VOLUME 5, ISSUE 1

CANADIAN IONM NEWS

Official Newsletter of CANM

Message from the President

The New Year is well under way and it is time to renew your CANM membership if you have not done so already. It is especially important for IONM practitioners in Canada to support CANM as the national body representing our collective interests because it is the most effective way to influence the future direction of our profession and ensure its continued success. The landscape of IONM practice is rapidly changing, increasing in both scope and sophistication. Given this dramatic and ongoing evolution, careful stewardship to foster and shape the future direction of IONM in Canada is crucial. Membership in CANM provides an opportunity for all to voice opinions and ideas about how our profession should be structured and positioned within the larger context of the Canadian health care system. CANM is already forging ahead and taking a leadership role in IONM education and we are on track to formalize and raise standards of practice through implementation of a national exam and credentialing strategy. As we navigate our way forward, CANM will continue to engage stakeholders and government-related health regulatory bodies to establish IONM as an independent and self-regulated Allied Healthcare Profession in Canada. CANM member support and active involvement will be essential to the achievement of this ultimate goal and the establishment of IONM as a critically important part of our health care system.

Failure of IONM practitioners to present a unified voice and advocate for ourselves will inevitably signal the beginning of the end of IONM as an independent entity on the Canadian health care continuum. The fight for each and every health care dollar in Canada is fierce and we must work together to communicate our unique role and its rightful place on the front line of patient care to surgeons, hospital administrators, government, and the public. A strong and unified CANM membership voice will help to ensure that we are valued and supported both in theory and in practice. Our profession is at a pivotal crossroads and our actions now will have a dramatic and lasting effect on how IONM is practiced in this country in the future. The bottom line is that it is up to all of us to decide whether we choose our own path or we acquiesce and let others choose for us. The time for action is now and the most immediate form of action is to visit www.canm.ca where a membership application is waiting just for you!

Membership in CANM has advantages that extend beyond borders and professional boundaries and we encourage physicians, other health care professionals and non-Canadians to join our ranks as well. Members enjoy exclusive access to our web forum, the *Intraoperative Neurophysiology Discussion Board*, which offers a venue for sharing professional information, opinions and ideas. Members also have preferred access to our CANM *talks* webinars that showcase high profile speakers engaging the audience in important topics that are relevant to everyday practice. Full members also have the option of enrolling in individual courses of the Michener Graduate

CANM
CANADIAN ASSOCIATION OF NEUROPHYSIOLOGICAL MONITORING

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Certificate Program in IONM, for instance, without the requirement of taking all six courses which is the case for non-members. Last but not least, CANM members will enjoy a reduced registration fee for our Annual Symposium.

This year the Annual Symposium will be in beautiful Halifax, Nova Scotia on Friday, September 30th and Saturday, October 1st. I can tell you from first-hand experience that the Maritimes is a truly magical place to be – especially in autumn. The venue will be situated along Halifax's charming waterfront that boasts everything from Tall Ships to "old salts" telling tall tales at one of our many lively pubs. If you enjoy lobster, foot stomping fiddle music, a hearty maritime folk song washed down with a pint of local ale, the 2016 Annual CANM IONM Symposium should not be missed.

I hope to see everyone's name on the updated 2016 CANM membership list and in person in Halifax this fall!

Sincerely,

Susan Morris, PhD Neurophysiologist
President, CANM Executive Board
IWK Children's Health Program
CDHA Division of Neurosurgery
Assistant Professor (Surgery) Dalhousie University
Halifax, Nova Scotia

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2016
CANM IONM
Symposium
September 30th to October 1st
Halifax, Nova Scotia
Details Coming Soon...

Announcing CANM *talks* Sessions for 2016!

On behalf of the CANM Executive Board, I am delighted to announce that the next round of CANM *talks* webinars have been planned for 2016. Our online webinar was launched in 2014 to placate the need for further education and training in addition to our annual symposium. The hour long webinar focuses on current "hot button" topics relating to the field of IONM. Attendees are treated to a live online didactic lecture followed by an interactive discussion period in which all are encouraged to join in and participate.

CANM strives to provide an engaging learning experience with lectures given by esteemed experts in the field of IONM. In our inaugural CANM *talks* session, David Houlden, PhD led a provocative discussion on "Who Should Interpret IONM?" Previous speakers also included Brett Netherton, MS, FASNM, CNIM who presented on "Recording Concepts that Hopefully Improve your Practice." In our most recent CANM *talks* webinar, Jamie Johnston, PhD, CNIM delivered 3 intriguing case studies. All CANM members have access to CANM *talks* webinars. Become a member today and view all our past webinars on the *Intraoperative Neurophysiology Discussion Board* at: http://canm.proboards.com/

We invite you to join us on May 12 for the first CANM *talks* webinar in 2016. Our guest speakers will be Drs. James and Maria Zuccaro from Shiners Hospital for Children in Philadelphia, PA who will be sharing their experience of how they developed the IONM program at their centre.

CANM *talks*
Date: May 12, 2016 @ 7:30 EST
Speakers: Drs. James and Maria Zuccaro
Topic: "Practice Models within the Field of IONM"

CANM *talks* webinars are open to all interested parties however priority registration will be given to CANM members and space is limited for each session. So consider joining CANM today!

