

Motor Evoked Potentials in 43 High Risk Spine Deformities

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ABSTRACT

Introduction: Correction of pediatric spine deformities is challenging surgical procedures. This fragile group of patients has many risk factors, therefore prevention of most fearing complication- paraplegia is extremely important. Monitoring of transmission of neurophysiological impulses through motor and sensor pathways of spinal cord gives us an insight into cord's function, and predicts postoperative neurological status. Goal: Aim of this work is to present our experiences in monitoring of spinal cord motor function - MEP during surgical corrections of the hardest pediatric spine deformities, pointing on the most dangerous aspects. **Material and methods:** We analyzed incidence of MEP changes and postoperative neurological status in patients who had major spine correcting surgery in period April '11- April '14 on our Spine department. **Results:** Two of 43 patients or 4.6% in our group experienced significant MEP changes during their major spine reconstructive surgeries. We promptly reduced distractive forces, and MEP normalized, and there were no neurological deficit. Neuromonitoring is reliable method which allows us to "catch" early signs of neurological deficits, when they are still in reversible phase. Although IONM cannot provide complete protection of neurological deficit (it reduces risk of paraplegia about 75%), it at least afford a comfort to the surgeon being fear free that his patient is neurologically intact during long lasting procedures.

Key words: monitoring, neglected, spine, deformity, neurological deficit

1. INTRODUCTION

Over the past 80 years spine surgeons have increased their capability to provide substantial surgical correction for spinal deformity. The fusion described by Hibbs in 1924 was essentially an in-situ fusion with a post-operative cast applied to gain a small amount of correction. Cast immobilization allowed some rigidity but both pseudoarthrosis and scant correction of the deformity were common. Subsequently, spinal implants were designed to apply corrective forces and provide rigidity to the spine. Unfortunately with improved correction came occurrences of spinal cord injury. These neurologic injuries happened secondary to either direct, mechanical force applied to the spinal cord from implants, instruments, or bony structures or the injuries were the result of indirect ischemic changes from vessel ligation during exposure or cord distraction/compression during corrective maneuvers. The wake up, or Stagnara test was the first method to monitor spinal cord function during surgical correction of deformity. The wake up test had several disadvantages including: only gross motor function could be assessed,

the test was time consuming and typically occurred at a time remote from the application of corrective forces, was difficult to perform repeatedly, and finally there was a risk of accidental extubation with the patient in the prone position.

Innovations required for better spinal deformity surgery included improved spinal implant design and more sophisticated peri-operative care. Safer anesthesia, the invention of the cell saver, and spinal cord monitoring all assisted the evolution of spinal deformity surgery. Of these, the ability to monitor spinal cord function and the use of better spinal implants were paramount in facilitating better deformity correction. Modern implants enhanced the ability to change the position of the spinal elements using strong corrective forces and required that surgeons have a better ability to identify impending spinal cord injury. Quickly identifying impending spinal cord injury gave surgeons and anesthesiologists the potential to act before the injury became irreversible (1).

In an experimental rat model, Glassman et al correlated TcE-MEP changes during distraction with post-oper-

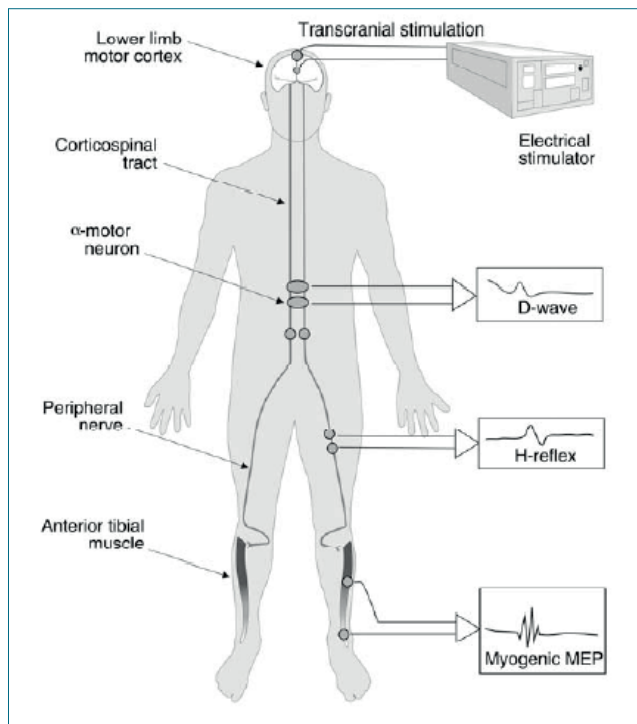


Figure 1. Schematic view of MEP recording

ative neurologic function (2). Identification of TcE-MEP changes and early reversal of the distraction improved subsequent neurologic function (Figure 1) (3).

