CHAPTER 5
SOMATOSENSORY EVOKED POTENTIALS: CLINICAL USES

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INTRODUCTION

Evoked potentials (EPs) are time-locked responses of the nervous system to external stimuli. Somatosensory evoked potentials (SEPs) are one type of EP, which are generated by stimulation of afferent peripheral nerve fibers elicited by electrical, tactile, or other stimuli. Following either mixed nerve or sensory nerve stimulation, SEPs can be recorded over more proximal portions of the peripheral and central nervous system including peripheral nerves, spinal cord, and/or brain. By stimulating the skin in various dermatomal areas, an SEP may also be recorded (dermatomal SEP or DSEP).

"Short-latency" SEP refers to that portion of the waveform of an SEP normally occurring within 25 ms after stimulation of upper limb nerves, 40 ms after stimulation of the peroneal nerve, or 50 ms after stimulation of the tibial nerve. "Long-latency" SEP refers to that portion of the waveform recorded after 100 ms following stimulation; "mid-latency" SEP refers to the portion of the waveforms occurring between those 2 time periods.[1]

SEPs may be useful in studying disorders of the brain and brainstem, spinal cord, dorsal roots, and peripheral nerves. The exact sites of stimulation, and the number of nerves/roots tested is dependent upon the clinical problem presented and the information desired. When possible, recordings should be made from peripheral nerves and over the spinal cord, as well as from the scalp. In order to identify the best cortical waveform, multiple scalp montages are frequently required. In most cases, bilateral recordings are appropriate. At times, special montages may be required.

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SEPs are often helpful in localizing the anatomic site of somatosensory pathway lesions. SEPs may be used to identify impaired conduction caused by axonal loss (which may result in a reduced amplitude or absent response) and/or demyelination (which may produce prolonged or absent waveforms).

SEP abnormalities are not disease specific, but can indicate afferent conduction impairments associated with certain disorders. SEPs are useful in identifying clinically inapparent abnormalities and lesions causing only vague or equivocal signs or symptoms, and offer a noninvasive, often quantifiable, method of assessing known lesions. SEPs may also be useful in certain conditions in which the diagnosis is uncertain, by indicating involvement of central somatosensory pathways, as well as suggesting the type of involvement (e.g., demyelination).

In addition, SEPs are useful in confirming nonorganic sensory loss. In such cases, SEPs generated from stimulation of virtually any "numb" area may be compared to recordings obtained from asymptomatic contralateral stimulation.

BRAIN AND BRAINSTEM

SEP abnormalities may occur in conditions impairing the somatosensory pathways in the brain and brainstem, including both diffuse and focal disorders. Some of the conditions in which SEP testing provides useful clinical information are discussed below.

Multiple Sclerosis

SEP abnormalities, reflecting pathology in the brain or spinal cord, are present in up to 90% of patients with definite multiple sclerosis (MS) and in approximately 50% of MS patients without current sensory signs or symptoms.[10] Lower limb (e.g., tibial) SEPs are more likely to be abnormal than upper limb (e.g., median) SEPs.[81] However, both upper and lower limb SEP testing are often indicated because patients may demonstrate abnormalities in only one of these regions.

The most frequently observed SEP change in MS is the prolongation of central latencies. Amplitude reductions or absence of responses may also be seen. SEP abnormalities in MS are sometimes detected only in montages that selectively record subcortically generated potentials, which are more easily recorded following median nerve stimulation than posterior tibial nerve stimulation.

Other Diseases of Myelin

Other diseases affecting myelin, such as adrenoleukodystrophy,[29] adrenomyeloneuropathy,[92] metachromatic leukodystrophy,[90] and Pelizaeus-Merzbacher disease[18] also produce SEP abnormalities. In adrenoleukodystrophy and adrenomyeloneuropathy, SEPs may be abnormal in asymptomatic heterozygotes.

