Intravenous anaesthesia and repetitive transcranial magnetic stimulation monitoring in spinal column surgery

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Background. Transcranial magnetic stimulation with motor evoked potential monitoring is a non-invasive method for monitoring motor tracts during surgery. However, anaesthetic agents such as propofol and volatile agents reduce responses to single transcranial magnetic stimulation. We assessed an intravenous technique for anaesthesia to allow motor evoked potentials (MEPs) to be monitored using repetitive transcranial magnetic stimulation (rTMS).

Methods. We applied three-pulse rTMS (TriStim) in 11 patients undergoing spinal column surgery after spinal column injury and recorded the latency and peak-to-peak amplitude of MEPs. Anaesthesia was maintained with propofol and remifentanil.

Results. MEPs were monitored successfully intraoperatively in all patients.

Conclusions. It is possible to monitor intraoperative MEP using rTMS during anaesthesia with propofol and remifentanil.

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We reviewed our use of transcranial magnetic motor evoked potential responses during spinal cord surgery when we used an i.v. anaesthetic technique, which was as reliable but simpler than previous anaesthetic methods used with single pulse stimulation.1 Our results may encourage others to use this form of monitoring to monitor long motor tract function during surgery when there is a risk of neural damage during spinal column surgery.2 Non-invasive monitoring is possible with either magnetic or electrical stimulation of the motor cortex, and recording motor evoked potentials from a suitable muscle. Muscle responses to transcranial magnetic stimulation (TMS) are more sensitive to anaesthetic-induced depression than are responses to transcranial electrical stimulation.3 However, temporal summation using high-frequency repetitive stimulation can overcome the inhibition caused by anaesthesia.4 We successfully monitored the long motor tracts in 11 patients undergoing spinal fixation surgery using TriStim—three stimuli with an interstimulus interval of 2 ms (500 Hz)—during anaesthesia with propofol and remifentanil.

Methods and results

We reviewed adult patients who had internal fixation of the spinal cord after spinal cord trauma (10 patients) or laminectomy and syringopleural drainage (one patient) between July 1999 and January 2003. There were seven males and four females, with mean (range) age 32 (17–60). All were ASA I or II. Six patients had thoracolumbar injuries and five had cervical injuries. According to the American Spinal Injury Association (ASIA) impairment scale (modified from Frankel),5 six intact patients were grade E, four patients grade D and one grade B. The grade B patient was a T6 paraplegic undergoing syringopleural drainage and was monitored because of the risk of extension of the neural deficit.

Transcranial magnetic stimulation was provided in bursts of three pulses, 2 ms apart, based upon previous work.4 The single-pulse Magstim 200 had been upgraded with a Bistim to provide a three pulse stimulus, which was considered to be nearly as effective as the four-pulse Quadropulse 500 (Magstim Company, Whitland, UK). The double-cone coil recommended for stimulating the lower limbs was generally used, but on occasion the circular 90 mm coil was easier to place over the skull within the confines of a halofixation system. The coils were handheld to allow localization of either the right- or left-sided muscle by slightly altering the direction of focus. After positioning the patient prone in the operating theatre, nitrous oxide was discontinued and the stimulus was repeated to find the best position and determine if nitrous oxide was interfering with the response.

Nine of the 11 patients were tested before the operation to record baseline motor evoked potentials (MEPs), limiting the output to 30–60% to prevent jerking of the unstable
spine. Patients who had partial neurological loss usually needed a stronger stimulus output and the responses could sometimes reveal that one side was more compromised than the other. The muscle selected was just below or at the neurological level of actual or potential deficit and when, during the course of this study period, a two-channel stimulator became available the homologous right and left muscles were both stimulated.

We recorded the selected responses with a Dantec Keypoint Workstation (Dantec Dynamics UK, Bristol, UK). This displays sequential MEPs until a successful response is obtained, which may then be printed out. Amplitude and latency are available either as hard copy or stored. Peak-to-peak voltages and latencies were recorded every 2 min during the operation when damage could occur, and compared with preoperative values where possible. As responses are Reduced during anaesthesia, the Magstim output was increased to 100% during surgery. Possible neural damage was considered to be shown by an increase in latency of 5 ms or a decrease in amplitude of >50%. Six patients were premedicated with oral promethazine 50 mg. Three patients required awake fibre-optic intubation and were given i.m. glycopyrrolate 200 µg and Cyclimorph-10 1 ml. One patient was given oral lorazepam 2 mg for awake intubation, although benzodiazepines were generally avoided because of their potential to suppress the MEP. While the patient was placed prone we administered nitrous oxide and isoflurane. Once the patients were positioned safely, anaesthesia was maintained with infusions of propofol and remifentanil and monitoring was started.

In eight patients, propofol was infused at 10 mg kg⁻¹ h⁻¹ for 10 min, 8 mg kg⁻¹ h⁻¹ for the next 10 min and then at 6 mg kg⁻¹ h⁻¹. In the other patients we gave target-controlled infusions using a Diprifusor set to obtain a predicted plasma concentration of 3.5–4 µg ml⁻¹. We gave a dose of remifentanil 1 µg kg⁻¹, followed by infusion of 0.5–1 µg kg⁻¹ min⁻¹ to all patients.

