

ANS/BSCN Guidelines for Neurophysiological Recordings of the Spinal Cord during Corrective Spinal Deformity Surgery

Contributors:

Peter Walsh MSc Clinical Physiologist ¹, Dr Joseph Cowan Consultant in Neurophysiology and Rehabilitation Medicine ², Dr Alan Forster FRCP Consultant Clinical Neurophysiologist ³, Lesley Grocott Lead Scientist/Service Manager Clinical Neurophysiology ⁴, Dr Peter Heath, MA, DM, FRCP Consultant in Clinical Neurophysiology ⁴, Dr Nick Kane MSc MD (Hons) FRCS Consultant Clinical Neurophysiologist ¹, Karen Plumb BSc, MSc. Clinical Neurophysiological Technologist ²

Institutions:

1. The Grey Walter Department of Clinical Neurophysiology, Frenchay Hospital, Bristol.
2. Royal National Orthopaedic Hospital, Stanmore, Middlesex.
3. Aberdeen Royal Infirmary, Aberdeen.
4. University Hospital of North Staffordshire (NHS) Trust, Stoke on Trent.

Introduction:

There are experimental reasons why monitoring of sensory and motor pathways during corrective spinal surgery may provide warning of impending neural injury at a reversible stage, presumably due to mechanical stress causing ischaemia of neural tissue (Seyal and Mull, 2002), and thereby providing a theoretical window of opportunity for therapeutic intervention. The landmark multicentre survey of Nuwer and colleagues (1995), capturing 51,263 monitored cases in 97,585 surgeries, suggested that somatosensory evoked potential monitoring helped to significantly reduce neurological deficits after scoliosis surgery (Chi-square = 10.8, $p \leq 0.01$). However, experience has taught us that some patients still develop neurological deficits, even in spite of unchanged somatosensory evoked potentials (Lesser *et al*, 1986), making an argument for monitoring of the cortico-spinal motor pathways (Deletis and Sala, 2008). Conversely only a proportion of patients (16% to 40%) who do demonstrate important changes in their somatosensory and/or motor evoked potentials will develop paraparesis, paraplegia or quadriplegia (Nuwer *et al*, 2012). Recent data from the Scoliosis Research Society has shown a disappointing sensitivity for both somatosensory and motor evoked potentials of only 43%, and lack of standardisation may be a contributing factor (Eccher, 2012). Clearly neurophysiological monitoring does not have a perfect predictive ability, with its trade off between sensitivity and specificity, and this limitation means we should not assume that it safeguards the spinal cord. However, significant motor deficits are so devastating for patients that we are duty bound to maintain our efforts to improve safety of patient care undergoing spinal surgery; by continuing to develop good medical practice through implementing guidelines, research and audit in the field of neurophysiological monitoring.

Rationale:

- There are currently no up-to-date quality standards in the UK with respect to Intraoperative Monitoring (IOM) during scoliosis surgery.
- An advisory board was set up consisting of leading centres in the UK who perform IOM to help develop the following guidelines.
- This document seeks to recommend guidelines which are evidence based, relevant to current and future practice, auditable and in a comprehensive form that is achievable.
- This document is aimed to support people in their clinical practice and is not intended to exclude existing protocols and procedures in departments depending on local practice and resources.
- These guidelines are subject to change and will be regularly reviewed.
- IOM should be carried out by competent medical and physiological staff trained in this speciality.

Corrective Spine Surgery:

IOM is indicated in all corrective spine surgery procedures where there is potential serious risk to the spinal cord. IOM is used to help guide the operating team and to prevent or minimise iatrogenic damage. IOM can be used to give information about the central and peripheral nervous system.

Recommended indications for the potential use of IOM include:

Anterior releases

Anterior instrumented fusions

Posterior instrumented fusions

Growth rod lengthening

Revision cases (on a case by case basis)

Instrument removal (removal of Harrington Luque instrumentation)

However, in all cases it is the responsibility of the operating spinal surgeon and team to establish the indication and appropriateness for IOM.

PRACTICE:

Three levels of practice are identified:

- 1) **Standards** – represent the minimum that must be achieved in all cases
- 2) **Guidelines** – suggestions that may be helpful in some clinical circumstances
- 3) **Practice** – the practical application of the standard/guideline

General Principles**Standard 1:**

Prior to Surgery the patient is identified, the clinical information is verified and the need for IOM is assessed.

