PEDICLE SCREW STIMULATION TECHNIQUE IN LUMBOSACRAL SURGERY

DAN FILIP[1], MARCEL PEREANU[2]

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

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Abstract *Intraoperative neurophysiological monitoring in complex lumbosacral surgery - such as arthrodeses involving pedicle screw vertebrae fixation - is useful in early, real-time detection of any radicular irritation or injury. The methods used are spontaneous electromyography and electromyography associated with pedicle screw stimulation. By establishing an intensity of stimulation threshold, we can appreciate the right position of the pedicle screw, so that to avoid any radicular damage or any sensory or motor neurological deficit.*

INTRODUCTION

Lumbosacral spinal pathology is a common problem in adults, lumbosacral surgery rate being about 136/100000/year. The incidence of neurological complications in spinal surgery is about 6%, depending on the extent and complexity of the intervention. The aim of the intraoperative neurophysiological monitoring in lumbar surgical procedures is to detect any radicular irritation in an early stage and potentially reversible when it can alert the neurosurgeon and thus, prevent significant damage, respectively a postoperative deficit.(1)

Electromyography (EMG) is the most used electrophysiological method in order to monitor the function of the nerve roots in the spinal surgery. Pedicle screw stimulation technique is useful to check the correct placement of the transpedicular screw for lumbar arthrodeses. Most spinal fusions with fixation and instrumentation use the pedicle screws as intervertebral fixation means. Vertebral pedicle is carefully punctured up to the vertebral body to ensure a fixed fusion. Studies on cadavers have shown that 20% of screws were misdirected, coming out through the pedicle wall. Clinical studies have detected postoperative symptoms from irritation to radicular lesions due to misplacement of the screw in 5-10% of cases.(2)

METHODOLOGICAL ISSUES

Discectomy is the surgical removal of herniated disc to decompress the nerve root or the spinal canal. Laminectomy consists of surgical excision of the posterior longitudinal ligament and spinous apophysis to reduce lumbar stenosis by creating a wider space for thecal sac and nerve roots. Spinal fusion (arthrodesis) uses bone graft to fix two or more vertebrae in order to limit their abnormal movement. In these cases, the fusion is performed by fixation with metal pedicle screws, plates, bars or "cages".

During these interventions, nerve roots can be damaged by drilling, testing, elongation or misplacement. There is a risk of 8-10% of developing a new neurological deficit through a nerve root injury during a lumbosacral arthrodesis.

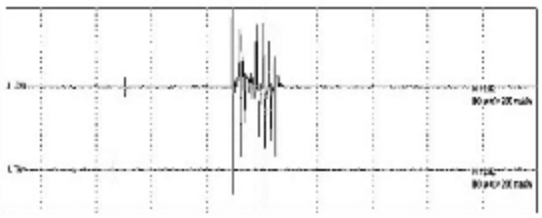
The most common type of deficit is the "foot drop" through L5 root damage, as well as other events in other dermatomes - paresthesia, hypoesthesia, motor deficits or sphincter disorders. Nerve root damage is more frequent in the revisions after surgery, especially if more levels are involved.(3)

Free running electromyography is monitored from the muscles innervated by spinal nerve roots considered at risk during spinal surgery. Injury to the nerve root leads to its depolarization spreading and generating a motor potential in the muscle. Minor handling of the nerve root generates a short discharge of "spike" or "burst" potentials (figure no. 1a,b). A brutal handling that leads to damage or stretching/retraction of the nerve root will cause a "train" of high frequency electrical discharges, called neurotonic discharges (figure no. 1c). In the case of more severe injuries, more rarely can occur myokymias which are groups of high frequency repetitive discharges.(1)

Figure no. 1. Types of spontaneous electrical discharges on electromyography during handling nerve roots

Figure no. 1a. Spontaneous spike discharges

Figure no. 1b. Spontaneous group discharges



[1]Corresponding author: Dan Filip, Str. Şerpuită, Nr. 22, Sibiu, România, E-mail: fildaro@yahoo.com, Phone: +40721 212820
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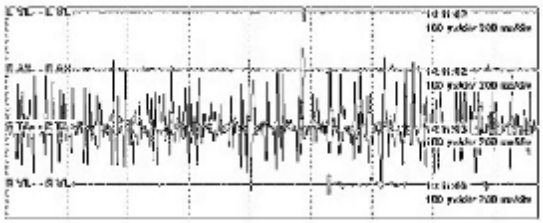
Figure no. 1c. Spontaneous train discharge



Limb muscles can be used to monitor the spinal radicular levels up to S2. Anal and urethral sphincters can be monitored when the medullary cone or the lower roots of the "horse tail" are at risk (table no. 1).

Table no. 1. Muscles uses in electromyography during sacral thoracolumbar arthrodeses

Spinal root at risk	Monitored muscle
T7-T12	Abdominal external oblique and straight muscles
L1-L2	Iliopsoas muscle
L2-L4	Vastus medialis
L4-L5	Tibialis anterior muscle
S1-S2	Medial gastrocnemius muscle
S3-S5	Anal and urethral sphincters

Pedicle screw stimulation technique can be used successfully to check its position in real time. The holes or screws properly placed in screws are separated by the nerve root through a bone layer (cortical bone), which has a high impedance to the passage of the electric current. A hole or screw that perforates the medial wall of the pedicle will be in close proximity to the nerve root that will be activated directly from the stimulus applied, evoking a compound motor action potential in the muscle of the corresponding myotome at much lower intensities of the electric current than those necessary to correctly placed screws.