Generally, neuromonitoring is most often used in surgery of pediatric spine deformities. This fragile subset group of patients has many risk factors: young age, undeveloped body, other congenital anomalies, low vital capacity-VC, already distracted medula, etc. Therefore, monitoring of gross motor function in pediatric spine deformity surgery is important and challenging, especially when there are neglected severe spine deformities to correct.

Additional neurological risk poses patients with neglected rigid scoliosis and kyphosis, congenital types of spine deformities (hemi vertebrae), revision spine surgeries, marfanoid patients with lord scoliosis, etc (4). Although such patients are not majority in everyday practice of one spine surgeon, it is of uppermost importance to be aware of their fragility and all possible surgical, neurological and anesthesiological complications.

Aim of this paper is to present our experiences in MEP monitoring during risky surgical corrections of pediatric spine deformities, pointing on the most dangerous aspects.

2. MATERIAL AND METHODS

In our paper we analyze incidence of MEP and post-operative neurological changes in patients who had posterior corrective spondylodesis w/wo spine osteotomies (PCR, PSO, PO), performed during last 3 years (April '11-April '14) on our Spine department.

Including criteria were: posterior corrective spondylodesis by transpedicular screws due to pediatric spine deformities with higher risk of neurological complications (rigid scoliosis $\geq 70^\circ$ of Cobb angle, midthoracic Schoerman kyphosis $\geq 90^\circ$, low thoracic Schoerman kyphosis $\geq 50^\circ$, thoracic hemi vertebrae, other congenital types of scoliosis

(4), Risser 5, normal neurological status prior surgery, and surgery performed by the same surgeon (MB).

Excluding criteria were: anterior corrective spondylodesis, flexible spine deformities (correction of Cobb angle on traction/bending films more than 40%), non adherence to standard anesthesiological/surgical protocol (total intravenous anesthesia-TIVA, MEP, fixation by other means). Above described requirements have completed 43 patients, average 17.3 (13-24) years old, mostly female gender (31:12).

Indications for surgeries were:

- adolescent idiopathic scoliosis-AIS $\geq 70^\circ$: 31 pts. (72,1%),
- revision of anterior surgeries: 3 pts. (7,0),
- lordoscoliosis at Sy Marfan patients: 2 pts. (4,6%),
- midthoracic Schoerman kyphosis $\geq 90^\circ$: 2 pts. (4,6%),
- thoracic hemivertebrae: 2 pts. (4,6%),
- lowthoracic Schoerman kyphosis $\geq 50^\circ$: one patient (2,3%),
- other congenital spine deformities: 2 pts. (4,6%).

Preoperative protocol, positioning of patient, surgical technique, system of drainage, wound closure, and post-operative care were identical at all our patients, with exceptions related to the specificity of each patient.

Transcranial electric motor evoked potentials are generated using an electric stimulus applied through needle or corkscrew electrodes inserted into the cranial scalp. These electrodes are typically placed over the motor cortex regions approximately 1 cm anterior to C1-C2. The stimulus intensity of 150-400 V, with stimulus durations of 50- μ sec, and using 2-4 pulses and interstimulus inter-

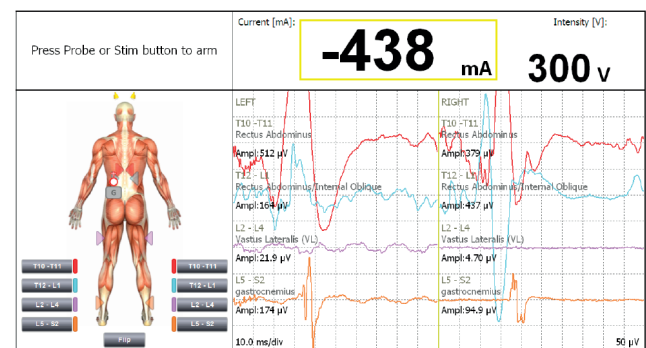


Figure 2. Baseline of MEPs at the beginning of surgery.

val of 1 to 5-msec. These stimulus parameters are typically varied to elicit highest quality baseline MEPs (Figure 2).

