Results
National audit of IONM of spinal cord during corrective spinal deformity surgery 2016

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Method
Prospective study

Participation
invited from all hospitals providing monitoring for spinal deformity surgery

Audit form B completed
5 consecutive spinal deformity cases (Feb-April 2016)

35 questions (yes/no answers) + 5 questions if neuromonitoring alert

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<table>
<thead>
<tr>
<th>Details of case</th>
<th>Patient age:</th>
<th>Type of Surgical procedure:</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 consecutive spinal deformity cases (Feb-April 2016)</td>
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</tbody>
</table>

**Please complete the questions 1-32 for 5 consecutive IONM cases for Corrective Spinal Deformity Surgery only (ie paediatric/ adult scoliosis or kyphosis corrective surgery). Questions 34-41 should be completed in the event of a neuromonitoring alert having been issued.**

<table>
<thead>
<tr>
<th>General</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Before the patient was anaesthetised patient was identified and the clinical information verified</td>
<td></td>
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<tr>
<td>2) Monitoring continued until at least 20 minutes after last surgical manoeuvre or until monitoring was no longer possible</td>
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<tr>
<td>3) Traces are available for review (i.e. offline or post-operative review)</td>
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<tr>
<td>4) Neuromonitoring log completed and available for review</td>
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</table>

**Are the following annotated in the Neuromonitoring log?**

| 5) Patient name, Date of birth and hospital NHS number |
| 6) Date of operation |
| 7) Type of surgical procedure |
| 8) Name of surgeon(s) |
| 9) Name of anaesthetist(s) |
| 10) Name(s) of neuromonitoring personnel |
| 11) Monitoring protocol used and any changes to protocol documented including any technical issues |

**LOWE LIMB SENSORY EVOKED POTENTIALS (LLSEP)**

| 12) LLSEPs performed |
| If LLSEPs not performed please state the reason: |

If LLSEPs are performed please complete the following section:

| 13) Reference LLSEP baselines recorded |
| 14) LLSEP - bilateral, independent stimulation of peripheral nerve below the site of surgery |
| 15) LLSEP - cortical, subcortical or epidural recording sites above the site of surgery |
| 16) LLSEP peripheral control e.g. popliteal fossa recording (guideline 9) |
| 17) LLSEP averaged traces obtained regularly throughout the monitoring period |
| 18) LLSEP waveforms are identified with the stimulation and recording sites (right/left, name of peripheral nerve etc.), amplitude/latency markers |
| 19) Recorded LLSEP waveforms are compared to baseline/preceding waveform |
124 Audit forms received

2 neurosurgical tumour cases did not fit inclusion criteria

122 spinal deformity cases
Standard 1
Prior to surgery the patient is identified, the clinical information is verified and the need for IONM us assessed.

Question 1

No- 2 hospitals

Yes- 23 hospitals (113/122 cases)
Question 2
Monitoring continued for at least 20 minutes after last surgical manoeuvre or until monitoring was no longer possible

Standard 2
…responses are monitored……throughout the surgical procedure.

Practice
Monitoring should continue for 20 minutes after completing instrumented fixation or until monitoring is no longer possible

Yes 25/25 hospitals
122/122 cases
Question 3 & 4
Traces and Neuromonitoring log are available for review

**Standard 7**
A clear concise and accurate record of annotated waveforms should be kept.

Yes 25/25 hospitals
122/122 cases
# Question 5-11-Annotations in the Neuromonitoring log

**Standard 8-Annotations in the record must include---**

<table>
<thead>
<tr>
<th>Annotation</th>
<th>Audit result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient name and date of birth</td>
<td>25/25 hospitals, 122/122 cases</td>
</tr>
<tr>
<td>Hospital/ NHS number</td>
<td>24/25 hospitals 117/122 cases</td>
</tr>
<tr>
<td>Date &amp; type surgical procedure</td>
<td>25/25 hospitals, 122/122 cases</td>
</tr>
<tr>
<td>Name surgeon &amp; anaesthetist</td>
<td>24/25 hospitals 117/122 cases</td>
</tr>
<tr>
<td>Name neuromonitoring personnel</td>
<td>25/25 hospitals, 122/122 cases</td>
</tr>
<tr>
<td>Monitoring protocol used &amp; any changes to protocol</td>
<td>25/25 hospitals, 122/122 cases</td>
</tr>
</tbody>
</table>
Lower limb somatosensory Evoked Potentials

**Standard 9**
Sensory evoked potentials are recorded

Q13 & 19 Reference waveforms recorded and subsequent waveforms are compared to baseline/preceding waveforms

Q14 & 15 Bilateral, independent stimulation below site of surgery, Recordings made above site of surgery

Q17 Averaged traces obtained regularly throughout

Q18 LLSEP waveforms identified with stimulation and recording sites, amplitude and latency markers

25/25 hospitals
122/122 cases

YES

Joint National Audit Project

BSCN

STRATEGIC Society

ANEN
Q16. Use of peripheral control for lower limb SEP recording

Guideline 'to help better distinguish technical and systemic changes from significant changes in spinal cord function related to surgery.'