Hereditary System Degenerations

Many patients with Friedreich's ataxia have abnormal SEPs, demonstrating delayed central conduction or absent short-latency scalp responses.[42] Similar abnormalities are found in patients with disorders such as hereditary cerebellar ataxias and hereditary spastic paraparesis.[65]

Myoclonus

SEPs are useful in classifying the type or origin of myoclonus. Abnormally high amplitude SEPs, reflecting enhanced cortical excitability, have been reported in patients with cortical myoclonus.[34] These findings are observed in progressive myoclonic epilepsy, late infantile ceroid lipofuscinosis, and in some patients with photosensitive epilepsy.[45]

Coma

EPs are useful in evaluating comatose patients in whom the scope of neurological examination is often limited or pharmacologic paralysis is confounding. Although they are sensitive to lesions impinging on the afferent sensory pathways, mixed nerve SEPs are affected only minimally by the patient's level of arousal. SEP abnormalities in the comatose patient can, therefore, be interpreted as reflecting specific lesions affecting neural pathways independent of the comatose state, per se. Caution should be exercised when interpreting SEPs in patients on neurosuppressive medications.

Bilateral SEPs may provide prognostic information in patients with severe cerebral injury resulting in coma.[6,17,27,39,60] Following severe cerebral injury, absence of both right and left cortical response to median nerve stimulation is a dependably poor prognostic sign. Patients in whom there is unilateral preservation of the initial cortical response, however, may still have functional recovery.[32]

Intraoperative Indications

SEPs can be used to localize the Rolandic fissure, facilitating intraoperative identification of the sensory and motor cortices. This is important clinically in order to avoid excision of the motor cortex, which would be likely to produce clinical deficits.[58,59] Similarly, the primary sensory cortex within the interhemispheric fissure may be identified using cortical SEPs following posterior tibial nerve stimulation. SEPs are also used in some medical centers to monitor for cerebral ischemia during vascular surgery or surgery following aneurysmal subarachnoid hemorrhage.[28,37,53,63,79,87] In addition, SEPs can be used for functional localization of the thalamus prior to thalamotomy.

SPINAL CORD

In many of the disorders affecting the ascending pathways of the spinal cord (e.g., MS), abnormal findings may be recorded over the spinal cord. Where possible, it is useful to record ascending potentials at appropriate standardized sites over the spinal cord, as well as over the somatosensory cortex. This is technically more feasible in children or young people than in older persons, and in slender persons than in obese persons. Spinal recordings can be obtained with mixed nerve or sensory nerve stimulation, but not with dermatomal stimulation.

Spinal Cord Trauma

The scalp SEP is absent in complete spinal cord injuries when stimulating a nerve below the level of injury, while the SEP is normal or shows a variety of abnormalities in incomplete spinal cord injury.[70,74] Segmental SEPs have been used to localize sensory levels in traumatic cervical spinal cord injury.[57] SEPs have also been shown to have prognostic value in functional outcome of acute spinal cord injury.[41,55,103]

Subacute Combined Degeneration

Short- and mid-latency SEP abnormalities have been found in upper- and lower-limb stimulation in patients with vitamin B_{12} deficiency.[26,51] EP delays generally correlate with the degree of neurological dysfunction, although some abnormalities may be present without clinical evidence of involvement.

Cervical Spondylosis and Myelopathy

Upper- and lower-limb SEPs may be helpful in assessing cervical spondylosis when spinal cord compression is present.[100] SEPs appear to be more sensitive to sensory pathway involvement than clinical sensory testing in myelopathy; however, the correlation of SEPs with radiographic data may be poor.[101] Additional montages may be required to obtain the most information about cervical spondylotic myelopathy.[71]

Syringomyelia

SEPs are useful in evaluating the effect of compression of the posterior columns in syringomyelia.[7] Segmental (i.e., dermatomal [DSEP]) testing may be useful to help delineate the neurophysiologic boundaries of the syrinx.

Hereditary Spastic Paraplegia

Abnormal cervical SEPs to median nerve stimulation in hereditary spastic paraplegia with normal peripheral nerve conduction have been reported.[91] These findings indicate selective degeneration of the centripetal processes derived from the dorsal root ganglion cells.

Metabolic Disorders

SEP abnormalities have been shown to be helpful in assessing peripheral and central sensory fibers in chronic renal failure[73] and in juvenile diabetes.[13]

Transverse Myelitis and Multiple Sclerosis

Spinal cord lesions may produce conduction slowing or block. SEPs elicited by stimulation below the level of the lesions can have prolonged latencies, low amplitudes, or absent responses.[44,80] Lower-limb SEPs have a higher yield for detecting abnormalities in MS[81] (see previous section: Brain and Brainstem).

