Intra-operative somatosensory-evoked potential monitoring

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ABSTRACT

Purpose. To evaluate the usefulness of intra-operative somatosensory-evoked potentials (SSEPs) in monitoring spinal cord status via the posterior tibial nerve.

Methods. 84 men and 28 women aged 16 to 66 years (72% were aged 20 to 40 years) with spinal trauma (63 in the lumbar and 49 in the thoracic spine) underwent posterior instrumentation and fusion using bone grafts. All 63 patients with lumbar spinal injury and 35 of the patients with thoracic spinal injury were treated with pedicular screws. The remaining 14 patients had their thoracic spinal injury fixed with sublaminar wires. Cortical scalp recordings were used. Baseline tracings were obtained prior to surgical intervention and after establishment of anaesthesia. If changes persisted for more than 15 to 20 minutes or if they did not show definite signs of resolution, event reversal was considered.

Results. Of the 112 patients, 74 (66%) had no changes in Cz-Fpz patterns and neurological status, whereas 14 (13%) showed improved patterns (2 of them had the same neurological status postoperatively) and 24 (21%) displayed deteriorated patterns prompting intervention. Of the 24 patients prompting intervention, 20 improved substantially (19 had no new neurological deficits and one had deteriorated neurological status) and 4 improved minimally (2 had no new deficit and 2 had new deficits), with 88% sensitivity and 78% specificity. 15 patients were true-positives with an identifiable cause; 21 were false-positives with no neurological deterioration or recognisable cause.

Conclusion. Intra-operative SSEP monitoring helps identify acute neurological and systemic (hypoxia or hypotension) impairment and enables prompt correction. This makes surgery available to high-risk patients and enables surgeons to carry out more extensive procedures. It also provides valuable documentation in the event of medico-legal dispute.

Key words: evoked potentials, somatosensory; monitoring, intraoperative; neurologic manifestations; surgical procedures, operative

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INTRODUCTION

Patients with spinal trauma are more susceptible to spinal cord injury during surgery because of compromised blood supply. The risk of neurological injury has increased markedly since the introduction of rigid spinal implants with strong corrective forces. The incidence of surgically induced spinal cord injury increased from 0.5 to 1% in the 70s to 17% in the 80s (4% endured major injury and 13% transient sensory changes).2

Intra-operative somatosensory-evoked potentials (SSEPs) constitute a representative index of motor function,3–6 as vascular compromise causes motor dysfunction or loss and affects the lateral corticospinal and dorsal spinocerebellar tracts.7 Intra-operative monitoring of the dorsal column function using SSEPs has been routinely used for over 20 years.2 SSEP monitoring is non-invasive, applicable to any surgical level and approach, and enables pre- and post-operative assessment of spinal cord function.7 SSEPs are elicited by stimulation of the median nerve at the wrist, the common peroneal nerve at the knee, and/or the posterior tibial nerve at the ankle and recorded from electrodes placed over the scalp, spine, and peripheral nerves. The dorsal column-lemniscal system is the major anatomic substrate of the SSEPs within the central nervous system.7,8

SSEPs can also be used to diagnose neurological disease. Abnormal SSEPs may result from dysfunction at the level of the peripheral nerve, plexus, spinal root, spinal cord, brain stem, thalamocortical projections, or primary somatosensory cortex. Because individuals have multiple parallel afferent somatosensory pathways (e.g. anterior spinothalamic tract, dorsal column tracts) within the spinal cord, SSEP recordings can be normal even in patients with significant sensory deficits.8

SSEPs depend on the functional integrity of the fast-conducting, large-diameter group-Ia muscle afferent fibres and group-II cutaneous afferent fibres, which travel in the posterior column of the spinal cord. When a mixed peripheral nerve (with both sensory and motor components) is stimulated, both group-Ia muscle afferents and group-II cutaneous afferents contribute to the SSEP.9 The short latency potentials which lie within 50 ms after the stimulus are of clinical interest, whereas potentials of the middle latency (50–100 ms) and long latency (100–300 ms) are of little clinical value because of their variability and inconsistency.9

We evaluated the usefulness of intra-operative SSEPs in monitoring spinal cord status via the posterior tibial nerve, as well as the true-positive and false-negative percentages, and the resulting sensitivity and specificity.

MATERIALS AND METHODS

Between August 2004 and July 2006, 84 men and 28 women aged 16 to 66 years (72% were aged 20 to 40 years) with spinal trauma (63 in the lumbar and 49 in the thoracic spine) underwent posterior instrumentation and fusion using bone grafts. All 63 patients with lumbar spinal injury and 35 of the patients with thoracic spinal injury were treated with pedicular screws. The remaining 14 patients had their thoracic spinal injury fixed with sublaminar wires.

Patients were excluded when (1) nitrous oxide/oxygen/narcotic was not used as the main anaesthesia; (2) tibial nerve SSEPs were absent; (3) they had very poor preoperative neurological function (e.g. complete paraplegia, in which pain is the indication for operation); or (4) they had a spinal tumour, infection, or congenital/developmental anomalies.

Nitrous oxide/oxygen with fentanyl and neuromuscular blockade by bolus injection was the main anaesthetic regimen. Halogenated gases were not used as they reduce SSEPs dramatically. Hypotensive conditions were created with nitroprusside and similar agents.5–7

Cortical scalp recordings were used because of their large amplitudes and signal/noise ratio.5 Baseline tracings were obtained prior to surgical intervention and after establishment of anaesthesia. If changes persisted for more than 15 to 20 minutes or if they did not show definite signs of resolution, event reversal was considered (e.g. release of the force applied by a distracted rod). Posterior tibial SSEPs at the ankle were preferred because (1) they were larger and less subject to variability; (2) they produced smaller muscle contractions with larger SSEP amplitudes; and (3) electrodes at the ankle were more easily accessible than those at the knee.

