
G. Saló, PhD, MD.
Senior Consultant Spine Unit.
Hospital del Mar. Barcelona.
Ass. Prof. Universitat Autònoma de Barcelona.
Introduction

- The management of spinal cord during spinal surgery should be done carefully.
- Surgical events that can lead to a spinal cord injury:
  - Ischemic events.
    - Maintained Hypotension.
    - Arterial occlusion / injury.
  - Mechanical events.
    - Compression.
    - Overdistraction.
    - Derotation.

<table>
<thead>
<tr>
<th>Time-to-onset of change in electrophysiological response</th>
<th>Ischemic</th>
<th>Mechanical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source of insult</td>
<td>Slow</td>
<td>Rapid</td>
</tr>
<tr>
<td>Typical spinal level of occurrence</td>
<td>Reduced spinal cord/nerve root perfusion from overdistraction (primary), hypotension (secondary)</td>
<td>Overdistraction, compression, derotation of the spinal cord, and/or nerve root irritation from transpedicular instrumentation</td>
</tr>
<tr>
<td>Responsiveness to intervention</td>
<td>More flexible segments of the spine</td>
<td>Spinal cord—more stiff segments</td>
</tr>
<tr>
<td>Effect on response characteristics</td>
<td>Good</td>
<td>Nerve roots—at any level</td>
</tr>
<tr>
<td></td>
<td>Latency—no significant change</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>Amplitude—significantly reduced</td>
<td>Latency—significantly prolonged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amplitude—significantly reduced</td>
</tr>
</tbody>
</table>
Introduction

Types of Spinal Cord Monitoring:
- Wake-up test (currently performed when there is no SSEP/MEP data available or in circumstances where these methods are not reliable).
- Intraoperative electrophysiologic monitoring: Directly monitors the neurological function of those structures at risk during the surgery.
  - Somatosensory-Evoked Potentials (SSEP)
  - Motor-Evoked Potentials (MEP)
  - Electromyography (EMG)
Somatosensory-Evoked Potentials (SSEP)

- Introduced for intraoperative monitoring during scoliosis operations.
- Predominant modality used for intraoperative monitoring.
- Recorded with surface or needle electrodes from the skin.
- Extracranial electrodes at the Erb's points.
- Limitations:
  - In some cases, baseline SSEPs cannot be obtained or are of poor quality (myelopathy).
  - Delay in processing and averaging SSEP
Motor-Evoked Potentials (MEP)

- Directly monitor motor pathways independently of the dorsal column tracts.
- Transcranial electrical stimulation. (Scalp stimulating electrodes)
- Recording from epidural space of the spinal cord, peripheral nerves or muscles.
- Limitations: children, general anesthesia.
Electromyography (EMG)

- Great value for nerve root and anterior horn cell preservation during tumor resection, nerve root decompression or spinal instrumentation.
- The recordings are obtained from the muscles.
- Electrophysiologic monitoring of external anal and bladder sphincter.
- Register the surgical events that are responsible for the activation of muscle action potentials, such as simple contact, suction, traction, distraction and coagulation.

<table>
<thead>
<tr>
<th>Spinal nerves</th>
<th>Muscle monitored</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>Deltoid</td>
</tr>
<tr>
<td>C6</td>
<td>Biceps brachii</td>
</tr>
<tr>
<td>C7</td>
<td>Triceps</td>
</tr>
<tr>
<td>C8-T1</td>
<td>First dorsal interosseous, thenar muscles</td>
</tr>
<tr>
<td>L2</td>
<td>Rectus femoris, vastus lateralis</td>
</tr>
<tr>
<td>L3</td>
<td>Vastus medialis, rectus femoris</td>
</tr>
<tr>
<td>L4</td>
<td>Vastus medialis</td>
</tr>
<tr>
<td>L5</td>
<td>Tibialis anterior</td>
</tr>
<tr>
<td>S1-S2</td>
<td>Gastrocnemius, soleus</td>
</tr>
<tr>
<td>S2-S4</td>
<td>External anal and bladder sphincters</td>
</tr>
</tbody>
</table>
Why, When and How to monitor?

Why?
• Prevention of mechanical injuries to spinal cord.
• Identification of neural structures at risk.
• Prevention of ischemia of spinal cord during surgery.

When?
• Spinal deformities.
  – Scoliosis.
  – Sagittal imbalance / Kyphosis.
• Spinal tumors.
• Spinal fractures.
• Others: infections, etc

How?
• It depends on experience of the center and the pathology to treat.
Management of Spinal Cord in Scoliosis.

CASE EXAMPLE
• 17 year-old female
• Idiopathic Scoliosis.
• Double structured curves.
• Lenke 3C
• Cobb Th 48° / L 45°
• Risser V
Management of Spinal Cord in Scoliosis.
Management of Spinal Cord in Scoliosis.

- 4 year follow-up
- Correction of 90%.
- Postoperative Coob: $4^\circ/4^\circ$
Management of Spinal Cord in Scoliosis.