Standard 2:

During surgery the evoked potential waveforms are identified, their repeatability is assessed and the responses are monitored against a reference waveform throughout the surgical procedure.

Practice:

A reference waveform should be obtained before any spinal surgery or instrumentation. Monitoring should continue for 20 minutes after completing instrumented fixation, or until monitoring is no longer possible.

Standard 3:

Waveforms should be identifiable with respect to both stimulation and recording sites used, including documentation of upper/lower limb and left/right side (as appropriate).

Standard 4:

A predetermined warning criterion is established that defines a significant repeatable change in amplitude, morphology and/or latency of the waveform, that cannot be explained by reversible technical or anaesthetic changes.

Standard 5:

The latency and amplitude of the waveforms are labelled where possible, and are compared to the reference waveform or if appropriate a preceding value.

Guideline:

Responses are accurately timed in relation to other in-theatre clocks to enable comparable timing of surgical/anaesthetic events.

Standard 6:

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

Standard 7:

A clear, concise and accurate record of the annotated waveforms should be kept. Any information conveyed to the surgeon and/or anaesthetist, and any response/action or outcome should be recorded/annotated.

Practice:

Data collection and storage will vary for different departments and equipment. An aspirational aim should be that all original data should be stored electronically, available for review at the time of reporting, and archived (with appropriate backup).

Archiving patient information needs to be in keeping with hospital policies.

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

- Patient name
- Patient date of birth
- Patient hospital or NHS number/IOM identifier
- Date of operation
- Surgical procedure (e.g. anterior/posterior fixation)
- Name of the surgeon performing surgery
- Name of the anaesthetist
- Name of person performing the monitoring
- Protocol used/changes to protocol
- Technical problems/changes

Guideline:**Annotations in the record could include:**

- Type of anaesthesia used - which is relevant to the type of monitoring being performed
- Pre-existing neurological status of the patient
- Patient position (prone, supine, left side/right side up)
- Stages of surgical procedure e.g.
 - Opening/Shrouding
 - Spine exposed
 - Loading of metal work
 - Rod placement and correction
 - Closing

Intraoperative Somatosensory Evoked Potentials (SEPs)

Guideline:

Recording of pre-operative SEPs.

Standard 9:

Sensory evoked potentials are recorded following stimulation of a nerve below the site of the surgery, and recordings made above the site of the surgery.

Practice:

Examples:

Stimulation of the tibial nerve at a supramaximal intensity either at the ankle and/or popliteal fossa or stimulation of the common peroneal nerve at the knee.

Recording from cortical, sub-cortical and/or spinal sites. Common sites include Cz', C3/C4, cervical vertebrae and epidural electrodes.

Bilateral independent peripheral nerve stimulation is advised.

Guideline:

The recording of control Peripheral Lower limb SEPs

Sensory nerves may be stimulated and the evoked potentials recorded **below** the site of the surgery, to help better distinguish technical and systemic* changes from significant** changes in spinal cord function related to the surgery.

Practice:

Stimulation of the tibial nerve at ankle, with recording at the popliteal fossae.

Guideline:

The recording of control Upper Limb SEPs

Sensory nerves may be stimulated and the evoked potentials recorded **above** the site of the surgery to help better distinguish technical and systemic changes from significant changes in spinal cord function related to the surgery.

Practice:

Examples:

Stimulation of the median, ulnar, and/or superficial radial nerves at the wrist, elbow/antecubital fossa (ACF), brachium or Erb's point.

Recording should be from the cortex and where possible one of the following sites: elbow/ACF, brachia, Erb's point or cervical spine.

Bilateral independent peripheral nerve stimulation is advised.

Standard 10:

SEP averaged recordings should be undertaken repeatedly throughout the procedure.

Practice:

Averaged recordings should be made approximately every 5 minutes where possible throughout the procedure (or more frequently at key points).

Standard 11:

A predetermined warning criterion is established that defines a significant repeatable change in amplitude, morphology and/or latency of the waveform that cannot be explained by reversible technical or anaesthetic changes.

