Intraoperative Neurophysiologic Monitoring for Degenerative Cervical Myelopathy

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KEYWORDS

• Degenerative cervical myelopathy • Intraoperative neurophysiologic monitoring
• Somatosensory evoked potential • Motor evoked potential

KEY POINTS

- Multimodal intraoperative neurophysiologic monitoring is a reliable tool for detecting intraoperative spine injury and is recommended during surgery for degenerative cervical myopathy (DCM).
- Somatosensory evoked potential (SEP) can be used to monitor spine and peripheral nerve injury during positioning in surgery for DCM.
- Compensation technique for transcranial evoked muscle action potentials (tcMEPs) should be adopted in intraoperative monitoring during surgery for DCM.
- Free-running electromyography is a useful real-time monitoring add-on modality in addition to SEP and tcMEP.

INTRODUCTION

In the past, a wake-up test was considered a gold standard for detection of spinal cord injury during spinal corrective surgery.[1] Because spinal cord injury occurs during surgical maneuver, such as corrective instrumentation, however, wake-up tests can easily lead to false-negative findings.[2] In the 1970s, somatosensory evoked potential (SEP) had been applied in scoliosis corrective surgery as intraoperative sensory tract monitoring.[3] In 1980, Merton and Morton[4] reported a breakthrough method called transcranial evoked muscle action potentials (tcMEPs) for monitoring motor tracts. With the widespread use of total intravenous anesthesia (TIVA) using propofol and opioids, intraoperative monitoring with tcMEPs has become popular in spine surgery.[5,6] Each method has characteristic advantages and disadvantages; therefore, a combination of multiple methods has been developed and accepted for intraoperative neurophysiologic monitoring (IONM) during spine surgery.[7] IONM is established as an effective method to predict an increased risk of the adverse outcome of paralysis after spine surgery.[8] IONM in spine surgery has become a standard during resection of spinal tumors and surgical correction for scoliosis. A large retrospective study reported that the incidence of major spinal cord injuries in cervical spine was 3 per 1000.[9] Although the likelihood of complication is low, IONM during

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decompressive surgery of degenerative cervical myelopathy (DCM) should be adopted.

SOMATOSENSORY EVOKED POTENTIAL

As IONM for spine surgery, SEP was first reported and suggested as having great potential for improving outcome of spine surgery. SEP, as an IONM tool, has been used in spine surgery for more than 40 years.[10] SEP is the most widely popularized technique among different modalities of IONM. In cervical decompression surgery, SEP is used not only to assess the function of somatosensory pathways but also to avoid injury to the spinal cord or the peripheral nerves during positioning.[11]

Surgery for cervical myelopathy requires monitoring of the 4 nerves of the extremities.[12] SEPs for IONM are typically elicited by stimulating the median nerve and the posterior tibial nerve in the upper and lower extremities, respectively.[13] Various electrodes can be used for stimulation of target nerves, such as bar electrodes, electroencephalographic metal disc electrodes, surface electrodes, and subdermal needle electrodes. Each electrode has characteristic advantages and disadvantages. For IONM, the most suitable stimulating electrodes are surface electrodes. The cortical potentials of SEP are recorded from CP3 and CP4 in the upper extremities and CPz in the lower extremities (depending on the 10–20 international electrode system).[14]

Evoked potentials of SEP are very low in amplitude and require averaging several times. Therefore, reducing or diminishing the noise of operating theater is necessary and requires a few minutes to evaluate the change in waveform. A warning signal is generally issued when there is a 50% decrease in amplitude or 10% increase in latency compared with baseline values.[14] SEP signal changes, however, are not always related to a postoperative neurologic deficit. The specificity of SEP during IONM was reported as 27%, whereas the sensitivity was 99%.[11] Low specificity of intraoperative SEP affects the utility of SEP alone for IONM. Waveform of SEP is influenced by many factors, such as blood pressure, body temperature, partial pressure of alveolar carbon dioxide, and anesthetic drugs, in addition to spinal interference.[15] Deletis and Sala[16] pointed out that the isolated use of SEP monitoring for IONM is inappropriate. The lack of specificity of SEP has favored the use of muscle evoked potential (MEP) for IONM during cervical decompression surgery.[16]

In addition, cases of degenerative cervical myelopathy have a potential risk of spinal cord compression or peripheral nerve injury during positioning.[11,17,18] Recording prepositioning and postpositioning SEP for spine surgery in skeletal dysplasia was reported by Ofiram and colleagues.[19] Only a few studies have reported the application of neurophysiologic monitoring for the position-related spinal cord dysfunction during anterior cervical discectomy and fusion (ACDF).[20] Chen and colleagues[21] reported postoperative neurologic deficits due to positioning by unrecognized coexisting cervical disk herniation during lumbar laminectomy. Although recording of MEP at the same time is ideal, it is often difficult because of the muscle relaxants used during intubation. It is the authors' practice to monitor prepositioning and postpositioning SEP as described in **Fig. 1**. Detection of postpositioning SEP changes can contribute to prevention of neurologic deficits.

SEP can also detect and prevent peripheral nerve injury during cervical spine surgery.[22] Peripheral nerve injury occurs in patients who are malpositioned during surgery.[23] Both prone and supine positions have a possibility of peripheral nerve injury and SEP can detect arm position-related waveform changes. The rate of reversible SEP changes with tucked arms were 1.8% in supine and 2.1% in prone positions.[24] IONM of SEP, including positioning-related changes, are of value in identifying and preventing spine and peripheral nerve injury during cervical spine surgery.

TRANSCRANIAL MOTOR EVOKED POTENTIALS

MEPs derived from transcranial stimulation for IONM have been used for more than 20 years and rapidly became popular in spine surgery.[25] Usefulness of tcMEP has been reported during spine surgery.[26–29] tcMEP is recognized as the most sensitive technique compared with other techniques, such as SEP or spinal cord evoked potential.[30] Some investigators argue that surgical decompression for symptomatic cervical spine may be safely done without IONM.[31] Contrarily, other reports conclude that intraoperative MEP monitoring during surgery for degenerative cervical spondylotic myelopathy may have prevented occurrence of permanent postoperative neurologic injury.[32] Although the requirement of IONM for DCM is controversial and literature specific to DCM is sparse, articles supporting the usefulness of IONM are increasing in recent years. tcMEP could detect acute-type postoperative C5 palsy after cervical laminoplasty for DCM.[33] A large study of multichannel tcMEP suggested its benefit