For more information on how to join our CANM *talks* webinar, please visit: www.canm.ca/canmtalks.html

Sincerely,
Nancy Lu, BSc. (Hons), CNIM
Treasurer, CANM Executive Board
Toronto Western Hospital,
University Health Network Toronto, Ontario

Strategies to Increase TcMEP Sensitivity for Dorsiflexion Injuries During Lumbosacral Deformity Surgery

Loss of dorsiflexion strength, also known as "foot-drop" injuries, can occur after spine surgery as the result of damage to distal lumbar spinous nerve roots. The incidence of these injuries is poorly defined, but they are more common in complex deformity procedures. In fact, damage to L5 occurs more often that any other nerve root.[1] L5 nerve root injury after L5-S1 spondylolisthesis reduction has been reported to be as high as 75%, but the range is quite variable.[2–5] It is also a frequent complication after lumbar interbody fusions.[6]

Neurophysiologic monitoring has been used to detect and prevent intraoperative neurologic injury. When focusing solely on lumbar spinous nerve roots, electromyography (EMG) has been considered highly sensitive to detect nerve root trauma.[7–9] However, more recent studies challenge this assertion, with the sensitivity of EMG to detect isolated nerve root injury ranging from 0 to 60% at best. In animal studies using direct retraction or compression of a nerve root, EMG activity was often quiet despite marked loss of nerve conduction.[10,11]

Additional modalities of neurophysiologic monitoring have been evaluated to improve our ability to tract injury to isolated lumbar nerve roots. Somatosensory Evoked Potentials (SSEP) have not been shown to be effective, as there is a high rate of false-negative changes. Motor Evoked Potential (MEP) monitoring has gained increasing popularity as a means to follow the integrity of individual nerve roots. Initially, MEPs were believed to be too insensitive to discriminate changes caused by decreased motor firing from one nerve root alone. Many lower extremity muscles are innervated by multiple nerve roots, e.g. the tibialis anterior typically by both L4 and L5. A loss of signal from a single root might not produce measurable changes to the MEP responses. Moreover, as each nerve root innervates several muscles, this "cross-talk" may make quantifiable changes difficult to isolate. However, several studies have validated the efficacy of MEP for nerve root injury monitoring.[12,13]

In order to assess how effective MEP monitoring has been for detecting nerve root injuries that produce deficits to dorsiflexion, we report our experience from a single institution. We used multi-myotomal MEP monitoring in over 500 patients who underwent posterior spinal fusion for correction of distal lumbar deformity at UCSF from 2009 through 2014. Approximately 58% of these patients had major ostetomies to correct spinal curvature (e.g., pedicle subtraction osteotomy), lumbar interbody fusion, or reduction of moderate to high-grade spondylolisthesis. MEP recording electrodes were placed into the rectus femoris (RF), adductor longus (ADD), tibialis anterior (TA), extensor hallicus longus (EHL), and the foot flexor (FF) muscles of the bilateral lower extremities in all patients.

We identified 20 patients who acquired new postoperative dorsiflexion weakness. The amount of weakness ranged from mild (4/5) to severe (0/5). MEP changes are shown for several patients in Figures 1–3.

Of the 20 patients who we observed new postoperative dorsiflexion weakness, all demonstrated some intraoperative changes to their MEP responses. All injuries were unilateral. There was a strong correlation between the degree of MEP amplitude change and the severity of motor grade weakness observed. Changes in both the EHL and the TA muscle MEP responses predicted weakness in the motor exam (Figure 4).

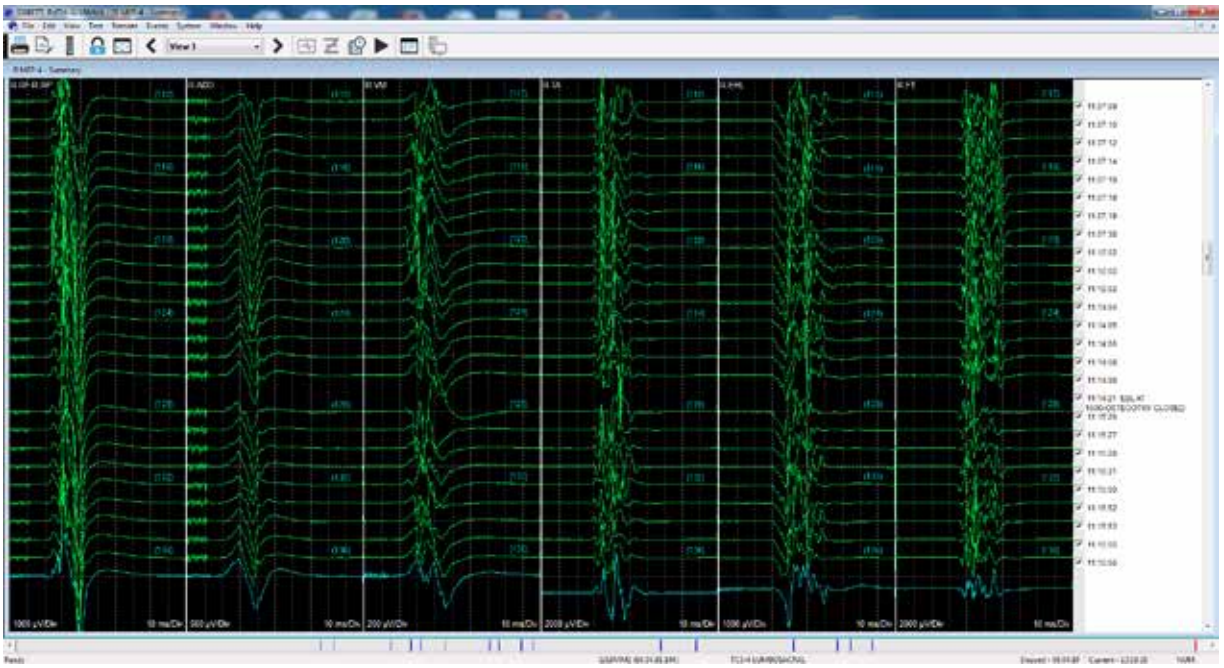

Figure 1A. Baseline MEP response from the right lower extremity in a 55-year-old patient undergoing lumbar posterior spinal fusion with an L4 pedicle subtraction osteotomy for fixed-sagittal imbalance. Initial signals were robust in all myotomes of the lower extremities.

