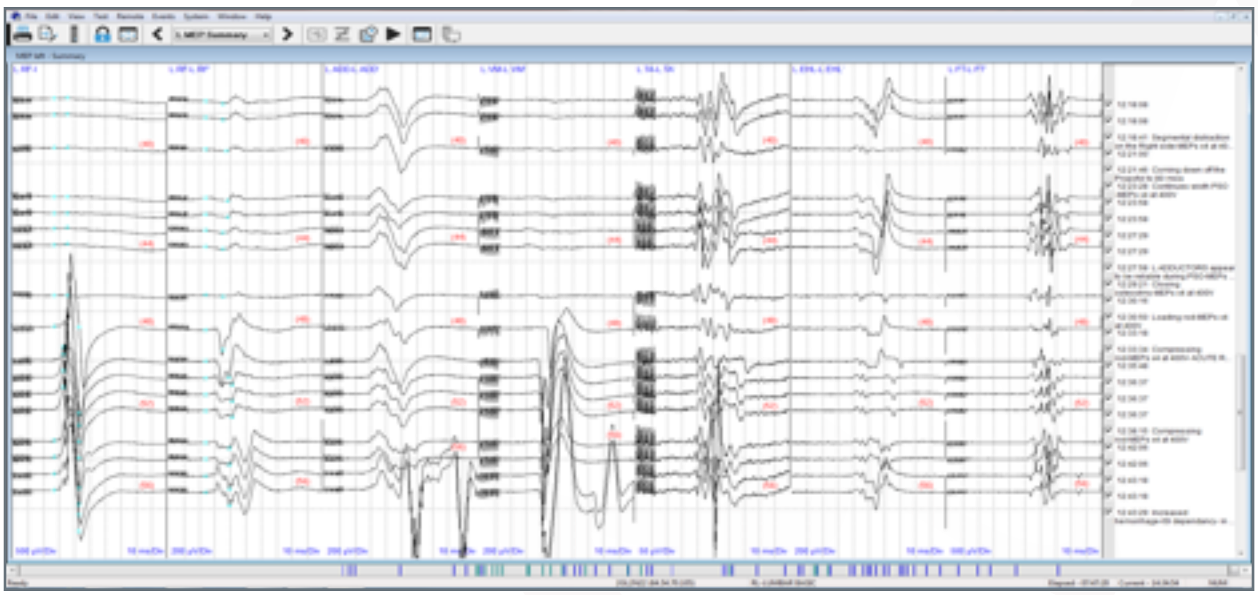


Figure 3C - Immediate recovery of the left quadricep TcMEPs following closing down of the PSO at L3

Discussion

The three case reports discussed illustrate the sensitivity of TcMEPs in detecting femoral nerve compression, the majority of which occurred either after exposure or shortly thereafter. This observation shows that femoral nerve compression evolves over time; in these case reports, the range was between 56 and 102 minutes with an average of 85 minutes, with exposure time taking on average 59 minutes. It should be noted that for all the cases mentioned, the anesthetic protocol for neuromonitoring was adhered to which consisted of a balanced IV anesthetic of propofol and a third MAC of vapor. Other complements often included a fentanyl, lidocaine, ketamine, phenylephrine, and/or tranexamic acid infusion. In some of the cases, a pure total intravenous anesthetic (TIVA) was used to help further optimize signals. Twitches were either checked by the anesthesiologist and/or by using the Cadwell train-of-four test, and reversal given if necessary.

