INTRAOPERATIVE ELECTROPHYSIOLOGIC MONITORING DURING SPINE SURGERY

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ABSTRACT:

During spine surgery assesing the integrity of the spinal cord can be difficult. To avoid complications like compression, streching and derangement in circulation it is important to be able to evaluate the neurologic status during surgery. The electrophysiologic monitoring techniques and/or Wake–Up test are still performed for this reason.

Elecrophysiologic recording demands the full attention of an experienced in operative monitoring of SEPs and other monitoring techniques, whether neurologist, neurosurgeon, or anesthesiologist, must be aviable to interpret the waveforms acquired during anesthesia and operation.

Key Words: *Spinal surgery, electrophysiologic monitoring, evoked potentials.*

INTRODUCTION

Intraoperative electrophysiologic monitoring is now commonplace in many large medical centers. Evoked potentials (EPs) are recorded during neurosurgical, orthopaedic and vascular operations that pose risks of neurologic complications, in an attempt to minimize postoperative neurologic morbidity (13, 14).

The several forms of electrodiagnosis used from the discoveries of Galvani. They include electroencephalography, electromyography, cerebral and spinal potentials evoked by sensory stimulation (EPs), motor evoked potentials (MEP), visual evoked potentials (VEP), brainstem auditory evoked potentials (BAEP), the recording of the action potentials of nerve, the electroretinogram and the contingent negative variation (CNV).

Transcutaneus electrical stimulation of the motor cortex of animals was reported in the 1870s; (9, 30) Fritsch and Hitzig in Germany and Ferrier in England showed that muscle twitches could be caused by the application of electrical stimuli to relevant areas of the scalp. Gotch and Horsley recorded electrical potentials on animals spinal cord in 1891. More than a century ago, Richard Caton showed visual evoked and somatosensory potentials in animal experiments (4) and the first recorded evoked potentials were not obtained from animals until 1913. Somato sensory evoked potentials (SEPs) were first recorded by Dawson in 1947 (7, 8). The largest collective experience with intraoperative EP recording is with SEPs, and the first EPs recording for intraoperative monitoring made by Nash in 1971 (24). Members of the Scoliosis Research Society drew attention to the incidence of cord injury during operative treatment of scoliosis in 1975 (21), and several authors have since described their experiences with SEP monitoring during orthopedic procedures on the spine (11, 32).

The spinal cord can be monitored intraoperatively with SEPs. Although this is only a posterior column test, it is sensitive to most acute cord impairment. Techniques have become standardized and include monitoring from scalp or around the spinal cord itself. Motor evoked potentials (MEP) are currently in use for investigations, and may some day supersede somatosensory testing as the monitoring tool of choice (12, 25). The correlation between the neurological troubles and the impairments of the potentials allowed us to define alarm criteria, and if they persist the Wake–Up test becomes necessary (5, 15, 35) (Table 1).

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Table 1. Intraoperative Monitoring of Spinal Cord Motor Function

Date	Technique	Author
1973	Wake–Up test	Vauzelle and Stagnara (35)
1977	Somatosensory evoked potentials	Nash (24)
1981	Direct spinal cord stimulation	Tamaki (34)
1983	Motor evoked potentials elicited by transcranial electrical stimulation	Levy and York (19)
1986	Transcranial electrical stimulation with a high voltage, low–output impedance stimulator	Boyd (1)
1987	Cerebellar evoked potentials	Levy (18)
1988	Neurogenic motor evoked potentials	Owen (26)
1989	Transcranial magnetic stimulation	Shields (31)

The operative treatment of scoliosis had begun with Hibbs (1931) who performed the first fusion for the condition. A number of devices have been introduced and some surgeon have aproached the spine anteriorly, some posteriorly. A knowledge of the orthopaedic instrumentation is essential for the anaesthesist because it determines the position of the patient on the operating table, the anticipated blood loss and in the case of the anterior or lateral thoraco abdominal approach, the necessity for postoperative mechanical ventilation and monitoring procedures.

Technical Considerations in the Operating Room

Electrophysiologic equipment is vital in the operating room, not only to obtain technically adequate recordings but also to prevent hazards to patients and personnel. Like all equipment to be used in operating standarts set by the National Fire Protection Association (NFPA) and the Joint Commission on Accreditation of Health Care Organisations (JCAHO) for electrically sensitive patients.

Systems for recording evoked potentials include several components (Table 2).

Alternatively, some computers can be used and programs can be developed locally. Two channels are necessary for effective monitoring, and at least four channels are highly desirable. Correct localization and meticulous attention to application of electrodes is important. Electrodes must be arranged to display optimally the EPs activity of interest while avoiding the surgical field. Activity arising in the cerebral cortex, subcortical structures, cranial nerve, spinal

Table 2. Systems for Recording EPs

- Devices that provide sensory stimulation
- Transducers for applying stimuli to the patient
- Electrodes for detecting neurophysiologic signals generated by the patient
- Filters and amplifiers the condition the recorded signals
- A computer to control stimulation and signal acquisition, to sum or avarage the acquired signals, and to measure latencies and amplitudes of peaks in the averaged wave forms.
- Programs for the computer
- Devices for display and storage EPs

cord, nerve root, plexus and peripheral nerve can be recorded noninvasively from electrodes fixed to skin or scalp (6, 10).