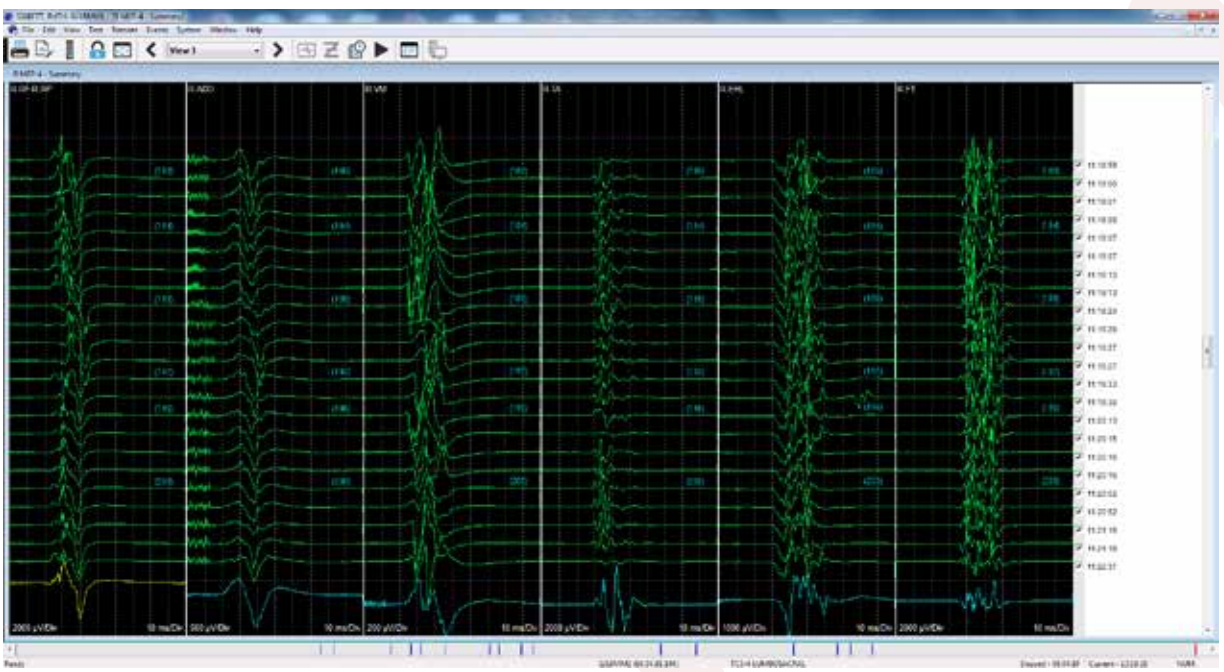

Figure 1B. Approximately 5 minutes after closure of the L4 PSO, there is a 70–90% decrease in the MEP amplitude measured from the Right TA muscle without significant changes to the MEP responses of the other myotomes. Additional decompression by the surgeon at L4 and L5 resulted in complete recovery of the amplitude in the TA. This patient awoke from surgery without detectable dorsiflexion weakness.

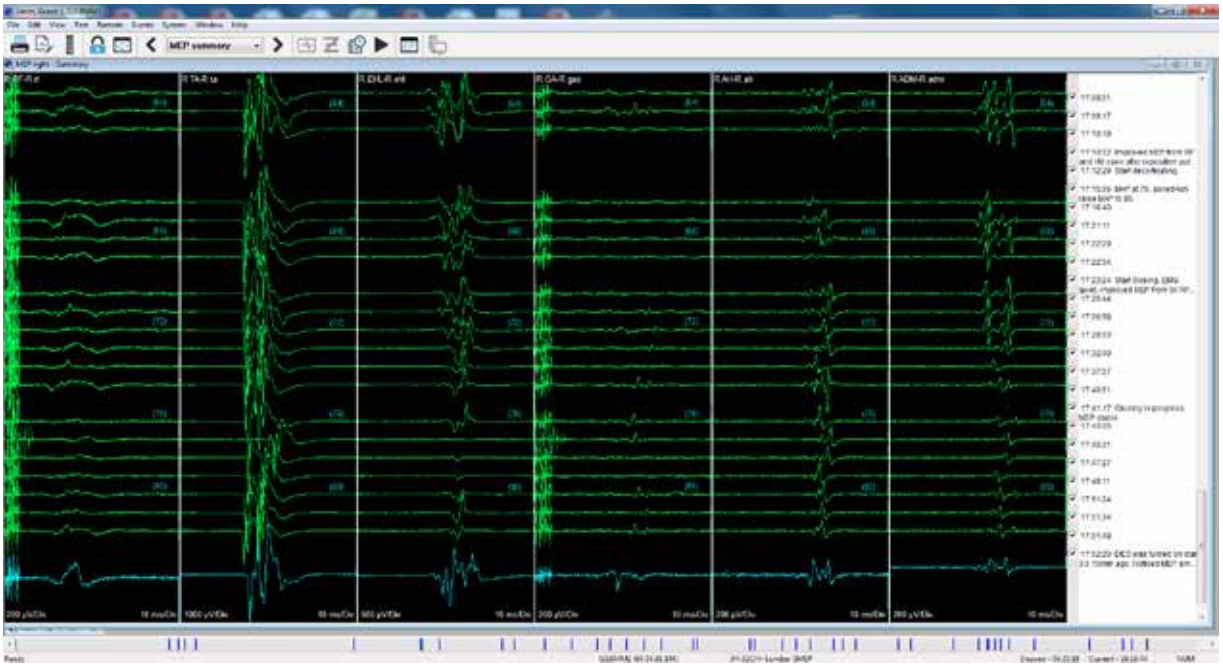

Figure 2. MEP tracings from a 65-year-old patient undergoing posterior spinal fusion and L5 PSO. At 50 minutes after reduction of the osteotomy, the patient developed an isolated 88% decrease from baseline to the MEP amplitude in the right EHL muscle. Despite surgical intervention, the amplitude remained less than 50% of baseline at the end of surgery. Postoperatively, she had new mild dorsiflexion weakness, motor strength 3/5 in the right EHL, 4/5 in the right TA.

