Dear all,

For the 5th clinical newsletter, we have chosen to send you a brief recap on recent publications regarding neuromonitoring techniques. As always, if you would like to receive more detailed data on this point or other specific data on a particular topic such as pedicle screw accuracy, pedicle screw complications, radiation exposure, economic studies, PediGuard clinical data or a similar subject that you think is important, please let us know, we will be glad to send you additional data.

Neurophysiologic monitoring is used to assist in the early detection of complications and possibly prevent post-operative morbidity in patients undergoing operations on the spine. The goal is to provide the surgeon with immediate feedback and warning before permanent nerve injury has occurred.

How neuromonitoring works?

Electromyography (EMG) is one of the neuromonitoring techniques commonly used to monitor the motor portion of the nerves during spinal surgery. Needle electrodes are placed in the muscle groups that correspond to the area where the surgeon will be working. Electrical activity from the muscle is monitored and recorded before and throughout the procedure. If a screw or other instrument impinges a nerve, the nerve fires off and activates the muscle. These may cause spikes on the EMG monitor alerting the surgeon or technician that the nerve in the area could be damaged. The surgeon can then take action to prevent permanent damage.

- **Free run EMG**: Continuous monitoring of the ongoing electrical activity of the muscle. Can detect changes to this signal possibly caused by impinged nerves.
- **Triggered EMG (T-EMG) (screw or probe testing)**: Single signals sent from screw or probe through nerve root to the muscle. Measured in milliamps (mA, current). Commonly used in the OR.
For pedicle screw placement, the surgeon may use a handheld probe that can give an electrical stimulation to the pedicle screw once it has been placed. If the screw is correctly placed inside the pedicle, it will take a certain amount of current to cause a muscle contraction and wave on the monitor. If the screw is close to or touching a nerve or the spinal cord, it will take less of current.

**Which threshold guarantees a safe placement?**

There is no true electromyography cut-off value that guarantees accurate placement and avoidance of neurologic injury. The exact stimulus threshold will vary based on the:

- **EMG technician** and each particular institution’s experiences.
- **Patients**: thresholds may be elevated by poorly conducting epidural tissues, decreased excitability due to neuronal injury, and inadequate EMG needle placement or contact with the target muscle.
- **Variability in metallic conductivity**.
  - the type of titanium metal alloy used (those with a high aluminum content are found to have an increased conductance),
  - the presence of anodized coatings (which reduced conductivity).
- **Substances** commonly used to control hemorrhage may also create high electrical resistance and thus may potentially prevent the detection of a pedicle wall breach. In particular, bone wax has the potential for creating high electrical resistance and should be avoided inside the pedicle hole or as a coating on the pedicle screw.
- **Anesthetic agents** that must be carefully selected and muscle relaxants that must be avoided with t-EMG.

**Is the EMG reliable in detecting breaches?**

It depends on the vertebral level.

The sensitivity and specificity gives us an idea about the reliability of EMG:

- **Sensitivity**: Probability of detection if there is a breach
- **Specificity**: Probability of no detection if there is no breach

The Graph 1 shows the sensitivity and specificity of the EMG for the lumbar and thoracic spine in comparison with the sensitivity and specificity of PediGuard in the thoraco-lumbar spine.
Graph 1: Sensitivity and Specificity for the EMG technique and PediGuard

<table>
<thead>
<tr>
<th>Ref</th>
<th>Type of study</th>
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<th>Screws</th>
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<td>PARKER 2011</td>
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<td>RAYNOR 2007</td>
<td>Systematic review</td>
<td>337</td>
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<td>ÖNER 2012</td>
<td>Prospective comparative</td>
<td>97</td>
<td>521</td>
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<td>BOLGER 2007</td>
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**Lumbar spine**

In the lumbar spine, EMG can help to detect medial perforation but does not help to detect lateral perforation. The Graph 1 shows that about 84% of the breaches are detected. However, false negative and false positive are reported in several studies. It is the case of Alemo’s study where false negatives are reported in 0.7% of the screws leading to neurologic injuries in 3.5% of the patients. False positive without clinical consequences are also reported for 4 screws (1%). However surgeons should keep in mind that false-positive results may lead to increased surgery time and increased blood loss.

**Thoracic spine**

In the thoracic spine, the EMG technique has low sensitivity to predict screw misplacement because of the lack of available recording sites. There is still no clear consensus on which neuromonitoring technique and which muscles to use. Beside, EMG cannot discriminate between medial cortex breakages and complete invasion of the spinal canal.

ÖNER’s review shows that the sensitivity using intraoperative EMG monitoring is relatively low (55%) whereas the specificity is higher (82%). In Rigidor’s clinical study, 14.7% of the screws were misplaced (False negative):

- 6 screws (2.5%) inside the spinal canal,
- 5 screws (2.1%) too lateral outside the canal
- 24 breaches (10.1%) of the medial cortex.

**MIS Lumbar pedicle screws**

In wang’s clinical study, it appears that tap stimulation with an insulating sleeve may not be reliable for detecting low-grade radiographically breached pedicles using typical stimulation thresholds (< 12 mA). Imaging-based modalities remain more reliable for assessing percutaneous pedicle screw trajectories. Among 409 screws inserted, there were no true-positive, 35 false-positive (8.6%), 5 false-negative (1.2%), and 369 true-negative results (90.2%). The authors concluded that the high false-negative rate and the high false-positive rate significantly decreased the reliability of this method.
Other limitations

Electrophysiological monitoring is largely used for spinal deformity correction procedure especially to control derotation maneuvers. But, in some countries, the decision to use electrophysiological monitoring during routine spine surgery is driven more by medicolegal concerns than by medical evidence\textsuperscript{14}. The use of electrophysiological monitoring does result in increased preparation time, change in anesthetic management, increased cost and a greater potential for additional complications\textsuperscript{14}. Intra-operative neuromonitoring requires also a knowledgeable professional and experienced clinical neurophysiologist\textsuperscript{15}.

How PediGuard can help

According to a prospective multicentric study from Bolger et al\textsuperscript{8}, the sensitivity of PediGuard is 98% and specificity 99% (Graph 1). If there is no breach, there is no detection in 99% of the cases. PediGuard detects 98% of the breaches.

In Ovadia’s retrospective, comparative study on scoliosis patients\textsuperscript{16}, clinically relevant misplacement of pedicle screws was established by intraoperative neurophysiological monitoring alarms concomitant with screw insertion. This study shows:

- 3 times less neuromonitoring alarms per screw when PediGuard is used.
- 2 times more screws used per patient when PediGuard was used (14.3 screws/patients instead of 8.5 without PediGuard).

Conclusion

Neuromonitoring techniques are not reliable to detect pedicle breaches particularly in the thoracic spine. Especially, they have shown:

- Low sensitivity: 55% in the thoracic spine and 84% in the lumbar spine (detection of medial perforations only but not lateral perforations)
- Huge variation of the stimulus threshold depending on the technician’s experience, the patient, the type of alloy and coating of the pedicle screw, the substance used to control hemorrhage and the anesthetic substance,
- Increased preparation time and cost,
- Greater potential for additional complications.

Non physiologic techniques such as the PediGuard are recommended to detect pedicle wall perforation\textsuperscript{9}. The sensitivity of PediGuard in detecting pedicle breach is 98% in the thoraco-lumbar spine\textsuperscript{8}. 
References


