THE ROLE OF INTRAOPERATIVE NEUROMONITORING IN SPINE SURGERY

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NEURAL INJURY DURING SPINE SURGERY

- Spinal Cord Injury
- Nerve root injury more frequent than spinal cord injury
  - 2.9% adult spinal deformity surgery (Pateder, Spine 2005)
  - Buchowski (Spine 2007)
    - n=108, 11.1% root injury
  - SSEPs, NMEPs, EMG
    - None detected

Recovery Rates of 172 New Neurological Deficits Associated with Surgery for Lumbar Degenerative Disease

Recovery Rates of 309 New Neurological Deficits Associated with Surgery for Scoliosis

MECHANISMS OF INJURY

- Degenerative (without manipulation)
  - Direct
  - Indirect
- Deformity (with manipulation)
  - Direct
  - Instrumentation
  - Decompression / dural tear
  - Cautery
  - Indirect
  - Spinal manipulation
  - Hypotension

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Diagnosis</th>
<th>PDL Level</th>
<th>Defect</th>
<th>Mechanism</th>
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<td>L1</td>
<td>Qualifying</td>
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<td>Direct management subluxation</td>
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</table>


UTILITY OF NEUROMONITORING

- Diagnosis
- Prediction / Prevention
- Intra-operative Surgical Response

MODALITIES

- Wake-up test
- SSEPs
  - Posterior tib. nerve to scalp
  - Examine the continuity of the dorsal columns
- EMGs
  - Free run
  - Direct - Stimulus applied to the nerve root
  - CMAP
- TcMEPs
  - Stimulus applied to the scalp
  - CMAP in different muscle groups
  - Direct Spinal Cord Stimulation

ALARM CRITERIA

- Threshold
  - CMAP
  - Measured Voltage increase to obtain baseline amplitude
- Amplitude
  - CMAP
  - Measured drop in amplitude from baseline
  - >50%
  - Latency
UNKNOWNNS

• CMAP
• Amplitude?
• Latency vs AUC?
• Change during injury
• Stepwise vs linear?
• Root Dominance
• Hemodynamics / Ca2+
• Anesthetics

BACKGROUND


CASE EXAMPLE ALIF

• 62 Y FEMALE
• SCOLIOSIS
• ALIF
MECHANISM OF INJURY

CASE EXAMPLE

- 81 Y FEMALE
- 45 DEGREE SCOLIOSIS
- BACK AND LEG PAIN
- 2 STAGE APPROACH
- TRANSPSOAS / PSF
CLINICAL TRANSLATION: TLIF

- Determine sensitivity and specificity of TcMEPs to detect and predict isolated nerve root injury.
- Transforaminal lumbar interbody fusion (TLIF) at L4/5, L5/S1 level.
- Retrospective chart review of 79 patients undergoing TLIF
- NASS 2009

METHOD

- Primary TLIF at levels L4-5, L5-S1: 42 L4/5 and 37 L5/S1
- Average age 59.2 yrs- 29 Male, 50 Female
- Multi-myotomal MEP

CLINICAL TRANSLATION: TLIF

METHOD

METHOD

METHOD

RESULTS

<table>
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<tr>
<th>Diagnosis</th>
<th>n</th>
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<tr>
<td>Degenerative Disc Disease + Stenosis</td>
<td>38</td>
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<td>Spondylolisthesis + Stenosis</td>
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<td>Osteomyelitis</td>
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<table>
<thead>
<tr>
<th>MEP</th>
<th>EMG</th>
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<tbody>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>n=</td>
<td>79</td>
</tr>
<tr>
<td>Threshold change</td>
<td>18</td>
</tr>
<tr>
<td>No recovery</td>
<td>6</td>
</tr>
<tr>
<td>Clinical deficit detected</td>
<td>5</td>
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<tr>
<td>Clinical deficit not detected</td>
<td>0</td>
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<tr>
<td>False +ve</td>
<td>1</td>
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</table>

- Warning criteria >80% drop in MEP amplitude in at least one myotome during sustained retraction of L4/L5 nerve root during diskectomy/insertion of cage.
- Nerve root damage = sustained changes on examination at hospital departure
- EMG warning criteria= >5s tonic EMG activity
CLINICAL TLIF

Nerve Root Retraction

% drop from baseline

Minutes of Retraction

RESULTS

• 7 patients had threshold EMG activity
• 2 of 5 deficits accurately predicted on EMG
• 3 false negative results produced
• Multimyotomal MEP 100% sensitive and 83% specific to isolated nerve root injury

HOW DID WE MISS NERVE INJURIES?

• false negatives
• IOM
• surgeon
• tech

VARIABILITY IN TCMEP

Figure 1. Average total frequency of TcMEP by diagnosis.