The use of TcMEPs to monitor the integrity of nerve roots have been used at UCSF Medical Center for well over a decade. The warning criteria used is a decrease in amplitude of at least 70% from baseline amplitude, which is supported by Kobayashi S *et al.*,, 2014. It has been generally observed that when using TcMEPs to monitor nerve roots, the proximals tend to be smaller in amplitude compared to distal TcMEPs (Parikh *et al.*, 2018). This can perhaps be explained by the fact that there is less cortical spinal representation and input to the proximals compared to the distals such as the hands and feet. Therefore, more attention is spent optimizing proximals, especially in the geriatric population. This age group can often be more challenging to obtain reliable quadriceps/adductors TcMEPs, since these muscles tend to be the first to atrophy from disuse. Another factor to consider is the amount of adipose tissue surrounding the proximal musculature compared to distals, (eg tibialis anterior) where the former is not as superficial. For this reason, long subdermal needles (22mm length) are often used to get as close as possible to the muscle to optimize responses. Sometimes it may not be possible to monitor proximal TcMEPs if the baseline is already poor, which will only become susceptible to anesthetic 'fade' during the course of a long surgical procedure (Lyon *et al.*, 2005). In this situation, the surgeon is often notified early that these responses may not be reliable for monitoring, after attempts of optimization of anesthesia and technical parameters. It is therefore often easy to dismiss proximal TcMEPs as unmonitorable following exposure, when in fact it may be due to femoral nerve compression. A crucial step to making this determination is to have the anesthetic optimized as soon as possible prior to incision. This requires cooperation from the anesthesia team, which entails a quick turnover from a halogenated anesthetic to a TIVA. Furthermore, one must also be aware of the neurological status of the patient. For example, patients with motor grades of less than 4/5 become increasingly difficult to monitor (Guo *et al.*, 2018).

A clue to femoral nerve compression lies in the observation that it is usually unilateral therefore 'big asymmetries' in quadricep responses following exposure should be given special attention to, especially if they were not noted at pre-incision baseline. It is not to say that bilateral femoral nerve compressions cannot occur, but that this occurrence is extremely rare. Li *et al* (Spine Deformity, 2018) discuss a case report where a patient with fixed sagittal imbalance had lost bilateral vastus medialis TcMEPs during exposure and that repositioning of the bilateral lower extremities resulted in recovery. Another interesting observation is that the adductor TcMEPs can act independent of the quadriceps when there is femoral nerve compression. This can be explained by the fact that they are supplied by the obturator nerve as seen in Patient A and C, in which the adductor TcMEPs were preserved, despite a significant reduction in the individual muscles of the quadriceps.

In all but one of the cases discussed, surgical intervention led to immediate improvement of the quadricep TcMEPs. Patient C was the only exception and was an unusual case because the actual closing down of the PSO indirectly led to full recovery. The use of multiple myotomal TcMEPs to monitor the functional status of nerve root integrity during PSOs is a long-established practice at UCSF Medical Center and has proven to be highly effective and reliable (Lieberman *et al.*, 2008). Patients with flatback syndrome often require a PSO to help restore sagittal balance. The closing down of the wedge osteotomy can create >30° of lordosis at that level. The recovery of the left quadricep TcMEPs in Patient C, can therefore be explained by the fact that the increased lordosis had shifted the leg position on the bolster, from the upper thigh, more distally, alleviating pressure off the femoral nerve.

Other authors have shown the use of TcMEPs to monitor the femoral nerve to be an effective method of detecting nerve injury during trans-psoas lateral lumbar interbody fusions (Silverstein *et al.*, 2016; Chaudhary *et al.*, 2015; Block *et al.*, 2015). Similarly to the above mentioned articles, there was no abnormal EMG activity during femoral nerve compression, which arguably puts TcMEPs in favour of being more superior to EMG monitoring for detecting nerve root injury. EMG monitoring is still a useful adjunct to intraoperative neurophysiological monitoring, particularly when there is blunt nerve root trauma, but its use alone is not sensitive enough in detecting nerve root injuries.

Conclusion

In conclusion, these 3 case reports illustrate the effectiveness of using TcMEPs in detecting femoral nerve compression that was caused during positioning. It is therefore important for the surgical team to pay special attention to patient positioning since prolonged cases in the prone position can lead to a femoral nerve palsy. Repositioning of the bolster or adjusting the leg in a hip sling is a quick and effective method in relieving pressure off the femoral nerve and can quickly result in an improvement and should be attempted when there is suspicion of femoral nerve compression. The acquisition of proximal TcMEPs can be especially challenging in the geriatric population, therefore good communication with the anesthesiologist is paramount in optimizing such signals, to make this technique effective and reliable.

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