Neurophysiologic procedures administered during spinal surgery can be divided into two general categories; procedures that project spinal cord function and procedures that project nerve root function (Table 3).

Electrophysiologic recording demands the full attention of an experienced in operative monitoring of SEPs and other monitoring techniques, whether neurologist, neurosurgeon, or anesthesiologist, must be avaible to interpret the waveforms acquired during anesthesia and operation.

Clinical experience with intraoperative monitoring

To reduce the risk of paraplegia after spinal surgery (neurogical and orthopaedic) surgeons often monitor spinal cord function by means of SEPs. But post operative paraplegia has been reported despite preserved SEPs (22, 36). One explanation is that motor pathways might be more susceptible than sensory pathways to damage. If so, monitoring of both sensory and motor function seems desirable. However, spinal motor–evoked potentials (MEPs) are technically more difficult to elicit than SEPs, and they are affected by anaesthesia and muscle relaxants.

Scoliosis Research Society (SRS) and Europan Spinal Deformity Society (ESDS) reported 60.000 operation and electrophysiologic monitorization (37) (Table 4).

The Wake–UP test can be done only intermittently and involves some risks of its own. The patient may injure himself, disconnet or dislodge life support or monitoring devices, or dislodge bony fragments or orthopedic instrumentation. Also the Wake–Up test may be dangerous in patients with an acutely injured, unstable spine. Spontaneus inspiration may cause air embolism, and physical and emotional distress may produce subsequent psychiatric symptoms (3, 20).

Electrophysiologic monitoring of the spinal cord is not straight forward. Body temperature and hypotension during operation can affect SEPs (24), so blood pressure should be monitored with this possibility in mind. Diathermy can interfere with prolonged anesthesia, too.

Table 3. Neurophysiologic Procedures Required for Surgey of the Spinal Cord or Nerve

Roots

Surgeries affecting the SPINAL CORD

- Mixed–nerve SEPs to stimulation at:
  - Median nerve
  - Ulnar nerve
  - Posterior tibial nerve
  - Peroneal nerve
  - Femoral nerve
- Motor evoked potentials to stimulation at:
  - Cerebral cortex (motor strip)
  - Spinal cord

Surgeries affecting the NERVE ROOTS

- Mixed–nerve SEPs to stimulation at:
  - Median nerve
  - Ulnar nerve
  - Posterior tibial nerve
  - Peroneal nerve
- EMGs following:
  - Mechanical irritation of nerve roots
  - Electrical stimulation of pedicle holes and screws
- EMG, electromyelogram

Alarm Criteria for SEPs (37)

- Prolongation in latency more than %10
- Decrease in the amplitude more than %50

Effects of Anesthesia on Evoked Potentials

Evoked potential latency increases, amplitude decreases, and morphology changes often result from the use of general anesthesia. All inhalation anaesthetic agents cause a marked dose–related depression of cortical SEP amplitude (28). Nitrous oxide does not influence latencies, but depresses SEP amplitudes by about %50 of control values (33). Continuous infusions of an opioid with nitrous oxide have been advocated as the optimum anaesthetic technique, giving minimal depression of SEP amplitudes (27). Alfentanil has only minor effects on posterior tibial nerve (PTN) SEP given in large doses for cardiac surgery, it did not increase latencies of

Table 4. Electrophysiologic Monitoring in 1971–1994

Total case	60.000
Wake–Up test	42.400
False positive result	1002
Neurologic deficit	364
True positive	263
False negative	101

early cortical PTN–SEP amplitudes decreased to %60 of the awake value 1 h. after induction (16).

Propofol has a short duration of action and is ideally suited for total intravenous anaesthesia in combination with an opioid (29). Because of the rapid recovery after propofol, it cold be ideal for orthopaedic operations on spine, where clinical evaluation of motor function during operation (Wake–up test) or in the early post operative period is important. Wake–up test can be conducted faster and better with midazolam–flumazenil sequence compared with propofol (17).

Valium and other benzodiazepines can increase background EEG activity and cause evoked–potential latency increases. High–dose narcotics (fentanyl, sufentanil) may also decrease the amplitude of evoked potentials. The effects are most dramatic following bollus injections. The use of muscle relaxants does not directly influence SEPs recorded over the scalp or over the spinal cord. However, muscle artifact could decrease the quality of SEP recordings by adding noise to the signal. Therefore, the use of muscle relaxants to eliminate this problem is recommended, but their use should not interfere with other types of neurophysiologic monitoring used together with SEPs (such as motor evoked potentials recorded over the muscle).

Compared with cortical somatosensory evoked potentials, neurogenic motor evoked potential signals are well preserved in patients undergoing surgery to correct scoliosis under general anesthesia suplemented with isoflurane or desflurane in concentrations as great as 1 MAC (2). In 1995 the authors reported that train spinal stimulation overcomes the suppressive effects of anaesthetics and allows potentials to pass trough synapses, thereby enabling a reliable recording of lower extremity compound muscle action potential (23).

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