Electromyography is recorded from limb muscles using paired needle electrodes. Subdermal needle-electrodes are suitable for most muscles. Monopolar needles or needle-wire may be required for muscles deeper than the iliac or abdominal muscles. The electrodes are placed in the muscles next to each other, about 2 cm, and are secured with tape to prevent their movement during patient handling. For anal and urethral sphincters, special electrodes are used.

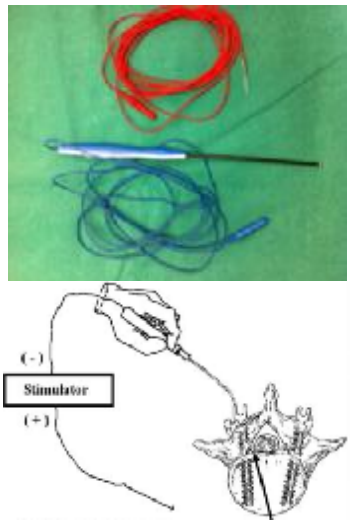
Although the neurosurgeon manipulates the stimulator, the neurophysiologist controls the electrical stimulation and must be sure that it functions. Stimulations can be single or repetitive, with a duration of 0.2 ms and an initial intensity of 8 mA. Repetitive stimulations can be fixed at 2 Hz (or 2.3 Hz to prevent network artifacts), with intensities ranging between 0-25 mA. The neurophysiologist will inform the neurosurgeon when there occurs a motor response and the intensity, then to lower the intensity in order to reach the stimulation threshold.(4,5)

Pedicle screw stimulation technique

Pedicle screw and holes are tested using a cathodic monopolar stimulator adding an anodic electrode in a wound, near to the site of stimulation. Recording is made from the muscles chosen according to the spinal roots at risk. After perforation of the pedicle, the stimulator is being introduced at half height of the canal so that, its stripped portion to be close to the nerve root (figure no. 2).

Screws are then tested by applying the stimulator on their proximal end being careful not to interfere with other tissues or fluids. Every hole and screw is being tested as they are perforated, respectively inserted. A misaligned screw should be redirected and then retested before the final fixing. Frequent redirection of the canal closes the breach of the pedicle wall with bone.

Figure no. 2. Electrodes and pedicle screw stimulation technique

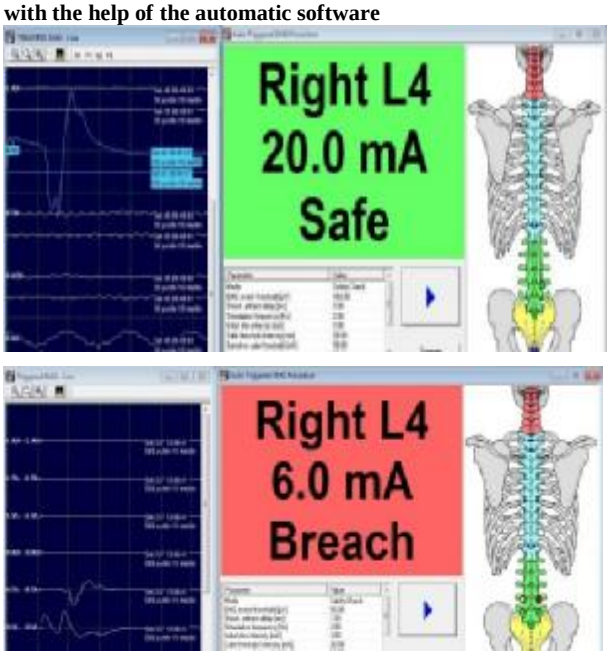


To save time, each screw and each canal will be tested starting with a stimulation intensity of 8 mA. If there is no motor response, it may be considered that the screw is in the correct position.

If a compound motor action potential is obtained, current intensity is gradually reduced until obtaining a stimulation threshold that should assess the possibility of a pedicle breach.(4,5)

Stimulation and results analysis can be performed using the Xltek Protektor intraoperative neuromonitoring device (produced by Natus), which has an automatic software that indicates pedicle breach alert (figure no. 3).

Figure no. 3. Results of pedicle screw stimulation technique with the help of the automatic software



The canals or screws having a stimulation threshold below 4 mA are likely to be misplaced and should be removed or repositioned; thresholds between 4-6 mA are at limit and the screws should be checked more closely by the neurosurgeon.

For a stimulation with a duration of 0.2 ms, Schwartz et al. (6) suggested the alert criteria listed in table no. 2.

Table no. 2. Alert criteria for pedicle breach according to intensity threshold that generates the motor response

Threshold intensity	Interpretation
<5 mA	High probability for pedicle breach; screw penetration close to the dura and nerve root
5-6 mA	Probability for pedicle breach; screw close to the dura and nerve root
6-7 mA	Low probability for pedicle breach; relative good positioning of the screw
>7 mA	Very low probability for pedicle breach; well-positioned screw

CONCLUSIONS

Intraoperative neurophysiological monitoring during the complex lumbosacral complex (arthrodesis with pedicle fixation) may be useful in identifying potential nerve root injuries.

In this type of intervention, monitoring methods are spontaneous and stimulated electromyography or electrical stimulation of the pedicle screw.

These methods can prevent pedicle screw misplacement, respectively the occurrence of any radicular sensory or motor deficit.

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