Guideline not a standard
Why record a peripheral control?

Quick technical check of stimulus
Helps reduce false positives
Peripheral ischaemia?
Q20. The recording of control Upper Limb SEPs

Guideline
SEPs ‘recorded above the site of surgery’....

‘Practice: stimulation of upper limb peripheral nerve, recording from cortex & where possible one of following sites: elbow/ACF, brachia, Erb’s or cervical spine’

5 centres never record ULSEPs in thoraco-lumbar deformity cases

- 92 cases (75%) in 20 hospitals
- 30 cases (25%)

Joint National Audit Project
Reasons stated for not recording ULSEP

- ‘not routinely recorded in scoliosis surgery’
- ‘not department protocol’
- ‘surgery not below C7’
- ‘upper limb motor controls recorded instead’
- ‘not relevant’
- ‘not requested by surgeon’
- ‘LLSEPs sufficient’
- ‘not used in anterior surgery’

Guideline:
SEPs ‘recorded above the site of surgery to help better distinguish technical and systemic changes from significant changes in spinal cord function’
Example of usefulness of Ulnar nerve SEP during spine deformity surgery

Left ulnar SEP

After arm re-positioned

Left upper limb TcMEP
References for upper limb SEP & incidence ulnar neuropathy etc

Cheny et al 1999.
Ulnar neuropathy most common of cause lawsuit for anaesthetists
Brachial plexus injury second most common.

Warner et al 2000
0.5% Incidence ulnar neuropathy (all surgical procedures)

Priellip et al 1999
Prolonged upper limb SEP changes can result in permanent nerve injury

Kamel et al 2014
1-8% to 15%-Incidence of position upper extremity SSEP alerts in spine surgery
Grover
10% (unpublished data)

UPGRADE RECORDING UPPER LIMB SEP TO STANDARD?
Q 21-25 If ULSEPs are performed

Q22 Recordings made above site of surgery

Q24 ULSEP waveforms identified with stimulation and recording sites, amplitude and latency markers

Q25 Reference waveforms recorded and subsequent waveforms are compared to baseline/preceding waveforms

YES

20/20 hospitals
87/87 cases

Q21 ULSEP - bilateral, independent stimulation of peripheral nerve

82/87 cases

Guideline 9

39/87 cases (44%)

Q23 ULSEP peripheral control recorded eg Erbs, elbow
Q26 Transcranial Motor Evoked Potentials

Guideline
Corticospinal pathways of the spinal cord may be monitored using MEPs across the site of the surgery.

MEPs may be especially beneficial during ‘high risk’ cases or where SEP monitoring is limited.

Yes 25/25 hospitals

120/122 cases
2 cases in 2 hospitals
-growing rod lengthening
-no MEPs recorded

What does ‘high risk’ mean?

This is a Guideline- it should be a standard!
Recording TcMEPs

- Q27. Reference MEP baselines recorded
  - Standard 2
- Q28. Bilateral recording of 2 or more muscle sites below level surgery
  - Standard 12
- Q31. Each MEP trace is identified with recording site
  - Standard 12
- Q32. Recorded MEP is compared to baseline/preceding waveform
  - Standard 5
- Q33. MEPs recorded at key points during procedure
  - Standard 13
- Q29. Bilateral recording upper limb muscles
  - Guideline - recording control MEPs
  - 22/25 hospitals; 106/120 cases
- Q30. Each MEP trace is identified with stimulation site
  - Standard 3
  - 21/25 hospitals; 97/120 cases

25/25 hospitals
122/122 cases
Example of systemic MEP changes- why record

CHECK it is reversible- ?? could be cervical spine compromise eg. positional
Neuromonitoring alert criterion

**Standard 4**

A predetermined warning criterion is established......

...defines a significant repeatable change in amplitude, morphology and/or latency of the waveform, **that cannot be explained by reversible technical or anaesthetic changes.**

Q34. Predetermined definition of neuromonitoring alert for SEP available?  
Yes 25/25 centres

Q35. Predetermined definition of neuromonitoring alert for SEP available?  
Yes 25/25 centres

13/25 hospitals stated this in the alert criterion

Q39. reversible with technical changes?  
2 in 2 centres

Q40. reversible with anaesthetic changes?  
1 centre
Neuromonitoring alerts

**Standard 6**
The operating team is alerted to a significant change in the waveforms in a timely manner.

**Standard 7**
---any information conveyed to the surgeon and/or anaesthetist, and any response/action or outcome should be recorded/annotated