Common SEP alert criteria include:

- Loss of waveform
- Amplitude reduction (50% or more)
- Latency increase (10% or more)
- Change in morphology
- Any change that cannot be explained technically or anaesthetically

Intraoperative Motor Evoked Potentials (MEPs)

Guideline:

The corticospinal pathways of the spinal cord may be monitored using MEPs across the site of surgery.

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

There are contraindications for the use of transcranial electrical stimulation in the published literature (MacDonald 2002).

Relative contraindications include:

- Epilepsy (which is poorly controlled)
- Implantable brain devices
- Brain injury
- Skull defects
- Pace Makers

Standard 12:

MEPs require stimulation of a neural structure above the site of the surgery with responses recorded below the site of surgery

Practice:

High voltage electrical stimulation is delivered across the scalp†.

Multiple pulses (2-9) are given with an inter-stimulus interval of between 1 and 5 msec.

A range of stimulating electrode montages can be used to elicit responses.

Examples include: Cz-Fz, C3-C4, C1-C2. Polarity can be switched to optimise stimulation.

Bilateral recording from muscles is indicated.

Common sites include: quadriceps, tibialis anterior, gastrocnemius and abductor hallucis.

Standard 13:

MEPs should be recorded at key points during the procedure.
Stimulus should only be delivered when it is safe to do so.

Practice:

MEPs can be interleaved with SEP recordings.

Guideline:**The recording of control MEPs**

MEPs may be recorded **above** the site of the surgery to help better distinguish technical and systemic* changes from significant** changes in spinal cord function related to the surgery.

Practice:

A range of stimulating electrode montages can be used to elicit responses. Examples include: C3-C4, C1-C2. Polarity can be switched to optimise stimulation.

Bilateral recording from muscles is indicated.

Common sites for muscles above the site of surgery include small hand muscles, forearm flexors, forearm extensors.

Standard 14:

A predetermined warning criterion is established that includes a repeatable change in amplitude, morphology and/or latency of the waveform that cannot be explained by reversible technical or anaesthetic changes.

Common MEP alert criteria include:

- All or nothing (Most commonly used)

- Amplitude reduction

- Latency increase

- Change in morphology

- Need to increase stimulus intensity (Threshold method)

- Any change that cannot be explained technically or anaesthetically

Other IOM techniques that can be used at the time of surgery include:

D wave recordings.

H reflex

Epidural electrode stimulation and recording

Free-running electromyography (EMG)

Pedicle screw monitoring

* systemic changes include anaesthetic changes, temperature, blood pressure etc.

** 'significant changes' include pathological events, ischemia, traction and compression etc

†Advice that a bite block (or other means of protecting against tongue bite injury) is used

References:

Deletis V, Sala F. Intraoperative Neurophysiological monitoring of the spinal cord during spinal cord and spine surgery: a review focussed on the corticospinal tracts. *Clin Neurophysiol* 2008; 119: 248-264.

Eccher M. Intraoperative Neurophysiological monitoring: are we really that bad? *J Clin Neurophysiol* 2012; 29: 157-159.

Lesser RP, Raudzens P, Luders H, Nuwer MR, Goldie WD, Morris HH, Dinner DS, Klem G, Hahn JF, Shetter AG, Ginsburg HH, Gurd AR. Postoperative neurological deficits may occur despite unchanged intraoperative somatosensory evoked potentials. *Ann Neurol* 1986; 19: 22-25.

MacDonald DB. Safety of intraoperative transcranial electrical stimulation motor evoked potential monitoring. *J Clin Neurophysiol* 2002; 19:416-29.

Nuwer MR, Dawson EG, Carlson LG, Kanim LEA, Sherman JE. Somatosensory evoked potentials spinal cord monitoring reduces neurological deficits after scoliosis surgery: results of a large multicenter survey. *Electroencephalogr Clin Neurophysiol* 1995; 96: 6-11.

Nuwer MR, Emerson RG, Galloway G, Leggatt AD, Lopez J, Minahan R, Yamada T, Goodin DS, Armon C, Chaudhry V, Gronseth GS, Harden CL. Evidence-based guideline update: Intraoperative spinal monitoring with somatosensory and transcranial electrical motor evoked potentials. *Neurology* 2012; 78: 585-589.

Seyal M, Mull B. Mechanisms of signal change during intraoperative somatosensory evoked potential monitoring of the spinal cord. *J Clin Neurophysiol* 2002; 19: 409-415.