CONFERENCE PROCEEDING

Current status of motor evoked potentials

Matthew TV Chan

INTRODUCTION

Surgery on the spine and the thoracic aorta impose great risks to the spinal cord. Intraoperative somatosensory evoked potential (SEP) records electrical potentials along the somatosensory pathway in response to stimulation of peripheral nerves (usually the median or the posterior tibial nerves) and indicate the integrity of the spinal cord. The principles and utility of SEP have been previously reviewed.[1-3] In general, spinal cord injury should be suspected when there is a 50% or more decrease in SEP amplitude and/or 10% or more increase in latency. In a well-known multicentre survey conducted by the Scoliosis Research Society (n = 51263 scoliosis repair), SEP monitoring alone detected neurological injury in 77% of the cases with a specificity of >98%.[4] However, the real concern of SEP lies with the incidence of false negative cases (0.13–25%), where patients develop new post-operative deficits in the absence of intraoperative SEP change. Apart from the technical and pharmacological problems that may interfere with SEP recording, it is now recognised that isolated injury to the anterior corticospinal tract can go undetected with unchanged SEP recordings.[5-7] Intraoperative 'wake-up' test assesses spinal cord motor functions and has been a useful adjunct to SEP during spinal instrumentation for many years.[8] However, wake-up test cannot be repeated frequently during the whole course of surgery and cannot be applied to 'uncooperative' patients. Motor evoked potentials (MEPs) have been developed to overcome the limitations of SEP by monitoring the descending motor pathways in the anterior and lateral part of the spinal cord.

Department of Anaesthesia and Intensive Care, The Chinese University of Hong Kong, Hong Kong, China

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MOTOR EVOKED POTENTIALS

In MEP, the response of muscle or peripheral nerve is recorded after stimulation of the cerebral cortex or spinal cord (usually the cervical segment). Out of the four possible stimulation-recording combinations, three modalities have been feasible in clinical setting. A position statement on intraoperative MEP monitoring has been recently published by the American Society of Neurophysiological Monitoring.[9]

Myogenic transcranial motor evoked potentials

Transcranial MEP (tcMEP) records the distal compound muscle action potentials (CMAP) of the peripheral muscle (myogenic signals) after stimulation of the motor cortex through the intact skull. To overcome the impedance of the skull, a transient (50–100 ms) high voltage (up to 1.2 kV) current (up to 1000 mA) of electrical impulse is applied. Alternatively, localised strong (2 Tesla) magnetic field can be applied. Stimulation may be applied as single or multi-pulse (typically at interval of 2–4 ms). Clinically, tcMEP is specific to the motor tract and sensitive to spinal cord ischemia. During thoraco-abdominal aneurysm surgery, disappearance of tcMEP occurs within seconds after cessation of spinal cord blood flow.[10] However, both electrical and magnetic tcMEPs are exquisitely sensitive to anaesthetics, so that low concentrations of isoflurane (1.2%, 1 minimum alveolar concentration [MAC]),[11] sevoflurane

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(1.6%, 0.7 MAC),[12] desflurane (5.7%, 0.9 MAC)[13] and nitrous oxide (>50%, 0.4 MAC)[14] are sufficient to abolish tcMEP. Although the depressive effect of propofol, etomidate, ketamine and dexmedetomidine may be less compared with inhalational agents,[15-17] tcMEP are often difficult to elicit and sensitive to noise interference. Nevertheless, current evoked potential machines with better shielding have overcome many of these problems. Currently, myogenic transcranial electrical MEP is the most commonly used technique.

Neurogenic transcranial motor evoked potentials

Neurogenic recordings of MEP following transcranial electrical stimulation are possible by placing an electrode over the dura (near-field) during laminectomy. Alternatively, an epidural catheter can be placed percutaneously using fluoroscopy. In this modality, pyramidal cells in the motor cortex are discharged and travels along the corticospinal tract.[18] This produces a characteristic deflection in the epidural recording and is known as the D-wave. This is followed by a series of indirect I waves, as the initial impulse synapsed with interneurons. As I waves are generated by synaptic connections, it is not surprising that I waves are sensitive to anaesthetic.[19,20] In contrast, the D-wave is relatively resistant to anaesthetic and is unaffected by neuromuscular blockade. However, impulses terminate at various segments and leave the corticospinal tract; D-wave cannot be recorded reliably below T10. Ideally, D-wave monitoring requires proximal and distal recordings to assess the risk of injury at any specified segment of the spinal cord.