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<th>Audit result</th>
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<tr>
<td>Q36. Time of alert noted in log</td>
<td>23/24 cases (1 no answer)</td>
</tr>
<tr>
<td>Q37. Surgical team informed at time of alert</td>
<td>24/24 cases</td>
</tr>
<tr>
<td>Q38. Surgeons response noted in log</td>
<td>24/24 cases</td>
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</table>
Reported Neuromonitoring alerts

25 alerts reported (20.5%) in 15 centres

97 cases - no alert

- 3 Technical/anaesthetic
- EMG
- 5- LL SEP + MEP alert
- 4- LL SEP only alert
- 7- LL MEP only alert
- 5- Upper limb only

16 cases (13%) Spinal cord

2 cases reported new neurological deficits (1.6%)
(Scoliosis Research Society 2007 1.87% risk iatrogenic spinal cord injury)
16 spinal cord monitoring events

= 13%

Why so many alerts?

Too small sample size to make any conclusions

? what percentage of these are false positives (14 with no NND)

Published figures for alerts during spinal deformity surgery:

Samandi et al, 2016 - 5.3 % alerts in series 676 patients

Bhagat et al, 2014- 7.1% alerts in series 354 patients

Swartz et al 2007. 3.4% alerts in 1121 patients
Major / moderate alert criteria

MacDonald et al 2013


(1) Disappearance is a MAJOR criterion mandating restorative efforts, including undoing surgical manoeuvres and modifying or even abandoning instrumentation.

(2) Depending on the monitoring program’s technique and experience, marked amplitude reduction or acute threshold elevation (based on deterioration clearly exceeding spontaneous variability with no apparent confounding factor explanation) could be MODERATE criteria prompting restorative efforts, but might not justify major surgical modifications and might increase false positives. There are currently no published studies of morphology criteria for orthopaedic surgery.
2 MEP + SEP monitoring events with new neurological deficit (NND)

2 Major alerts

- 1 bilateral loss LLMEP + reduced LLSEP with spinal cord contusion
  \[\rightarrow\text{not reversible} \rightarrow \text{NND}\]

- 1 loss Right LLMEP + reduction Rt SEP evolving to bilateral loss LLMEP
  \[\rightarrow\text{not reversible} \rightarrow \text{NND} = \text{weak R leg}\]
3 MEP + SEP monitoring events with no NND

2 MAJOR ALERTS

● 1 bilateral disappearance LLMEP + reduction LLSEP
  → reversal of correction & recovery signals

● 1 unilateral disappearance LLMEP and reduction LLSEP
  → reversal of correction & recovery signals

? alert
1 bilateral 50% reduction LLMEP + 40% reduction LLSEP
  → during insertion cages, no other details

Note this hospital's alert criteria 50% MEP and 30% SEP amplitude reduction
Reported LLMEP monitoring events

7 Lower limb MEP - no NND +1 difficult to assess NM

4 Major alerts
- 2 unilateral disappearance MEPs - recovered by reversal of surgical correction
- 1 bilateral disappearance MEPs - reversed by loosening of wires
- 1 unilateral disappearance MEPs not reversed by surgical changes (no details)

Moderate alert

1 unilateral 90% reduction MEPs after cord contusion, recovered after surgical pause

2 focal MEP alerts - limited detail
- 1 loss single muscle LLMEP and reduction bilaterally post correction, no recovery of responses
- 1 loss single muscle MEP, other muscles OK, occurred during correction, recovered with surgical pause
Reported LLSEEP monitoring events

4 Lower limb SEP alerts- no NND

1 bilateral >50% reduction cortical LLSEEP only, no ULSEPs recorded, no MEP change-post correction? details

1 bilateral 30% reduction cortical LLSEEP, no ULSEPs recorded, no MEP change, artefact, no alteration surgery?

1 unilateral 50% reduction LLSEEP, no ULSEPs recorded, during unspecified surgical event, ? If reversed

1 bilateral reduction cortical LLSEEP with preservation subcortical ULSEPs during growing rod lengthening (MEPs & cortical ULSEPs not recorded)

→spont recovery responses after 15 minutes
Overall adherence to standards

Adherence to standards

- All stds
  - 16 hospitals

- 9 hospitals

Adherence to standards AND guidelines

- All stds + guidelines
  - 6 hospitals

- 19 hospitals
Recommendations

• TcMEPs as ‘standard’ when not contraindicated
  – (inc bilateral upper limb MEPs)

• Bilateral Upper limb SEP recording as ‘standard’

• Peripheral nerve recording for SEP recording as ‘standard’

False positives- can standards help reduce these???

More specific Alert criteria required (evidence based)
MEP-No evidence for use change of morphology (MacDonald et al 2013)
MEP-‘major’ / ‘moderate’ (MacDonald et al 2013)
Include details of technical/ anaesthetic checks
Alert criteria for SEP standardised >50% amplitude and 10% latency increase
Acknowledgements

Thank you to

- all participants of the audit
- the ‘trial’ centres for their comments
- members of the Joint National Audit Planning committee
- ANS/BSCN


