Assessment: Intraoperative neurophysiology
Report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology
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Electrophysiologic monitoring of the nervous system is now widely used to help prevent complications and to identify structures during neurosurgical and other procedures. These techniques include EEG, evoked potentials, EMG, and NCV testing and monitoring. The principal goal is the prompt identification of nervous system impairment in the hope that this can be reversed by an intervention that prevents the impairment from becoming permanent. Such impairment may be due to correctable factors such as circulatory disturbance, excess compression from retraction, bony structures or hematomas, or mechanical stretching. Monitoring can also identify new systemic impairment, identify or separate nervous system structures (eg, around or in a tumor), and can demonstrate which tracts or nerves are still functional. Monitoring may provide relative reassurance to the surgeon that no identifiable complication has been detected up to that point, allowing the surgeon to proceed further and provide a more thorough or careful surgical intervention than would have been provided in the absence of monitoring. Some high-risk patients may be candidates for a surgical procedure only if monitoring is available.

Monitoring requires a team approach. A well-trained physician-neurophysiologist needs to provide or supervise monitoring. Care must be taken to assure patient safety and to overcome technical obstacles. Monitoring personnel need to be thoroughly familiar with the effects of anesthetic agents and other potentially confounding factors.

EEG monitoring has long been carried out in an effort to safeguard the brain during carotid endarterectomy. This technique has been shown to be safe and efficacious for such use and for other similar situations in which cerebral blood flow is at high risk. For this purpose, monitoring should be carried out at least at the anterior and the posterior regions over each hemisphere. Sixteen channels are preferable to identify occasional embolic complications. Median nerve somatosensory evoked potentials (SEPs) provide an alternate means for monitoring a hemisphere at risk for ischemia, although SEPs measure only a restricted portion of cortical function compared with the EEG and have a significant time lag.

Electrocorticography (ECoG) from surgically exposed cortex can help to define the optimal limits of a surgical resection, identifying regions of greatest impairment. Regions with attenuated or absent EEG, or those with relatively increased slow activity, decrease in fast activity, or abnormal spike discharges help to define regions of cortex that are impaired or abnormal. When used together with ultrasound, ECoG can help to define the limits of resection or location for a biopsy. When used together with long-term EEG/video monitoring, ECoG can help to define the limits of resection for surgery for epilepsy. Sensory cortex localization using median nerve SEPs is also helpful for identifying the location of the central fissure and motor cortex in many such procedures. These tests are safe and effective when carefully used for these reasons.

Functional localization of cerebral cortex can be performed using direct cortical stimulation techniques, as initially popularized by Penfield and Jasper. When carried out in expert hands, these techniques can help to identify eloquent, motor and sensory cortical regions in the awake patient. These techniques are useful in planning the limits of a resection and would be applied only when there is the possibility of varying where the limit of the resection will be, such as in surgery for epilepsy.

During posterior fossa neurosurgical procedures, brainstem auditory evoked potentials (BAEPs) can be used, along with cranial nerve monitoring by EMG recording and nerve stimulation. These techniques can be supplemented by auditory evoked potential recordings made directly from the 8th nerve itself. All these methods can define the functional status of various cranial nerves throughout the procedure. BAEPs also help to assess the state of the auditory pathways within the brainstem, and are also sensitive to ischemia at the cochlea and 8th nerve. These techniques can help to identify the 7th and other cranial nerves and permit recognition of functional change from compression, retraction, or ischemia, or other complications.

Spinal cord monitoring with posterior tibial, median, or ulnar nerve SEPs is frequently used to monitor the state of the spinal cord during orthopedic operations to correct scoliosis, neurosurgical procedures around the spinal cord, or cross-clamping of the thoracic aorta. This procedure directly monitors the posterior column pathways, but may detect significant degrees of cord ischemia even with anterior spinal artery impairment. These techniques are also sensitive to cord...
damage from excessive compression, mechanical distraction or other causes. A substantial number of reports of animal and human studies have demonstrated that these techniques, when used in expert hands, probably have a high degree of sensitivity and specificity. Several different techniques are commonly used, including monitoring from the scalp, from interspinous ligament needle electrodes, or from catheter electrodes in the epidural space.