Neurogenic transcervical motor evoked potentials

In contrast, the evoked responses in the peripheral nerves (neurogenic) or distal muscle (myogenic) to electrical stimulation of the spinal cord (transcervical) are more robust and easy to perform. Typically, electric current (0.5 Hz, 0.1–0.5 ms square pulse, 20–40 mA) is delivered to the spinal cord through an insulated needle electrode rostral to the segment of interest. Ideally, the needle should be placed through the inter-spinous ligament between two adjacent vertebrae (usually, C5–C7) and situated within 1 cm to the spinal cord. Obviously, spinal stimulation is impractical during high cervical cord surgery.

Neurogenic responses are usually recorded in the popliteal fossa over the posterior tibial nerve. Although neurogenic MEPs are unlikely to be influenced by anaesthetics,[21] there is now increasing evidence to suggest that the evoked response is not specific to the motor tract and may be conducted antidromically through the sensory fibres in the dorsal root.[14,22] Theoretically, it is possible to elicit normal neurogenic MEPs during isolated anterior spinal cord injury.

Myogenic transcervical motor evoked potentials

Myogenic MEPs are more specific for motor tract conduction. However, recordable CMAP cannot be elicited when neuromusclar block is complete. Although myogenic MEPs could be recorded if muscle relaxant is omitted, excessive bleeding and violent movement can be expected. In this regard, there is no recommendation as to the maximum neuromuscular block permitted.

ANAESTHETIC PROTOCOL FOR MOTOR EVOKED POTENTIALS MONITORING

When intraoperative SEP and transcranial electrical MEP monitoring are required, we now resort to provide target controlled total intravenous anaesthesia with effect site propofol and remifentanil concentrations of 2.5–3.5 μg/ml and 1–2 ng/ml, respectively. Nitrous oxide and neuromuscular block should be avoided. Alternatively, muscle relaxant is administered by a closed-loop feedback infusion system, so that a stable neuromuscular block can be maintained. Neuromuscular block monitoring at the ulnar nerve by electromyography using a train of four stimulation must be assessed. The level of block is then adjusted to achieve reliable MEPs before surgical exploration. It should be noted that at least 50% of the first twitch response is required before any decent MEP can be elicited.

SAFETY OF TRANSCRANIAL ELECTRICAL MOTOR EVOKED POTENTIALS MONITORING

Given that transcranial electrical stimulation is the most popular technique for eliciting MEP, there is an obvious concern on the safety of repetitive high voltage electrical stimulation for MEP monitoring. MacDonald reviewed 15,000 cases receiving transcranial electrical stimulation for MEP monitoring.[23] There were 43 (0.29%) adverse events attributable to transcranial electrical stimulation. Majority of them were bite injuries, lacerations and other movement-related injury. Seizures were reported in five cases (0.003%), although there is currently no identifiable risk factor for seizure after electrical brain stimulation. At present, patients with epilepsy are not excluded from transcranial electrical MEP monitoring.

UTILITY OF MOTOR EVOKED POTENTIALS MONITORING

Although MEP has been widely used in many complex spinal procedures, there is no prospective randomised trial showing favourable outcome after MEP monitoring.[24]

Current data are derived from case studies that do not contain a proper control group. In their original study of 32 patients undergoing resection of intramedullary spinal cord tumour, Morota *et al*. reported fewer post-operative motor deficits in patients who were successfully monitored than those who are 'unmonitorable,' i.e. without elicitable baseline potentials.[25] One should be reminded that patients who could not be monitored generally had more extensive disease. It is also not clear whether treatment was randomly assigned in this study. However, it is important to note that complete resection was achieved in all patients undergoing surgery with monitoring, whereas only 90% of procedures without monitoring were considered radical resections. This data suggested that monitoring does not limit surgical resection, but rather allows surgeons to perform more radical surgery within the confines of monitoring data.

SUMMARY

MEP is a neuro-monitoring tool that is specific and sensitive to anterior spinal cord injury. Currently, transcranial electrical stimulation using high voltage/current with myogenic response is commonly adopted. A specific anaesthetic protocol using propofol infusion and avoiding neuromuscular block are recommended.

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Conflicts of interest

There are no conflicts of interest.

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