Surface electrodes were used because they were non-invasive, did not interfere with surgery, and provided good electrical contact. The main recording electrode was placed over the post central gyrus (Cz) and the reference electrode was placed over the forehead (Fpz). A third electrode (to provide common mode rejection) was placed over the clavicle or shoulder. Electrode impedances were typically ≤500 ohms.

The stimulus consisted of 200 microsecond pulses, 10 to 18 mA in amplitude (constant current), at 3.1 Hz delivered to the posterior tibial nerve (the side
with better neurological status) by electrodes, with a cathode placed midway between the Achilles tendon and the medial malleolus, and an anode 3 cm distal to the cathode.⁷

Each waveform was a mean of cortical responses to 750 repetitions and was recorded every 15 to 20 minutes. To determine the variability of SSEP waveforms, recordings at approximately 30-minute intervals were analysed. SSEP waveforms were noted during major steps of the surgery (preinduction, postinduction, during decompression, postdecompression, and postoperation). If changes occurred, recordings were repeated more frequently.

The variability and quality (changes in amplitude and latencies) of the SSEP recordings were measured, according to (1) major intra-operative changes in SSEPs suggested ≥10% latency increase and ≥50% amplitude loss of pressure on the spinal cord¹³⁻⁵; (2) monitoring quality score⁷ using a 5-point ordinal scale (Table 1).

Reliability of the SSEP monitoring included sensitivity (i.e. whether early cord changes can be detected by waveform changes) and specificity (i.e. whether the detected changes are associated with cord compromise and can be distinguished from other less important changes).

**RESULTS**

The duration of surgery ranged from 2.5 to 8 hours; most operations were between 4 and 5 hours long. Of the 112 patients, 74 (66%) had no changes in the Cz-Fpz pattern and neurological status, whereas 14 (13%) showed improved patterns (2 had the same neurological status postoperatively) and 24 (21%) revealed deteriorated patterns that prompted intervention, including shoulder tape release, traction release, patient repositioning, surgical decompression, and truncation of surgery.⁹ Of the 24 patients prompting intervention, 20 improved substantially (19 had no new neurological deficits and one deteriorated neurologically); 4 improved minimally (2 had no new deficit and 2 had new deficits), with 88% sensitivity and 78% specificity.

15 patients had true-positive results with an identifiable cause (e.g. patient positioning in the presence of an unstable spine, curve correction [mainly distraction], passing or tightening sublaminar wires), irrespective of neurological outcome. In 21 patients the tests yielded false-positive results, with no neurological deterioration and recognisable causes (e.g. changes from non-surgical factors, changes associated with critical surgical manipulation, and changes related to unidentifiable factors) [Table 2].

**DISCUSSION**

In a retrospective study of 442 major spinal operations with spinal cord monitoring, 23 were technical failures and 70 had major intra-operative changes (10 of these were true-positive and 60 were false-positive), with 100% sensitivity and 85% specificity.¹⁰

In a study of 213 patients having surgery on 318 levels, 32% underwent an instrumented fusion.

<table>
<thead>
<tr>
<th>Score</th>
<th>Quality</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>None</td>
<td>No consistent or repeatable pattern. Primary complex is not seen or extremely rare.</td>
</tr>
<tr>
<td>1</td>
<td>Poor</td>
<td>Weakly repeatable. Primary complex appears 10 to 50% of time, but may be abnormal and amplitude is not strong.</td>
</tr>
<tr>
<td>2</td>
<td>Fair</td>
<td>Repeatability is in moderate range. The primary complex appears in 50 to 90% of recordings and is identifiable even in poor traces. Amplitude is quite variable and reliance on latencies predominates.</td>
</tr>
<tr>
<td>3</td>
<td>Good</td>
<td>Waveforms are quite repeatable and 90 to 100% of the traces have primary complex. Amplitude is quite strong and latencies repeat to within a few milliseconds.</td>
</tr>
<tr>
<td>4</td>
<td>Excellent</td>
<td>Recordings are repeatable in almost every detail—amplitude, latency, shape. The primary complex is present in 100% of traces.</td>
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<tr>
<th>Neurological status</th>
<th>SSEP pattern (n=112)</th>
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<tbody>
<tr>
<td></td>
<td>Same</td>
</tr>
<tr>
<td>Same</td>
<td>74 (true-negative)</td>
</tr>
<tr>
<td>Improved</td>
<td>0</td>
</tr>
<tr>
<td>Deteriorated</td>
<td>0</td>
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Table 1

Monitoring quality scores using a 5-point ordinal scale

Table 2

Relationship between neurological status and somatosensory-evoked potential (SSEP) patterns
Considerable electromyographic activation was observed in 78% and considerable SSEP changes in 7% of the patients. 14 (7%) patients had new postoperative neurological symptoms; all had considerable electromyographic activation, but only 4 had considerable SSEP changes. Electromyograph activation had 100% sensitivity and 24% specificity for detecting new neurological deficits, whereas SSEPs had 29% sensitivity and 95% specificity.\(^2\)

CONCLUSION

Intra-operative SSEP monitoring helps identify acute neurological and systemic (hypoxia or hypotension) impairment and enables prompt correction. This facilitates safer surgery for high-risk patients and enables surgeons to carry out more extensive procedures. It also provides valuable documentation in the event of medico-legal disputes.

REFERENCES