Distal recordings are typically acquired through needle electrodes inserted bilaterally into the following upper extremity muscles, the first dorsal interosseous and abductor pollicis brevis. In the lower extremity the quadriceps, anterior tibialis, abductor digiti minimi, and the abductor hallucis are typical distal recording sites. MEP "alert" would involve a unilateral or bilateral, greater than 65 to 75% reproducible decrease in TcE-MEP amplitude from baseline (5).

3. RESULTS

Results of our research are presented by Table 1 and by Figures 3 and 4. Descriptive data of analysed group is presented in Table 1.

	average	SD	min.	max.
age (years)	17.3	4.1	13	24
correction of Cobb angle (%)	69	23	52	92
blod loss (l)	1.2	0.5	0.4	2.1
number of fused vertebrae	12.7	1.8	10	18
duration of surgery (hours)	5.1	0.9	2,5	8

Table 1. Descriptive data of analyzed group of the patients in our sample

All surgeries were performed without MEP changes and changes of postoperative neurological status except in three cases, which we described shortly.

First patient were 23 year old man with neglected right thoracic AIS of 130°. After application of 16kg on halo



Figure 3. HF traction is necessary for gradual correction of spine deformity during surgery.

femoral traction- HF (Figure 3), insertion of screws, and posterior release (SPO-osteotomies), MEPs on left, concave side were decreased more than 65%.

Reduction of HF traction from 16 to 10kg, immediately restored MEPs on the normal levels. Additionally, anesthesiologist has increased mean blood pressure from 90 to 100mm Hg. Such delicate surgical procedure has been justified by huge postoperative clinical benefit of this and other similar patients (Figure 4).

Second patient was 19 year old man with thoracolumbal lordoscoliosis of 70° due to Marfan syndrome. There was identical situation with MEP decreasing and its recovering. Both patients have wake up without any neurological deficit.

Third patient was 19 years old, 201cm high, with neglected angular thoracolumbal Schoerman kyphosis of 50°. MEPs were normal whole the time on legs, and low on both arms (about 15 μ V). Since we have paid much more attention on legs, we ignored low MEPs on arms, which gradually reduced for additional 30% at the end of surgery. After patient wake up, he could not move his right hand, left hand was normal. We started physiotherapy from the first postoperative day, and gradually motor function of right arm was recovered. In next few days, patient could move his fist and fingers, after three weeks he had elbow extension, and initial shoulder abduction and elbow flexion. Full motor function has recovered after 4 months of physiotherapy.

4. DISCUSSION

Intraoperative neurophysiological monitoring today is the golden standard which decreases a fear of spinal surgeries. History of monitoring of neurological function developed from the Stagnara wake-up test to the era of neuromonitoring, first SSEP 1977, reported by Nash and coworkers (6), and three years later MEP, thanks to the work of Merton and Morton (7). After 1990 the neurogenic MEPs were developed as an alternative means of motor monitoring that would bypass the complicated anesthetic requirements of transcranial MEPs, and two years later a triggered EMG appeared due to works of Calancie (8). SSEP is the most common monitoring modality today, where cortical or sub-cortical responses to repetitive electrical stimulation of a peripheral nerve are continuously recorded, monitoring the dorsal column pathway. Its sensitivity is up to 92%, and specificity up to 100%, and do not need a special anesthesiological protocol. MEP has sensitivity and specificity up to 100%, but requires avoiding of halogenated anesthetics, and neuromuscular blockade (succinylcholine, vecuronium, rocuronium etc.), like EMG.

Generally, IONM may be able to reduce neurologic deficits by as much as 50%, depending of identification of anatomical structures at highest risk and rational preoperative planning. Patient related risk factors are: age, comorbidities, pre-existing neurodeficits, hypothermia, decreases CNS activity, hypoxia, destabilization of neurotransmitter activity, anemia, etc. It of uppermost importance to have team approach of surgeon, anesthesiol-



Figure 4. Pre and postoperative clinical and X-ray status.

ogist, and neurophysiologist, but the final responsibility has surgeon. He has to define goals of surgery, needed equipment, and announce parts of surgery which are under highest risk. For posterior approach SSEPs may be sufficient, but it does not cover anterior spinal artery and spinal cord ischemia, where transcranial MEPs are indicated. When there is nerve root concern, spontaneous EMG and triggered EMGs are the first choice. Therefore, combination of different IONM modalities is the best.

When there is positive intraoperative neuromonitoring, it should be excluded technical factors (electrodes), anesthesia related factors (inhalation agents, check hypotension, hypoxia and hypothermia), surgical factors (tension of retractors and spinal instrumentation, screw positioning). If potentials fail to return, then the wake-up test should be performed, and considered the use of corticosteroids. The most dangerous moments are: curve correction, distraction, osteotomy, hypotension, screw insertions, but we should be aware that all neurologic deficits were preceded by electrophysiological changes.