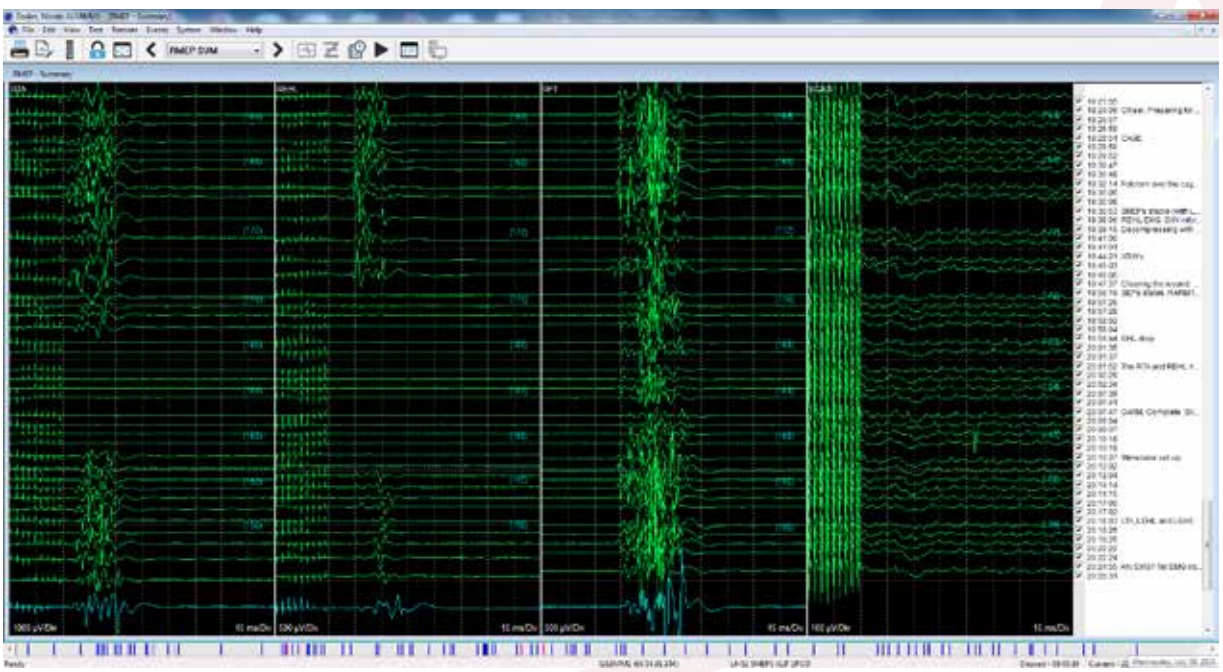

Figure 3. 15-year-old undergoing reduction of a Grade IV spondylolisthesis at L5-S1. During reduction, complete loss of both TA and EHL MEP responses is observed. When the surgeon removes some of the correction, there is partial recovery of MEP amplitude. At closure, the MEP amplitude of the right TA was 46% below baseline; the EHL was 85% below baseline. The patient awoke with 3/5 motor strength in both the right TA and EHL muscles.

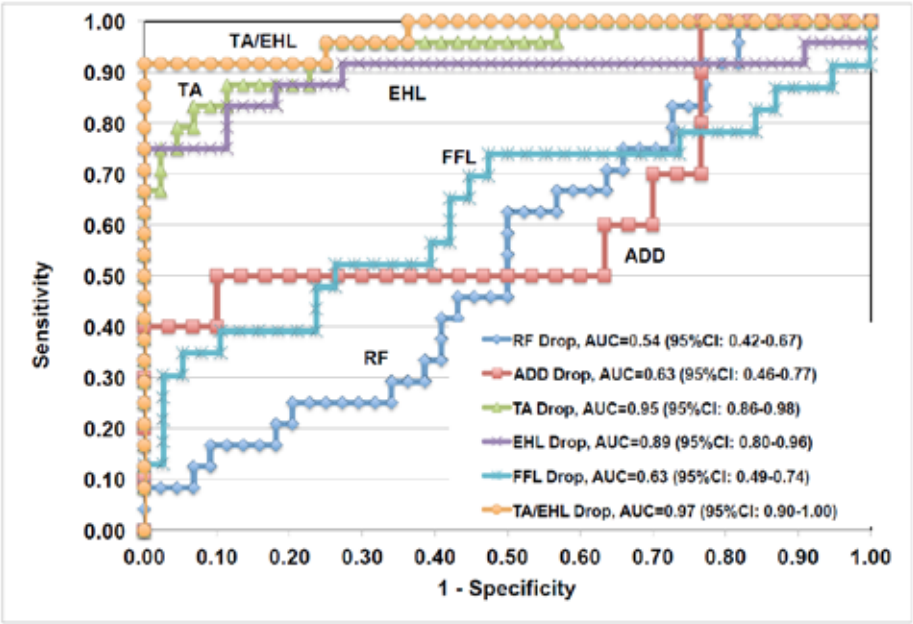

Figure 4. Receiver Operating Characteristic curve correlating the changes of MEP amplitude in a given muscle or muscles with postoperative dorsiflexion weakness. The EHL and TA alone were highly predictive with AUC at 89 and 95% respectively. Looking at changes to either TA or EHL produced a curve with the highest AUC at 97%.

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Intraoperative Neuromonitoring: Establishing a Positive Working Relationship in the Operating Room

Intraoperative neurophysiological monitoring (IONM) is the use of physiological techniques to assess and map neural integrity and navigate within at-risk neural structures.[1,2] Structures that may be monitored during surgery include the brain, spinal cord, cranial nerves, spinal nerve roots, or peripheral nerves. Somatosensory evoked potentials, transcranial motor evoked potentials and electromyography are the most commonly employed IONM modalities.

IONM is used predominantly in high-risk brain, spine and peripheral nerve surgeries. It has been suggested that IONM should be conceptualized as an "interventional cascade" of test–interpretation–communication–intervention to improve outcomes of surgery.[3] To this end, effective IONM requires a highly adaptive and communicative multidisciplinary surgical team made up of the neurosurgeon, anesthesiologist, clinical neurophysiologist, monitoring technologists, and surgical nurses. With prompt and real-time identification of emerging neurologic compromise as well as mapping of neural structures in the operative field, the neurosurgeon can take appropriate steps to adapt the procedure and minimize permanent postoperative neurological deficit.