- Corrective surgeries for deformity are at a higher risk of spinal cord injury (0.5-3%).
- Increases risk in:
  - Corrections > 50%.
  - All-screws technique.
- Distraction may cause paraplegia especially in rigid angular curves.
- Identify the presence of malformations like diastematomyelia, where distraction of the spinal cord can move the cord along a bony or fibrous spur in the cord.
- If there are changes in MEPs or SSEPs:
  - Check the leads.
  - Make sure the irrigation being used is of appropriate temperature.
  - Increase the blood pressure.
  - Check all implant sites.
  - Release the correction.
CASE EXAMPLE 1

- 61 year-old male
- Car accident 2 years ago without fractures.
- Progressive Chin-on-Chest deformity.
- Kyphosis at cervico-thoracic area.
Management of Spinal Cord in Adult Deformities.
Management of Spinal Cord in Adult Deformities.
Management of Spinal Cord in Adult Deformities.

No postoperative neurological deficit
CASE EXAMPLE 2

- 56 year-old male.
- Previous illness:
  - Tuberculosis at 3 years of age.
  - Pott’s disease at 27 years of age.
  - Restrictive pulmonary disease.
  - Dorsal mielopathy with progressive neurological dysfunction.
- Sphincter dysfunction. Urinary incontinence, persistent constipation and erectile dysfunction.
- Spastic walking, two crutch-assisted. Perimeter of walking 10 minutes.
- Muscular balance: 3/5 global in lower extremities, spastic muscles, bilateral inexhausting clonus, OT reflex exacerbated.
Management of Spinal Cord in Adult Deformities.
Management of Spinal Cord in Adult Deformities.

Unable to obtain good intraoperative SSEP’s & MEP’s due to myelopathy.
Management of Spinal Cord in Adult Deformities.

- 4 year follow-up
- Sphincter dysfunction. Urinary incontinence, persistent constipation.
- Muscular balance: 2/5 global in lower extremities.
Management of Spinal Cord in Adult Deformities.

- In cases with large deformity corrections, low postoperative hemoglobin and hypotension should be avoided for an adequate vascularization of the spinal cord, which may be compromised by the correction.
- Patients with cystic myelopathy or progressive myelomalacic myelopathy (Tethered Cord Syndrome) should be recognized prior to surgical interventions to avoid unexpected neurological deterioration.
- In anterior approaches, ligation of anterior segmental arteries has also been suggested to increase the likelihood of ischemia of the cord.
- Myelopathy could affect the intraoperative SSEP.
- If there are changes in MEPs or SSEPs:
  - Check the leads.
  - Increase the blood pressure.
  - Reverse the correction.
  - Remove the implants.
Management of Spinal Cord in Tumours.

CASE EXAMPLE

• 10 year-old female.
• T12 Aneurismal bone cyst.
• Spinal cord compression.
• Treatment: embolitzation + surgery (non-instrumented resection)

• Recurrence at 12 years old:
• Treatment: Embolization + surgery (instrumented) + RT postoperatively.
Management of Spinal Cord in Tumours.

- New recurrence at 21 years old.
- Involving T11, T12, L1.
- Spinal cord compression.
- Without neurological deficit.
Management of Spinal Cord in Tumours.

Exposition of a long section of the cord. The potentials remained stable.
Management of Spinal Cord in Tumours.

- 3 year follow-up
Management of Spinal Cord in Tumours.

- Adequate visualization of spinal cord is mandatory during tumor resection.
- In tumors close to the dura, a careful resection is needed to preserve the neural elements.
- Place an stabilizer rod during resection in patients with wide tumor involvement of the spine (to avoid instability).
- In anterior approaches between T4 and T9 it’s necessary to have preoperative arteriography in order to know the origin of Arteria Vertebralis Magna (Adamkiewicz).
- In anterior tumor resection, bilateral artery ligation may be required and it is recommended to provisionally clamp vessels (control the effect with MEPs).
- SSEP’s are likely to be false negative at the onset of the anterior spinal artery syndrome, but MEP’s will show the lesion immediately.
Management of Spinal Cord in Fractures.

CASE EXAMPLE

• 57 year-old male.
• Car accident with a fracture-dislocation C4-C5.
• Without neurologic injury.
• Primary stabilization with a halojaquet.
Management of Spinal Cord in Fractures.

- Prevent further neurological damage during the mobilization of the patient.
- Care must be taken during positioning on the surgical table.
- Avoid excessive hyperextension or rotation.
- Conscious nasal fiberoptic intubation should be gently performed in patients with cervical fractures.
- Preoperative paraplegic patients have no recordable MEPs.
- Direct injury may occur by improper placement of screws, hooks, sublaminar wires or may be caused by a fracture of the lamina, pedicle or posterior wall of the vertebral body during correction maneuvers.
Conclusions.

- Surgeon must know the anatomical structures at risk during spinal surgery.
- Excessive compression, distraction or derotation may lead to neurological injury.
- The surgeon must be careful during ligation of the anterior segmental arteries in order to avoid ischemia of the cord.
- Release of the correction and restoration of a sufficient perfusion should be done if neurological injury is noticed intraoperatively.
- Intraoperative application of neurophysiological procedures has reduced the incidence of surgically induced postoperative neurological deficits.