Vascular Lesions

SEPs have been used to help clarify deficits in patients with vascular spinal cord lesions and arteriovenous malformations.[80] Abnormalities typically consist of low amplitude or absent responses, rather than prolonged latencies.[49]

Spinal Cord Tumors

SEPs have been used for assessment of spinal cord tumors to determine the impairments in the various physiologic pathways. In addition, DSEP studies can help establish the boundaries of physiological unaffected neural tissue; this assists in surgical management.

Myelomeningocele

SEPs have been found useful in patients with myelomeningocele by providing information about physiologic and functional deficits.[77]

Tethered Cord Syndrome

Posterior tibial SEPs have been shown to be sensitive indicators of neurological impairment in children and young adults with tethered cord syndrome.[98] Abnormalities in lumbar spine EPs, delayed or reduced amplitude scalp responses, and/or delays in central conduction have been documented.[75] The severity of the SEP responses correlates with the severity of both clinical and intraoperative findings. Changes in preoperative versus postoperative SEPs correlate with functional outcome after untethering.

Spinal Cord Monitoring

In many medical centers, SEP monitoring during spinal surgery is the standard of practice. The purpose is to warn of physiologic compromise of the spinal cord or dorsal nerve roots in an anesthetized patient during scoliosis correction, fracture reduction surgery, or other procedures which might injure neural tissue. Change in waveforms is more reliable when recorded over the cord than over the scalp. The most commonly monitored procedures include surgery for scoliosis and surgery following spinal trauma (e.g., stabilization after cervical fracture).[16,20,56,66] Intraoperative monitoring is not of proven benefit for routine lumbar or cervical laminectomy or fusion.

VENTRAL ROOTLETS AND ROOTS

SEP and DSEP techniques are still under evaluation for the study of root disease. In some limited situations, they can be useful in studying disorders peripheral to the spinal cord. Although initial evaluations of nerve root dysfunction were conducted using mixed nerve and sensory nerve SEP techniques, they were often not useful because they are never single root pathways.[25] More recent studies have indicated that sensory nerve SEPs and single root DSEPs may provide useful information about rootlet and root dysfunction.[83,84,97] Since cutaneous afferent fibers are smaller in diameter (and therefore conduct more slowly) than the 1A afferent fibers stimulated in standard mixed nerve SEPs, specific reference data are required to analyze the values obtained. Sensory nerve SEP and DSEP latencies are longer than mixed nerve SEP latencies obtained over the same distance.[69,83]

DSEPs have been used to evaluate acute radiculopathies.[3,4,14,21,24,33,46,47,54,57,61,72,76,78,83,89] Generally speaking, these studies indicate that the yield obtained from DSEPs for acute radiculopathies in an otherwise healthy back is low compared to information obtained from the neurological examination, needle electromyography (EMG) and H-reflex studies.

Lumbosacral Root (Rootlet) Disease: Radiculopathy and Lumbar Stenosis

SEPs and DSEPs are generally not useful in the evaluation of acute radiculopathies, offering no more information than can be obtained by a careful clinical and needle electromyographic evaluation. For this reason, DSEP studies for acute lumbosacral radiculopathy are considered investigational at this time. In the assessment of chronic, multi-level multiple rootlet disease, such as that associated with lumbosacral spinal stenosis (LSSS) resulting in chronic compression of relatively long segments of dorsal rootlets, there is a greater physiologic rationale for expecting abnormal DSEPs.[47,84,86,93] Preliminary data suggest that DSEPs and sensory nerve SEPs may be useful in defining the neurophysiologic deficits of LSSS and, therefore, potentially may be useful to direct further evaluation and treatment.[84,97] Level-by-level waveforms may be absent, prolonged, and/or reduced in amplitude.

Thoracic Root Disease

While DSEPs may be used to evaluate chronic compressive syndromes at the lumbar and sacral root levels, no data are available for their use in thoracic root disorders. Therefore, DSEP studies for the evaluation of thoracic root disease must be considered investigational at this time.

Cervical Root Diseases

Although the few studies of DSEP testing for cervical root disease report sensitivities in the range of 65% to 85%, specificities are poor. There is still controversy about whether or not they provide more useful information than does the clinical evaluation and needle EMG examination.[14,54,78,89] Further research is needed to determine their clinical value.

