MULTIMODAL INTRAOPERATIVE NEUROPHYSIOLOGICAL MONITORING DURING SPINAL SURGERY

DAN FILIP[1], MARCEL PEREANU[2]

[1,2]*"Lucian Blaga" University of Sibiu*

Keywords: *intraoperative neurophysiological monitoring, motor evoked potentials, sensory evoked potentials*

Abstract: *Intraoperative neurophysiological monitoring in spinal surgery requires a multimodal approach in order to assess the integrity of ascending, descending tracts and of nerve roots. To this end, it is recommended to continuously record during surgery, the motor and sensory evoked potentials (MEPs, SEPs), as well as the electromyographic (EMG) activity. Sensory evoked potentials are obtained by peripheral stimulation of nerves and recording at scalp level. Motor evoked potentials are obtained by transcranial or cortical electrical stimulation recorded at selected muscles level, from where spontaneous electromyographic routes are also obtained.*

INTRODUCTION

In the early stages of intraoperative neurophysiological monitoring (IONM), sensory evoked potentials (SEPs) were the only means available to monitor the integrity of the spinal cord and have been used for a long period of time in the US, Europe and Japan.

This unique modality soon showed many drawbacks:

- it is no specific to motor tracts;
- it is sensitive to inhaled anesthetics;
- it requires relatively long time for data acquisition;
- patients with spinal pathology can sometimes have poor quality SEP.

Some authors have shown that bone marrow lesions occurred without SEP parameters damage.(1,2)

The main discovery in IONM was the monitoring of motor evoked potentials (MEP) by transcranial electrical stimulation (TES) and recording of D waves in the vicinity of the spinal cord. Using short repetitive stimulation technique instead of single-pulse stimulation allowed obtaining MEP by direct excitation on the exposed transcranial or motor cortex and the recording in the exposed limb muscles.(2,3)

Methodological aspects

Electric assembly for SEPs

Electric placing for the recording of SEP is made at scalp level based on the EEG 10/20 system. Corkscrew-like electrodes are used in the Cz`-Fz` locations for lower limbs and for upper limbs in C3`-C4` locations. Corkscrew-like electrodes are used for secure fixing and low impedance (<1 kΩ).

Stimulation is made peripherally on the median and ulnar nerves at wrist level, respectively on the tibial nerve at ankle level. Sensory evoked potentials are being used, the most important being the N20 for the upper limbs and P40 for the lower limbs. Latency and amplitude of these potentials are monitored compared to their value at the beginning of surgery. Any latency elongation of over 10% and an amplitude decrease above 50% are considered an alert and must be reported to the neurosurgeon, who further decides what measures should be taken to remedy the changes when possible.(2,3)

Electric assembly for MEPs – single pulse and multipulse stimulation

Transcranial electrical stimulation electrode placement is based on the 10/20 EEG system. The skull is a great barrier to the transcranial direct current stimulation, therefore complete control of current transmission cannot be made. Therefore, there are tried several combinations of assemblies to get an optimal response. MEP standard fitting for the upper limbs is C3/C4 and C1/C2 for the upper limbs. With a proper intensity, C1/C3 stimulation reveals MEP in the right limbs and C2/C4 stimulation in the left limbs, the first electrode being the anode.(3)

MEP recording at bone marrow level (subdural/epidural space) as D and I waves by single pulse stimulation

The neurophysiological mechanism for obtaining MEP by stimulating the cortex in the anesthetized patients is different from the vigilant ones. In the latter, the electrical current stimulates the body of the transsynaptic motor neuron through a chain of excitatory neurons, resulting I waves (indirect activation). At the same time, the current directly activates the axons of the cortical motoneurons generating the D wave. In the anesthetized patients, the anesthetic blocks the vertical excitatory chains, so that in most patients, only D waves are obtained.(4)

Disposable catheter-type electrodes are used, inserted epidurally, percutaneously or after laminectomy/flavectomy. There are two electrodes, one rostral, control electrode unaffected by surgical procedures and one caudal, which monitors the changes induced intraoperatively on the corticospinal tract. D wave amplitude at cervical level is around 60 μV and at thorax level - 10 μV. With a stimulation rate of 2 Hz, it is necessary a mediation of 2-4 responses for one optimal D wave.(1,4)

D wave is a neurogram of the corticospinal tract, which is not significantly influenced by nonsurgical factors. No synapse is interposed between cortical stimulation and marrow recording, so that D wave is very stable and secure. Therefore, it is considered the "gold standard" in measuring the integrity of the corticospinal tract.