Results in our work suggest that neuromonitoring is essential in such type of surgery, and allows us to "catch" early signs of potential neurological deficits, when they are still in reversible phase. Two of 46 patients, or 4.6% in our group experienced significant MEP changes during their major spine reconstructive surgeries. We promptly reduced distractive forces, and MEPs normalized, and there were no neurological deficit. At the third patient we did not linked MEPs decreasing in arms with malpositioning of a patient on operation table, and he had a transitional postoperative neurological deficit (three months weakness of his right arm). In the work of Raynor and coworkers there was 3.1% true positive findings in 12375 cases (386) spine deformity, degenerative, pathologic, trauma surgery, primary 2.3%, and revision 6.1%, while 89% of true positive events reversed with corrective action (9).

Regarding the costs of neuromonitoring, average 4 hour spine case SSEPs costs \$942, and transcranial MEPs \$1115, while in combination \$1423 (10). Except of costs increasing and duration of anesthesia due to MEP/SSEP setting, IONM has no adverse effects. Theoretical contraindications might be children with seizure disorders. They may not be candidates for TcE-MEP monitoring, as well as children with skull defects. There have also been concerns that tongue lacerations, scalp burns or abductor hallucis compartment syndrome might occur during the electrical stimulation. However, complications are very rare and most authors have experienced no adverse effects of IONM (11).

Several authors have described good results with IONM in children with neuromuscular scoliosis (12). A MEP assesses both spinal cord and nerve root motor function and as such is an excellent method to evaluate a particular root (i.e. L5 with a spondylolisthesis reduction maneuver or possible pedicle screw violation of a root). Combining SSEP and TcE-MEP monitoring has been most commonly utilized in thoracic spine surgery, especially in deformity correction (13). In 2004 Hilibrand reported clear benefits from using both during cervical spine surgery in patients with pre-operative myelopathy and ossification of the posterior longitudinal ligament (14).

Monitoring with both SSEPs and TcE-MEPs decreases the rate of false negative responses which were very common using only SSEP monitoring. Unfortunately, false negative results can still be found with TcE-MEP monitoring. Diab and coworkers reported a surgical series of 1301 adolescent idiopathic scoliosis patients; all were monitored with both SSEPs and TcE-MEPs. One patient had no identified monitoring change with either technique but still awoke with a spinal cord injury (15).

Interestingly, the evidence that monitoring in spinal deformity surgery has decreased the overall incidence of spinal cord injury is lacking. In the pre-monitoring years from 1971 to 1979, Schmitt reported a post-operative spinal cord injury rate of 0.5% using the data from the Scoliosis Research Society (SRS). In 1972, also before monitoring, MacEwen reported a 0.72% incidence of post-operative spinal cord injury (16). Schwartz et al reported 9 post-operative spinal cord injuries in a series of 1121 monitored, adolescent idiopathic scoliosis patients for a rate of 0, 8% (17). Thus while changes in spine cord monitoring have allowed surgeons to recognize injuries intra-operatively, the rate of patients awaking from anesthesia with neurologic defects seems unaltered by the monitoring. This could reflect underreporting of all the neurologic events in the past, better capture of current data, or the likely possibility that the injuries are less severe because they are found quickly when spinal cord monitoring is used. Finding a potential change in spinal cord function during surgery rather than post-operatively allows an immediate decrease in the amount of deformity correction and reversal of excessive blood loss or hypotension. This may be permitting more patients to recover completely now than in the past. The 4 patients in Diab's series and the 9 patients in the Schwartz study, all recovered completely. Where as in MacEwen's pre-monitoring series, 32% of the 79 patients undergoing a posterior spinal fusion had permanent spinal cord injury. MacEwen also noted an inverse correlation between neurologic recovery and the time to implant removal with one partial post-operative spinal cord injury progressing to full paralysis before the implant could be removed. This patient had no neurologic recovery (1).

But, the most important reason for same percentage of neurological injuries might be that today's spine surgeries are much more technically demanding, risky and challenging in comparison to the surgeries before 40 and more years ago.

5. CONCLUSION

IONM is a golden rule in spinal surgery, which at least affords a comfort to the surgeon being fear free that his patient is neurologically intact during long-lasting procedures.

CONFLICT OF INTEREST: NONE DECLARED.

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