PERIPHERAL NERVOUS SYSTEM

SEPs can be especially useful in assessing the peripheral nerves when severe peripheral nerve disease is present and nerve conduction study (NCS) techniques are inadequate, or when the afferent nerves to be studied present insurmountable technical difficulties.[2]

Peripheral Neuropathy

In generalized peripheral neuropathies, SEPs have been useful in measuring the afferent fiber conduction velocity of proximal segments and the presence of central responses when the peripheral responses were absent or low. SEPs have been used to evaluate a variety of peripheral nerve disorders, including hereditary neuropathies,[8,12] diabetic neuropathy, [9,64,102] inflammatory polyradiculoneuropathies,[30,67,68,95] infectious disorders,[62] and toxic neuropathies.[50] The value of SEPs for diagnostic purposes in peripheral nerve disease, particularly acute inflammatory demyelinating polyradiculoneuropathy (AIDP), is not yet established; some reports suggest they are valuable, if the results of conventional electrodiagnostic medicine (EDX) testing methods are normal.[30,67,95]

In addition, SEPs may be useful in peripheral neuropathies with unobtainable peripheral sensory responses. In such circumstances, they may be the only means of obtaining information about the conduction velocity of peripheral afferent fibers. SEPs may also be helpful in the presence of focal lesions, or when it may be important to know if there are both central and peripheral abnormalities.

Focal Neuropathy

Focal nerve lesions,[23,40] including entrapment neuropathies, have been studied using SEPs. Carpal tunnel syndrome, lateral femoral cutaneous neuropathy,[52] medial and lateral plantar neuropathy,[22] saphenous neuropathy,[94] intercostal neuropathy,[19] and trigeminal neuropathy[85] are examples of focal nerve lesions that have been evaluated. These reports have not provided convincing evidence that SEPs provide information that cannot be better obtained with conventional NCS techniques.

Plexopathy

Several studies have reported using SEPs to evaluate brachial plexopathy.[5,15] In patients with idiopathic brachial plexopathy, there appears to be little advantage over conventional EDX techniques (needle EMG and NCS) for diagnosis or localization. In traumatic plexopathies,[35,36] however, SEPs may be useful for detecting superimposed root avulsion by identifying a pattern of preserved peripheral nerve action potentials and absent SEPs. SEPs have also been used to evaluate patients with neurogenic and nonneurogenic thoracic outlet syndrome.[11,31,88,96,99] In general, SEPs do not provide additional information beyond that obtained from needle EMG and NCSs.

Surgical Neuromonitoring

Evidence of the utility of SEPs for monitoring the integrity of the peripheral nervous system during surgery is insufficient. Nevertheless, SEP techniques are useful for evaluating the integrity of very proximal peripheral nerve lesions where peripheral nerve recording methods may not be possible. In such cases, intrafield stimulation with SEP recording is essential for establishing whether continuity of afferent fibers is present through questionable regions of the peripheral nervous system.[48,56,82] The sciatic nerve can be stimulated during hip surgery with SEP recording. This technique may be useful where peripheral nerve recordings are not feasible.[56]

Intraoperative monitoring of the brachial and lumbosacral plexus may be valuable. By stimulation of individual components of the plexus, it may be possible to determine the roots that are in continuity with the spinal cord.[35,38,43]

CONCLUSION

This summary of the various uses of SEPs is meant to outline the useful indications for these procedures. It is neither meant to serve as an exclusive indicator of recommended uses, nor as a comprehensive source of references. New research is constantly being conducted in this area and, as it is evaluated, indications may change. The physician is therefore urged to closely follow developments in this rapidly changing field.

DISCLAIMER

The review was undertaken by the AAEM at the request of members and third parties. This report is provided as an educational service of the AAEM. It is based on an assessment of the current scientific and clinical information. It is not intended to include all possible methods of care of a particular clinical problem, or all legitimate criteria for choosing to use a specific procedure. Neither is it intended to exclude any reasonable alternative methodologies. The AAEM recognizes that specific patient care decisions are the prerogative of the patient and his/her physician and are based on all of the circumstances involved. This statement was not written with the intent that it be used as a basis for reimbursement decisions.

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