While teamwork is being increasingly recognized as an essential element of delivering high quality and safe health services, communication breakdown continues to be a real threat undermining optimal delivery of health care.[4] In fact, poor communication within surgical teams has been found to be a significant risk associated with major postoperative complications.[5–7] In their review of surgical claims over a nine-year period, the Controlled Risk Insurance Company (CRICO) identified communication breakdown accounting for 15% of claims.[8] Another review of surgical adverse events leading to malpractice litigations demonstrated that communication failures accounted for 87% of claims ending with an indemnity payment.[9] Communication failures occurred primarily between caregivers rather than between caregiver and patients. Analyzing content, audience, purpose and occasion, Lingard and colleagues observed that 30% of communications in the operating room (OR) failed; one third of which jeopardized patient safety by increasing cognitive load, interrupting routine and increasing tension.[7] Further, evidence suggests that 50% of surgical complications are avoidable.[10,11]

Experts consider the complex multidisciplinary surgical operating room environment akin to commercial aviation cockpit or control room of nuclear power plant. As such, in an effort to reduce surgical adverse events, health care professionals have started to examine the experience of aviation industry in their safety improvement initiatives.

The majority of aviation disasters are caused by human error – most commonly miscommunication. The problems of group interaction in high-risk environments have been studied by psychologists, psycholinguists and aviation experts. One of the best work done in this field is the publication by Swiss Re (leading global reinsurer) Centre for Global Dialogue and Gottlieb Daimler and Karl Benz Foundation titled *"The Better the Team, the Safer the World" Golden Rules of Group Interaction in High Risk Environments: Evidence based suggestions for improving performance*. This publication is also known as Swiss Re White Book 2004.[12] Published in 2013, *Safety Management in Context. Cross-Industry Learning for Theory and Praxis* is an update of this publication.[13] Key recommendations were to:

a) change high performing individuals into a high performance team
b) make teamwork the norm in high risk environment
c) develop good teamwork and communication by fostering a shared mental model of goals and procedures, and
d) implement tools to improve teamwork and systems to facilitate familiarity and standardized communication pattern

Observational evidence suggests that stress and high workload lead to incorrect or incomplete information transfer between individuals. In fact, cockpit crew performance was noted to be more closely associated with the quality of crew communication than the technical skills of an individual pilot.[14] Similar findings were observed in the operating rooms and intensive care units.[15] As such, researchers of organizational behaviour and performance recommend a "Shared Mental Model" that encourages individual team players to "think out loud," share perspective and establish a common understanding of the situation in the beginning of the case and adapt their behaviour to the demands of the task and emerging challenges.[16,17]

Weick and Roberts conceptualized the "collective mind" as a "pattern of heedful interrelations of actions in a social system.[18] The two scientists differentiated between heedful interaction and habitual interaction in the sense that with the latter phenomenon, actions are modified with experience overtime. Further, heedful interaction is a deliberate effort to continually consider one's own actions in relation to the divergent goals and actions of others. Within an organizational system, heedful actors *contribute* their actions with the understanding that they are part of a dynamic interacting system involving other actors that are also *represented* in the system. As such, individual contributions are tailored and *subordinated* within the interrelated system. Higher rates of heedful interacting were found to be associated with lower rate of errors in aircraft carrier crews.[18]

As mentioned above, effective IONM for complex neurosurgery cases requires a multi-disciplinary team effort. In reality, however, team interactions are not as clearly structured as in analogous high intensity professions such as aviation. Diverse medical cultures and ambiguous team relations make effective communication in the OR a challenge. The comprehensive unit-based safety program developed by clinicians at the Johns Hopkins hospital identified four key components of effective communication:[19]

1. Complete – communicate all relevant information and avoid unnecessary details that add confusion
2. Clear – use common or standard terminology when communicating with team members
3. Brief and concise
4. Timely – offer and request information, promptly relay it, verify the recipient received the intended message and validate information received

There is empiric evidence demonstrating improvement in surgical mortality with a formal training program of effective communication in the OR.[20] Neily et al. evaluated the effectiveness of a medical team training program in the OR in 106 veteran hospital association facilities. The training program was based on the crew management theory of effective communication adapted from aviation industry. Surgeons, anesthesiologists, nurses, technicians were taught to:

- work as a team
- challenge each other when they identify safety risks
- have checklist guided preoperative briefings and postoperative debriefings
- use rules of conduct for communication
- step back to reassess the situation, and
- effectively communicate during care transition

The implementation of this program resulted in 18% reduction in surgical mortality. In a similar vein, a scientific statement regarding patient safety in the cardiac OR commissioned by the American Heart Association identified critical elements of the team work that included communication, cooperation, coordination, cognition (collective knowledge and shared understanding), conflict resolution, and coaching (team training).[21]

The key question is how can we translate the aforementioned knowledge base to improve neurosurgical team performance and optimize the effectiveness of IONM? While a sound answer to this question will require detailed multi-stakeholder consultations and a systematic review of the relevant

evidence, some provisional considerations from the perspective of an anesthesiologist are shared here.
Neurosurgical procedures are often complex and prolonged. Further, a high proportion of procedures are undertaken in emergent situations. As such, neurosurgical outcomes will be hugely impacted by formalization and standardization of teamwork that has been instrumental in performance improvement of aviation cockpit crews.

At the point of OR booking, the type of surgery and required neuromonitoring modalities should be clearly stated. The anesthesiologist should have adequate time to prepare an appropriate plan particularly if neuroanesthesia is not his/her area of expertise. Ideally, however, neuroanesthesiologists or anesthesiologists with interest and experience with neurosurgery should conduct neurosurgical cases requiring IONM. As the goal is not acceptable anesthesia but the most optimal anesthesia for neuromonitoring, there is a role for standardized anesthesia protocols prepared by expert neuroanesthesiologist.

On arrival of the patient in the OR, most hospitals follow the universal surgical protocol. The protocol includes, besides other steps, a verification of patient's identity, signing of consent, identification of the site of surgery and specific description of the surgical procedure. It is important for the IONM professional to introduce him/herself to the patient and explain, in terms understandable to the patient, the role of IONM in that particular surgery. It is also important that the IONM professional establish a rapport with the surgeon and anesthesiologist so free communication of IONM strategies and information can be discussed with them, as necessary, before and during the case. In this way, best IONM modalities and methods are employed to optimize neurological outcome and patient care. The IONM professional, surgeon and anesthesiologist must be aware of intraoperative surgical management strategies should the IONM professional detect a change in IONM that suggests impending neurological deficit. OR Nursing staff should also be made aware of the function of IONM (e.g., Nursing round presentation of IONM) so they may also facilitate optimal delivery of IONM.