Figure 2. Average frequency of TcMEP in non-critical and critical junctures of surgery by diagnosis.
FALSE POSITIVE / NEGATIVES

- tcMEPs
  - Trial to trial variability ~ 5%-10%
  - Hemodynamic fade – hypotension
  - Frequency of testing
- SSEPs
  - Injury to ventral cord
- EMG
  - Lesion proximal to stimulus
  - Missed tonic EMG

IMPORTANT FOR TRANSPSOAS APPROACHES

![Diagram showing head, point of injury, and foot with tcMEPs and EMG](image)

UNKNOWNS

- CMAP
  - Amplitude?
  - Latency vs AUC?
- Change during injury
- Stepwise vs linear?
- Root Dominance
- Hemodynamics / Ca2+
- Anesthetics

PURPOSE

- To develop an animal model
- To monitor TcMEPS changes during nerve root injury: compression vs retraction
- To compare tcMEPs changes to EMGs for nerve root injury: compression vs retraction
ANIMAL MODEL

- No reliable large animal model
- Anesthetic issue
- Team: anesthesiologist / neurophysiologist / surgeon

ANIMAL MODEL

- Porcine model
- Lumbar nerves similar to humans
- Overcome thickness of the calvarium
- Anesthetic regimen
- Venous plexus
- Mapping of the nerve roots

REDUCTION IN TCMEP AFTER NERVE ROOT LIGATION (% BASELINE TCMEP)

<table>
<thead>
<tr>
<th></th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
<th>S1</th>
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<tr>
<td>RF</td>
<td>48.29%</td>
<td>6.22%</td>
<td>1.17%</td>
<td>0.20%</td>
<td>1.48%</td>
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<td></td>
<td>(23.31-73.27, p=0.009)</td>
<td>(3.64-14.08, p=0.199)</td>
<td>(-0.29-2.71, p=0.097)</td>
<td>(-1.40-1.80, p=0.77)</td>
<td>(-3.65-0.70, p=0.15)</td>
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<tr>
<td>VM</td>
<td>28.88%</td>
<td>19.62%</td>
<td>0.73%</td>
<td>0.17%</td>
<td>0.51%</td>
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<td>(11.61-46.16, p=0.013)</td>
<td>(1.79-37.45, p=0.036)</td>
<td>(-3.42-2.31, p=0.65)</td>
<td>(-1.81-2.16, p=0.84)</td>
<td>(-1.25-2.26, p=0.51)</td>
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<tr>
<td>VL</td>
<td>20.99%</td>
<td>19.87%</td>
<td>2.45%</td>
<td>0.41%</td>
<td>0.70%</td>
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<tr>
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<td>(9.90-41.09, p=0.045)</td>
<td>(23.96-55.77, p=0.001)</td>
<td>(4.53-11.41, p=0.53)</td>
<td>(-2.71-3.53, p=0.76)</td>
<td>(-2.33-3.73, p=0.59)</td>
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<tr>
<td>TA</td>
<td>0.35%</td>
<td>15.67%</td>
<td>67.08%</td>
<td>14.95%</td>
<td>0.78%</td>
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<tr>
<td></td>
<td>(-1.02-1.72, p=0.47)</td>
<td>(1.71-29.63, p=0.033)</td>
<td>(56.69-77.58, p&lt;0.001)</td>
<td>(0.62-28.28, p=0.043)</td>
<td>(-0.02-1.58, p=0.055)</td>
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<tr>
<td>GAS</td>
<td>5.05%</td>
<td>17.00%</td>
<td>34.38%</td>
<td>15.18%</td>
<td>18.48%</td>
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<tr>
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<td>(-12.21-22.30, p=0.42)</td>
<td>(3.88-37.88, p=0.093)</td>
<td>(4.01-64.92, p=0.032)</td>
<td>(1.42-28.94, p=0.036)</td>
<td>(-1.80-38.75, p=0.067)</td>
</tr>
</tbody>
</table>
EFFECT OF RETRACTION FORCE OF TCMEP AMPLITUDE IN THE TIBIALIS ANTERIOR

EFFECT OF RETRACTION FORCE ON EMG THRESHOLD OF L5 NERVE ROOT

WHAT ABOUT COMPRESSION INJURIES?
**Discussion**

- Curvilinear change in TcMEPs following sustained retraction and compression – stretch injury has a much slower change.
- The rate of change proportional to force and predictable.
- The recovery of TcMEPs and NRT is inversely proportional to force.
- NRT and TcMEPs are correlated and proportional in both compression and retraction.
MODEL

ALGORITHM

• Short acting relaxant for exposure
• TIVA
• Dual modality testing
  • EMG / tcMEP
  • SSEP / tcMEP
• Maintain MAP
• Frequent tcMEPs
• Bight block
• Education

CHANGE IN PRACTICE

• TcMEPS may predict nerve root injury – application to patient set-up – application in indirect (stretch injury)
• Frequent motors during retraction OR spinal manipulation
• Development of automated algorithms and retractors to detect early changes

THANK YOU