Pyramidal tract monitoring has been proposed for use in spinal surgery. With these techniques, stimulation is delivered to the motor cortex or to the rostral spinal cord. Recordings are made from lower extremity muscles or from the spinal cord below the operative site, demonstrating intact conduction descending down the corticospinal tracts. These techniques have had only limited use in the United States, although similar techniques have been used for a long time elsewhere. Many neurophysiologists still consider this technique to be investigational in the way that it is typically applied in the United States. Considerable hope is held out that future advances in magnetic stimulation techniques, or other technical improvements, will lead to general acceptance of this approach to monitoring.

EMG and nerve conduction velocity measurements can be performed in the operating room, recording compound muscle or nerve action potentials. These techniques resemble traditional EMG and nerve conduction testing, sometimes done with additional averaging of results. When used in expert hands, these techniques are effective in identifying portions of the peripheral nervous system that are damaged and therefore need grafting, for identifying the limits of such a grafting procedure, for identification of nervous system structures in an area of pathology such as a tumor, and for monitoring these pathways during prolonged procedures on adjacent structures. EMG monitoring during procedures around the roots and peripheral nerves can be used to warn of excessive traction or other impairment of motor nerves.

All these techniques need to be reserved for situations in which there is significant risk of damage to nervous system structures. They should not be applied routinely in cases of low risk, such as uncomplicated lumbar disk surgery.

Monitoring personnel and the physician-neurophysiologist supervising the procedure need to have substantial expertise in routine neurophysiology as well as in its application to the operating room situation. They need to understand the technical, anesthesia-related, and surgical causes of changes in these various monitoring procedures. The monitoring and surgical personnel all need to be knowledgeable about possible false-alarm and false-negative monitoring situations. Electrical and other safety issues need to be addressed and understood. Results need to be documented for comparison during the case, for quality assurance purposes, and for review later as needed. Modern neurodiagnostic equipment should be used, with high-quality amplifiers and stimulators to reduce background noise and improve quality of monitoring surface.

Objections to the use of monitoring have been of 2 principal types. The 1st objection is to the use of monitoring in clinical situations in which the risk of nervous system damage is quite low. Careful assessment of an individual case circumstance is needed in order to ascertain whether a patient is indeed at risk for nervous system damage to a degree sufficient to warrant the use of monitoring. Care must be taken to avoid indiscriminate use of monitoring in routine, low-risk procedures. A 2nd major objection is philosophical. There has never been a double-blind prospective study of any surgical monitoring procedure in humans. This problem is unsolvable because of ethical problems in carrying out the needed study. In the absence of such a definitive study, judgment regarding the efficacy of monitoring must be based on animal experimentation, uncontrolled human studies, and general experience in applying these tools to humans. Considerable evidence favors the use of monitoring as a safe and efficacious tool in clinical situations where there is significant nervous system risk, provided that its limitations are appreciated.

Summary. Experience to date in both humans and controlled animal research studies substantiates that several electrophysiology tests and monitoring techniques are safe and efficacious, to a variable degree, as commonly applied in the operating room for the following procedures: EEG or SEP to monitor for cerebral ischemia; ECoG and SEP sensory cortex identification to define the limits of cortical resection; SEP spinal cord monitoring; BAEP and cranial nerve EMG monitoring during posterior fossa procedures; functional localization of cortex with direct cortical stimulation in expert hands; and EMG and compound muscle and nerve action potential measurements of various peripheral nervous system structures. All these techniques need to be applied by a well-trained, knowledgeable physician-neurophysiologist or personnel directly under his or her supervision. Clinical situations need to be chosen carefully, avoiding those in which the nervous system is only at low risk.

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