In the early stage of surgery there is usually a competition for access to some areas of the patient; as a priority, the anesthesiologist should establish their line access first. After induction anesthesiologist should inform IONM team once the stable level of anesthesia is achieved. IONM team should verify proper functioning of the equipment and get a good quality baseline recording before final positioning of the patient.

Throughout the surgical procedure communication between IONM team, anesthesia team and the surgeon is crucial. Because stable anesthesia is pivotal to effective neuromonitoring, any changes to the administered medications to maintain stable anesthesia should be promptly communicated to the IONM team. As the surgeon and anesthesiologist may have to make necessary adjustments, both should be immediately informed of all significant changes captured in neuromonitoring. Additionally, calm, professional, and effective communication helps in such a crisis situation; as a rule, a rushed environment should be avoided as much as possible.

It is hoped that with the passage of time and increasing number of surgical procedures, the neurosurgical team will co-evolve into an adaptive and effective organizational unit optimizing the effectiveness of IONM and improving outcomes of neurosurgery. Future research should consider building upon these preliminary considerations and formulating comprehensive guidance for effective functioning of neurosurgical team, measurement of outcomes and continuous quality improvement initiatives.[3]

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Dr. Francesco Sala, MD, PhD
Pediatric Neurosurgeon
Associate Professor of Neurosurgery at the University of Verona, Italy
IONM Advocate

Dr. Francesco Sala is a pediatric neurosurgeon and associate professor at the University of Verona, Italy. His field of practice is in intramedullary spinal cord tumours and tumours in the eloquent areas of the brain. In addition to his neurosurgery training, Dr. Sala also completed a Clinical Fellowship in Intraoperative Neurophysiology under the tutelage of Dr. Vedran Deletis.

Utilizing his clinical knowledge in IONM, Dr. Sala has been instrumental in launching neuromonitoring programs at several institutions around the world. In 2010 he introduced IONM to the University of Cape Town in South Africa during his assignment as visiting professor. Dr. Sala then established an Intraoperative Neurophysiology Unit upon his arrival at his current position in Verona, Italy.

As a long-standing supporter of IONM, he has also been greatly involved with advancements in professional standards and guidelines. Dr. Sala was one of the co-founders of the International Society for Intraoperative Neurophysiology (ISIN) where he was chairman of their Education Committee and most recently he served as ISIN president (2013-2015). In 2013, CANM was honored to have Dr. Sala attend our annual symposium as our esteemed Keynote Speaker. I am fortunate, once again, that he has agreed to share his opinions on current issues influencing the practice of IONM today.

Gina Bastaldo, MSc, CNIM
Secretary, CANM Executive Board
Editor-in-Chief *Canadian IOM News*
Toronto Western Hospital, University Health Network
Toronto, Ontario

Gina Bastaldo (GB): You have extensive expertise in IONM, gained from completing a clinical fellowship in intraoperative neurophysiology at the Institute for Neurology and Neurosurgery. This type of advanced training in IONM is unique for a neurosurgeon. Can you describe what influenced you to pursue a clinical fellowship in this specialized field of allied health care?

Francesco Sala (FS): Actually, the decision to pursue a clinical fellowship in IONM was not mine. At that time, 1998, MEP monitoring was just being introduced in very few institutions worldwide. My chairman, Professor Albino Bricolo, had a specific interest in spinal cord and brainstem tumor surgery. He was enthusiastic about IONM techniques developed by Dr. Vedran Deletis for MEP monitoring and brainstem mapping. So, Professor Albino Bricolo asked me if I was willing to spend 18 months in New York City to learn about IONM and bring the expertise back to Verona. Ironically, at that time I had no interest at all in neurophysiology, but I thought that could be a good opportunity to get to know an emerging field.

GB: How has this training influenced your neurosurgical practice in Verona, Italy?

FS: That training (in IONM) turned out to be a milestone in my education and something which oriented my neurosurgical career towards a functional approach to neurosurgery. It was not easy at the beginning because I was a neurosurgeon performing IONM for my colleagues who were doing the surgical cases. However, that proved to be the best way to learn IONM and it was an opportunity to define my neurosurgical profile. Through the years everything was paid back. I started to work mainly as a neurosurgeon while growing and training a team of IONM technologists and neurophysiologists who took over the IONM duties in the OR. Meanwhile, I developed my academic profile as a neurosurgeon with specific expertise in the field of IONM, which was appreciated not only within the IONM community but within the neurosurgical community as well. I have no regrets and would take the same path over and over again.

GB: In addition to introducing IONM to the University of Cape Town you were also instrumental in establishing a successful neuromonitoring department at your current neurosurgical practice in Verona, Italy. What recommendations do you have for physicians who are struggling to launch a neuromonitoring program in their institution? Can you describe the "roadblocks" you encountered and what were the key factors that led to your success?

FS: It was rather easy to establish IONM in Verona because this was the goal of the chairman of our Department of Neurosurgery and he was the first supporter of that plan. When the request comes from the neurosurgical team then roadblocks can easily be overcome. Most of our anesthesiologists were supportive from the very beginning because Professor Bricolo and I spent time to explain why IONM was important.

Over time, the vast majority of my neurosurgical colleagues started to request IONM for their cases and I would joke with them "IONM is like honey for the bears; they couldn't resist it." I do admit that there can be some challenges with launching a neuromonitoring program. But its success depends on the correct mental approach. If you establish an IONM program because the surgeons ask for it and are prepared to modify their surgical attitude, then there is no reason why it should be problematic. If surgeons are committed, then the anesthesiologists usually share this commitment and are supportive. Vice versa, if IONM is performed just because "they say that you can't do without it" or for a "medical legal perspective" then we are in trouble because the real drive was just to say "we used IONM" instead of understanding and using IONM appropriately. Through the years "having IONM" has become trendy and "sexy" within the neurosurgical community because patients, health insurances and lawyers ask for it. But it is essential to believe in IONM and to understand it, at least a little bit, in order to use it properly.