Mivacurium was administered to all patients after induction of anaesthesia. Mivacurium infusion was continued for a period in five patients during diathermy to reduce muscle contractions, using an infusion of about 3 µg kg⁻¹ min⁻¹ to obtain two or three visible twitches in a train of four. Nine patients were ventilated with an air–oxygen mixture, and two patients received 50% nitrous oxide. End tidal isoflurane was less than 0.2% in all patients once TriStim monitoring started.

Reliable MEPs were obtained, monitored bilaterally in six patients and unilaterally in five. Values for latency were within 2 ms of preoperative values in five patients, increased by 4 ms in two and decreased by 4 ms in one. No patient sustained neurological damage or worsening of neurological deficit. A typical intraoperative course of latency and peak-to-peak amplitude is shown in Figure 1. Amplitude tended to increase with noxious surgical stimulus during initial dissection and with the decompression of the spinal cord towards the end of the procedure. Because the EMG signal could vary with surgical stimulation, conditions of anaesthesia and variations in coil positioning, the interpretation of amplitude and latency of the signal had to be related to these factors. Table 1 summarizes the results of each patient.

![Figure 1](http://bjj.oxfordjournals.org/) Peak-to-peak amplitudes and latencies measured before and during surgery in one patient undergoing open reduction of fracture dislocation of the first lumbar vertebra. The initial stimulus when awake was set at 65% and increased to 100%. The right and left tibialis anterior were monitored. The first recording (2 min) took place 15 min after initial surgical incision and subsequently at different times throughout the procedure; the corresponding data points are spaced evenly for clarity. Mivacurium and remifentanil infusions were stopped at 130 min and propofol at 145 min.
Table 1 Results for each patient showing the level of spinal cord damage and neurology, the muscles stimulated, Magstim output used before surgery, baseline latencies and amplitudes and results from the start and end of surgery. Where bilateral measurements were taken, the side with smaller preoperative amplitudes is given. ADM=abductor digitii minimi; ASIA, American Spinal Injury Association; n.a., not available; TA=tibialis anterior.

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Level of lesion</th>
<th>ASIA right/left</th>
<th>Muscle</th>
<th>Latency (ms)</th>
<th>Amplitude (µV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Baseline</td>
<td>Start of surgery</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Magstim output</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>L1</td>
<td>D/D</td>
<td>TA</td>
<td>65%</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>L1</td>
<td>E/E</td>
<td>TA</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>3</td>
<td>L3</td>
<td>E/E</td>
<td>TA</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>4</td>
<td>C8</td>
<td>B/B</td>
<td>ADM</td>
<td>30%</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>L1</td>
<td>E/E</td>
<td>Gastrocnemius</td>
<td>50%</td>
<td>31</td>
</tr>
<tr>
<td>6</td>
<td>C5/6</td>
<td>E/E</td>
<td>Biceps</td>
<td>40%</td>
<td>24</td>
</tr>
<tr>
<td>7</td>
<td>C6/7</td>
<td>E/D</td>
<td>Triceps</td>
<td>30%</td>
<td>17</td>
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<tr>
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<td>32</td>
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<tr>
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<td>TA</td>
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<tr>
<td>11</td>
<td>C4/5</td>
<td>E/E</td>
<td>TA</td>
<td>50%</td>
<td>36</td>
</tr>
</tbody>
</table>

Comment

A previous study from our centre used anaesthesia with infusions of methohexitone, alfentanil and ketamine since responses to TMS with single stimuli are suppressed by propofol. Since then, remifentanil has become available and methohexitone withdrawn. Propofol can be used with multiple-pulse stimulation, although volatile agents are still strongly suppressant.9 We found that even nitrous oxide markedly decreased peak-to-peak voltage recordings and we usually omitted this agent in the later patients. Neur muscular blockade should only be used during positioning and to reduce muscle contraction during the diathermy of back muscles since MEPs are more difficult to elicit with magnetic compared with electrical stimulation. With electrical stimulation, monitoring is possible during neuromuscular block with two twitch responses from the adductor pollicis,10 equivalent to 85% receptor block.8

Total i.v. anaesthesia can cause systemic hypotension, so i.v. anaesthesia was not started until positioning was complete. Finding the best cranial position usually needs repeated stimuli, at a time when the concentrations of volatile agents and mivacurium are decreasing. Variation of MEP is expected using TMS, partly because positioning of the hand held coil requires experience and practice. Some prefer to keep the position constant with a clamp. A halo fixation device can impair placement of the figure-of-eight coil but positioning was easier once the patient was prone. There is also some variation in waveforms produced by TMS, partly from changes in neuronal threshold during a sequence of stimuli, and also because a muscle like the tibialis anterior has innervation from L4, L5 and S1. The peroneus longus could be more suitable because it has a predominantly L5 supply. Once stable responses are obtained, it is not necessary to stimulate continuously, but to stimulate only when neural damage could occur.

TMS, compared with transcranial electrical stimulation, has minimal risk of electric shock or burns. Unlike electrical cortical stimulation, baseline recording and assessment after operation are possible with comparison of right and left sides. Stimulation of deeper and less accessible nerves is also possible.

In addition to the recent report of transcranial electrical stimulation during i.v. anaesthesia,11 we report that repetitive magnetic stimulation allows assessment of long motor tracts during anaesthesia using propofol and remifentanil with no more than 25% nitrous oxide. By evolving a reliable method of anaesthesia that allows comparison of preoperative magnetic MEPs with repeated intraoperative responses, operative procedures can be carried out more safely.

References