Dural massive adhesions after previous surgeries or radiotherapy may prevent placing the electrodes. Placing

[1]Corresponding author: Dan Filip, Str. Şerpuită, Nr. 22, Sibiu, România, E-mail: fildaro@yahoo.com, Phone: +40721 212820
Article received on 07.10.2015 and accepted for publication on 02.03.2016
ACTA MEDICA TRANSILVANICA March 2016;21(1):89-90

electrodes below the T10 vertebral level may not provide a D wave of sufficient amplitude because of the low number of fibers in the corticospinal tract. In patients with corrected scoliosis, D waves can vary because of changing the position of electrodes.(5)

MEP recording in limb muscles through multipulse stimulation

Muscles selection to be monitored is most important. For the upper limbs, abductor pollicis brevis muscle (APB) and first dorsal interosseus (FDI) are the most commonly used; flexors or long extensors of the forearm are also used, and less used are the proximal muscles (biceps, triceps, deltoid). For the lower limbs, the elective muscles are abductor hallucis brevis (AHB) and the tibialis anterior (TA). Standard muscle selection is as follows: APB, AHB and TA.(1,2)

Muscle MEP generation is more complex. It depends on many factors:

- excitability of the motor cortex and corticospinal tract;
- corticospinal axons spinal conductivity;
- α motoneurons excitability;
- the role played by the supportive medullary system;
- integrity of the motor nerve, of neuromuscular junctions and muscles.(2)

IONM nomenclature

The application of a single method for monitoring, such as SEP is not sufficient, and a multimodal approach is needed to assess the integrity of the ascending, descending tracts and of nerve roots. Surgeons and practitioners must be familiar with certain terms like D and I waves, subcortical and cortical free-running electromyography (EMG), triggered EMG, compound muscle action potential (CMAP), compound nerve action potential (CNAP), F answer, H reflex. Monitoring should be carried out by an experienced neurologist or neurophysiologist.(5,6)

Sensory evoked potentials (SEPs) assess the somatosensory system integrity within the dorsal columns. Motor evoked potentials (MEPs) consider the integrity of the motor corticospinal tract; descending corticospinal currents recorded epidurally, spinally are the D and I waves, and the muscle response is the motor evoked potential.(6)

The structures to be stimulated and recorded (brain, spinal cord, nerves, muscles) will be chosen based on existing and/or anticipated lesions. Evoked potentials monitoring is bilateral, proximal and distal to the lesion in order to distinguish the systemic changes induced by anesthesia, temperature, as well as to the other changes caused by ischemia or surgical procedure. Simultaneously monitoring the upper and lower limbs improves the differentiation but also ensures the protection of the brachial plexus and upper limb nerves.(5)

Regarding anesthesia, it is very important to use the total intravenous anesthesia (TIVA) protocol and to avoid the neuromuscular blockade after intubation for a safe neurophysiological monitoring.(5)

Efficacy and safety of the invasive spinal monitoring techniques are valid in the selected cases. MEP obtaining is mandatory; for intramedullary tumours, the invasive monitoring with D waves is also required. This results from the fact that intramedular dissection can selectively disrupt the supportive motor system, bringing about muscle MEP loss without damage to the corticospinal tract or to alpha-motoneurons. Under these special circumstances, the persistence of D waves indicates the integrity of the corticospinal tract and predicts a better long-term motor development; it also allows completing tumour resection despite muscle MEP loss.(6)

Multimodal IONM indications

Multimodal intraoperative neurophysiological monitoring is indicated in:

- all spinal surgical procedures with risk of injury to nerve structures;
- correction of deformities of the spine with scoliosis> 45^0;
- correction of congenital anomalies of the spine;
- extra- and intramedullary tumour resection;
- posterior or anterior decompression of stenosis of vertebral, cervical, thoracic or lumbar canal with myelopathy, radiculopathy or ponytail syndrome.(1,4,6)

CONCLUSIONS

Current knowledge justifies the development of the intraoperative neurophysiological monitoring and its establishment as a routine procedure in spinal surgery centers with a view to improve surgical outcomes and to reduce the risk of possible damage to the nerve structures. Therefore, we can draw the following conclusions:

- the neurosurgeon and the neurophysiologist should know the anatomical structures and the surgical manoeuvres that may cause neurological damage during spinal surgery;
- the combined use of SEP, MEP and of EMG spontaneously/simultaneously is mandatory and extremely useful in preventing neurological injuries during these spinal surgical procedures;
- intraoperative neurophysiological monitoring and the alarm criteria should be adjusted according to the type of lesion and intervention;
- although, there are no intraoperative neurophysiological changes, IONM is useful because it increases neurosurgeon's confidence and allows more radical resections.

REFERENCES

1. Deletis V. Intraoperative neurophysiology and methodology used to monitor the functional integrity of the motor system. In: Deletis V, Shils J (eds) Neurophysiology in neurosurgery. Dublin:Academic; 2002 .p. 25-51.
2. Deletis V. Basic methodological principles of multimodal intraoperative monitoring during spine surgeries. Eur Spine J. 2007; 16 Suppl 2 :S147-S152.
3. Szelenyi A, Kothbauer K, Deletis V. Transcranial electric stimulation for intraoperative motor evoked potential monitoring: stimulation parameters and electrode montages. Clinical Neurophysiol. 2007;118:1586-1595.
4. Sutter M, Deletis V, Dvorak J. Current opinions and recommendations on multimodal intraoperative monitoring during spine surgeries. Eur Spine J. 2007;16 (Suppl 2):S232-S237.
5. Macdonald DB. Intraoperative motor evoked potential monitoring: overview and update. J Clin Monit Comput. 2006;20(5):347-377.
6. Sala F, Faccioli F, Lanteri P, Gerosa M. Surgery for intramedullary spinal cord tumors: the role of intraoperative neurophysiological monitoring. Eur Spine J. 2007;16(Suppl 2):S130-S139.