GB: Although IONM has been widely practiced in North America for many decades, how often do you encounter European physicians who are unfamiliar with this important adjunct to surgery? What are common, misguided assumptions your colleagues have shared with you regarding IONM?

FS: The Old Continent has been as instrumental as North America in developing the field of IONM. Some of the most important achievements in modern IONM (e.g., transcranial MEPs) came from Europe, in particular from Germany. So, misguided assumptions towards IONM are not more common in Europe than in the U.S. or Canada. But, apart from this, I think the scenario has remarkably changed over the past decade. When I started, the most common prejudices about IONM were the poor reliability (false positive, false negative) and the fact that it was not evidence based. But neurosurgeons who were active in the 80s and 90s were mainly using SSEPs and BAERs and not MEPs. So, there were disappointing results and some misleading terminology contributed substantially to this lack of acknowledgment towards IONM.

For example, if a patient emerged from surgery with hemiplegia despite unchanged SSEPs, it was labeled as a "false negative SSEP" result. But of course this was incorrect because SSEPs are not supposed to provide information on motor pathways. Another misguided assumption was, and still is, the idea that IONM can merely predict a

neurological injury, but not prevent it. We know that this may be the case for some irreversible IONM changes but there is no doubt that the vast majority of IONM changes are reversible and allow for corrective measures that minimize morbidity. At the same time, we should accept that IONM cannot solve all of our problems and there are limitations. We have to be very honest about what IONM can and cannot do.

GB: As a neurosurgeon who utilizes neuromonitoring in complex surgical procedures, do you routinely make it a part of your practice to inform your patients that IONM will be performed during their surgery? What are the possible benefits and potential challenges of providing your patients with this information prior to their surgery?

FS: Many patients do not know about IONM and its value. I meet patients who nod their heads when I mention IONM maybe because the referring physician referenced IONM when speaking to them earlier or because they read something on the Internet about neuromonitoring. In general, however, they are not aware of the use of IONM. I do inform about my patients about IONM by explaining that these techniques carry minimal risk to them but are of great potential value in reducing the risk of a surgery-related injury to the nervous system. I also emphasize, especially for spinal cord tumour surgery, that IONM is our compass and it is of paramount importance to decide when to stop and, if needed, leave tumour behind in order to preserve function. But I also highlight that while neuromonitoring is helpful it doesn't always prevent morbidity. Transient deficits maybe be expected regardless of the use of IONM. This information is obviously tailored for each specific case based on the surgical risk, patient's expectations and goal of the surgery. This is why, in my opinion, the "one size fits all" approach doesn't apply to IONM and warning criteria should be tailored to each surgical procedure.

GB: The practice of multimodality monitoring begins with preoperative planning to determine what sensory and motor modalities should be performed. Describe your involvement in this planning process. Can you elaborate on the communication between you and the IONM practitioner?

FS: Honestly, I have to admit that this is not an issue in our practice in Verona anymore, as the caseload has reached over 2000 procedures and our IONM team members are fully aware of what modalities to monitor for each case. But there is no doubt that communication is of paramount importance between the neurosurgeon, anesthesiologist and IONM team. It is important because the IONM team must be aware of the goals of the surgery and of the most critical steps of the procedure. As I said before, warning criteria should be tailored to each individual case and one of the prerequisites to define these criteria is to know the goals of the surgical procedure and the expected rate of complications. I want the IONM team to feel involved in the care of the patient. So, for example, I like to show them the patient's MRI scans before the case starts to illustrate what we are going to do. Also, I encourage them to see the patient after the surgery because this is the best way to appreciate the value of IONM and the correlation between intraoperative neurophysiological data and post-operative outcome.

GB: While motor evoked potentials (TCE MEPs) are primarily performed to monitor the spinal motor tracts, this modality is increasingly being applied in intracranial procedures to assess the functionality of patients' motor cortices. In your neurosurgical practice you often incorporate TCE MEPs for your intracranial surgical cases. Can you describe the types of intracranial cases in which you believe TCE MEPs are most beneficial?

FS: In Europe, especially in Germany, TCE MEPs have been in performed in brain surgery for more than 20 years. TCE MEPs can be very useful in brain tumour resections as well as in aneurysm surgery but I would add, cortical MEPs are even more reliable. Nowadays, cortical and especially subcortical mapping is very popular. In the surgery of brain gliomas, and in particular for low grade gliomas, subcortical mapping of the various white matter tracts has become a standard technique to preserve function, including motor function. However, unless the patient is awake, the functional integrity of motor pathways cannot be assessed continuously by using mapping techniques alone. If you map the corticospinal tract at the level of the internal capsule, a muscle response will only tell you that the tract is intact from the point of stimulation to the muscle, but would not provide any information on the well-being of

the tract proximal to the point of stimulation. Therefore, any ischemic injury rostral to the point of stimulation will not be detected by subcortical mapping and the patient will wake up hemiplegic. Hence, to run cortical MEP from a strip electrode on the central region allows a continuous assessment of the functional integrity of the motor tracts and it is the only way to detect an ischemic injury. This is of great value especially in vascular neurosurgery and in the surgery of insular gliomas where the mechanism of injury is mainly vascular. Data from the literature suggest that MEP monitoring likely prevents or minimize motor deficits in about 66% of the cases where an MEP deterioration occurred. In the remaining 34%, MEP monitoring can merely detect but not prevent injury. With regards to TCE MEP versus cortical MEP, the latter has the advantage because much lower stimulating intensity is needed which significantly decreases the risk of a distal activation of the corticospinal tract and reduces the risk of false negative results. So, in brain surgery, I would recommend the use of cortical MEPs whenever feasible.

GB: Both neurosurgeons and IONM practitioners have suggested that neuromonitoring may have a negligible impact on minor neurosurgical procedures (e.g., lumbar discectomies). Have you made similar observations on the overuse of IONM? What are the possible advantages or disadvantages of this service being exceedingly allocated to "less" risky surgical cases?

FS: This is an interesting question. In Italy the resources allocated to IONM are scarce in terms of both equipment and personnel. So the problem is the opposite: We have to differentiate cases where monitoring is indispensable, from those where it is optional, from those where it could be considered a luxury (lumbar discectomies likely belongs to this third category). The Italian Neurosurgical and Clinical Neurophysiology Societies have recently established that IONM should be considered standard of care for: gliomas in eloquent brain areas, brainstem lesions, cerebellopontine angle lesions, intramedullary lesions and surgery of the conus/cauda. For everything else, including all spine pathologies, IONM is considered optional. This scale of priority has much to do with medical legal concerns but it also reflects costs and benefit. In my opinion, the indication for the use of IONM should be based on the risk of injury and local resources. To use IONM for lumbar discectomy surgery makes no sense if you compare the real risk of nerve injury with the number of surgeries that should be monitored. But, again it depends upon your resources. If you have the equipment and staff to cover a case where there is just a remote chance of doing any harm to the nervous system, you may consider using it. But would this make sense from a cost/benefit perspective? In addition, the "real world" has different realities in Italy, Canada, Germany, and the U.S. For example, while pedicle screw monitoring is a standard in North America, it is almost always neglected in Italy and I was never asked to monitor for such cases in Verona.

GB: There has been considerable debate within the IONM community regarding the use of "Remote Monitoring." Many have expressed apprehension with this practice which allocates neuromonitoring oversight to an individual who is not physically in the operating room. Do you share these concerns? Do you believe that "Remote Monitoring" can increase surgeons' access to IONM?

FS: I think true "remote monitoring," meaning an individual in Toronto monitoring a case in Ottawa, should not be allowed. Would any neurosurgeon accept "remote anesthesia" with a machine providing all vital signs and the anesthesiologist supervising from hundreds of miles away? Certainly not. So, why should IONM be sold cheaply? If you are not in the O.R. or in the hospital ("in house remote monitoring") and available upon request, then how can you possibly understand what is going on and discuss IONM changes with the anesthesiologist and the surgeon? I think "remote monitoring" can be considered when the alternative is to cancel the case. Technology nowadays allows us to see the IONM data from everywhere and to communicate easily. Therefore, if I cannot be in the hospital and a surgery must be performed promptly I may consider supervising remotely to provide feedback to the technologist in the O.R. However, this should be the exception to the rule.

Fortunately, "remote monitoring," to my knowledge, does not exist in Italy and it is my understanding that the IONM community in the U.S. has not been very happy with this modality to the point that this practice has been very much restricted in recent years. Vice versa, "In house remote monitoring" where the supervisor is in the hospital and can step into the O.R. is a quite acceptable practice and common due to limitation of human resources. But, the experience of the IONM team is a key factor in allowing more flexible models of neuromonitoring.

GB: The majority of recent literature surrounding the field of IONM has been dedicated to the use MEPs. As an avid supporter of IONM research, can you suggest another specialized area of neuromonitoring that has been neglected in the literature and deserves more attention from researchers?

FS: This is my top list of some areas in IONM which may require more attention in the years to come:

1. IONM techniques to monitor the afferent pathways of reflexes mediated by the lower brainstem (coughing, swallowing). These are still lacking but of paramount importance in brainstem and posterior fossa surgery.
2. IONM techniques for monitoring oculomotor nerves. Still not well developed.
3. Correlation between IONM data and clinical outcome. We need to focus on transient changes, which are rarely considered in the outcome analyses. We also must define false positive and false negative results in a more precise way. This requires a refined neurological assessment post-operatively and careful recording of all the intraoperative IONM events.

GB: You were a co-founder of the International Society for Intraoperative Neurophysiology (ISIN) and you served as the keynote speaker at the 6th Annual CANM IONM Symposium. Can you provide insight on how professional associations like those mentioned above have impacted the current practice of neuromonitoring today? How do you foresee these associations evolving in the future?

FS: I think scientific societies can play a critical role in promoting neuromonitoring. CANM, ASNM, ISIN (and other societies with chapters dedicated to IONM) are promoting IONM education on many different levels (national, international) and with different modalities. Moreover, these societies are working to establish IONM credentialing and standards of practice through the definition of curricula, publication of guidelines and promoting advancements in the field of IONM.

For an international society such as ISIN, the challenge is unique because we are dealing with IONM globally. The state of IONM is extremely variable around the world and the issue of credentialing and training should be tailored accordingly, but this is not easy. Nevertheless, over the past five years I've been amazed to see how interest for educational courses has increased exponentially. This means that there is a huge need for training opportunities and scientific societies are responsible for it. But educational courses and congresses are not enough as "hands on" experience is also necessary. We need training centers with a large enough IONM case load to offer proper training in a limited time frame. How to develop these training programs is problematic and I think this represents one of the challenges of IONM today.

GB: Although many neurosurgeons appreciate the value of IONM, lectures relating to neuromonitoring are not often featured at neurosurgical symposiums. As a member of several neurosurgical associations what IONM topic would you like to see discussed at a future neurosurgical meeting?

FS: As a neurosurgeon, I have to acknowledge that the interest for IONM has increased remarkably over the past few years not only within clinical neurophysiology societies but also within neurosurgical societies. I recently had the opportunity to serve as the Italian delegate within the Training Committee of the European Association of

Neurosurgical Societies. This is the most important scientific society providing neurosurgical education to European trainees. Over the past 7-8 years, IONM topics have progressively become part of the curriculum of these courses and all European trainees are exposed to IONM in the form of formal lectures and/or discussion groups. Similarly, the World Federation of Neurosurgical Societies has recently established a dedicated Neuromonitoring Committee to develop the field of neuromonitoring worldwide, within the neurosurgical community. These are very important signs that neurosurgeons have become more aware of the relevance of IONM in their practice and many (especially the younger generation of neurosurgeons) have completely changed their attitude towards neuromonitoring. The role of IONM was certainly very controversial in the past but I think we can now say that time has gone. Yet, we have to remain critical in evaluating what IONM can and cannot achieve. To ignore the limitations of IONM would harm the credibility of IONM itself and also those who believe in neuromonitoring.

(This interview was edited for length)

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