Continuous somatosensory evoked potential monitoring during brain tumor resection

Report of four cases and review of the literature

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Surgical removal of supratentorial neoplasms adjacent to eloquent somatosensory cortex entails a risk for the patient of postoperative functional morbidity. Visual identification of the central sulcus at the time of surgery when using surface topography techniques and intraoperative image-guided navigation can be unreliable because of cortical displacement or invasion by the tumor. Therefore, intraoperative SSEPs are used to identify the location of somatosensory cortex in relationship to the lesion.

An SSEP is generated by electrical stimulation of a peripheral nerve. Following electrical stimulation, the signal is transmitted via the dorsal column spinal cord pathways to the medial lemniscus, thalamus, and the contralateral somatosensory cortex. Cortical SSEPs can be recorded using a referential or bipolar montage. In a referential montage, the recording electrodes are referenced to a common reference electrode located away from the area of interest, typically the parietal scalp opposite the side of surgery (CP3 or CP4). In a bipolar montage, each electrode is referenced to the adjacent electrode. The SSEP mapping can be corroborated by cortical stimulation mapping of motor cortex.

The use of intraoperative monitoring of SSEPs prior to resection is a well-established technique to localize functional primary somatosensory cortex. We evaluated the novel technique of continuous SSEP monitoring during resection of parietal neoplasms adjacent to primary somatosensory cortex (S1) and ascending somatosensory white matter tracts. Four case examples are presented.

Abbreviations used in this paper: MR = magnetic resonance; SSEP = somatosensory evoked potential.

Surgical Technique

Techniques for intraoperative SSEP mapping are similar to those used for routine diagnostic studies. Electrical stimulation (current 5–15 mA; filter settings 5 Hz–3 kHz) comprising 0.2 msec current pulses was delivered to the median or tibial nerve and the stimulus intensity was adjusted to produce a small twitch of abductor pollicis brevis at a stimulus rate of 5.4 Hz. Reproducible cortical responses are identified by computer-assisted averaging (Nicolet Viking IV; Nicolet Biomedical, Madison, WI) of approximately 200 stimuli. Unlike scalp SSEPs in which a negative polarity, or N of 500 to 1000 is required to resolve the waveform, direct cortical SSEPs require an N of 200 or less. Cortical responses have a number of different components designated by their positive, P, or negative, N, polarity with respect to the reference electrode, followed by a number representing the typical latency of the peaks in milliseconds. An 8-contact strip electrode (1-cm center–center spacing) was placed transversely in the axial plane, crossing the presumed region of the somatosensory gyrus. A series of recordings were made from the cortical surface by moving the electrode to different areas to find and then verify the localization of somatosensory cortex by using a referential montage with median or tibial nerve stimulation. When using a referential montage, as in the cases presented here, somatosensory cortex is located beneath the electrode from which the N20 waveform with the highest amplitude and shortest latency is recorded. The central sulcus is identified by using a phase reversal between the N20 and P22 waves. After identification of the major cortical sensory response, the electrode strip was rotated and oriented medial to lat-
eral on the somatosensory gyrus. After baseline SSEP recordings were obtained, the strip electrode remained in position during the process or tumor resection and recordings were repeated every 40 to 50 seconds. Any drop in amplitude or prolongation of latency occurring at two consecutive sampling times was considered abnormal. Functional localization of primary somatosensory cortex was then corroborated by direct stimulation mapping of motor cortex by using a constant-current biphasic square-wave 60-Hz stimulus (Ojemann Cortical Stimulator; Radionics, Inc., Burlington, MA) at an appropriate current to elicit arm or leg movement.

**Case Reports**

To illustrate the technique of intraoperative continuous SSEP monitoring during tumor resection, we present the following case examples. There was no recorded change in SSEPs during resection nor any contralateral postoperative deficit in motor or sensory function. In all cases, sevoflurane was the anesthetic administered.

**Case 1**

This 65-year-old right-handed woman with a history of Stage 1B primary non–small cell lung carcinoma presented with progressive right upper-extremity and lower-extremity hemiparesis (Grade 2/5), but with preserved proprioception and light touch. Her strength markedly improved to Grade 4+/5 following administration of dexamethasone. Gadolinium-enhanced MR imaging revealed an enhancing cystic lesion in the left parietal region (Fig. 1 left). The patient then underwent a left frontoparietal craniotomy for resection of the lesion that was guided by continuous intraoperative SSEP monitoring, motor mapping, and frameless stereotaxy.

An eight-contact strip electrode was first oriented transversely in the axial plane from anterior to posterior to localize somatosensory cortex. The strip was then turned 90° (aligned in the coronal plane) to lie along presumed sensory cortex. Strip Contacts 5, 6, and 7 were positioned directly over somatosensory cortex and produced a well-developed N20 component (latency 27.4–28.1 msec) (Fig. 1 right). Contact 8 was overlying motor cortex and produced a P22 component. Functional localization established by SSEP recording was then confirmed by direct cortical stimulation mapping, and the strip electrode remained in position throughout the resection of the lesion for continuous SSEP monitoring.

**Case 2**

This 48-year-old right-handed woman with a history of breast carcinoma developed progressive dyspraxia in her left hand and was found to have a right parietal enhancing cystic lesion with surrounding vasogenic edema (Fig. 2 upper). The patient also underwent preoperative positron emission tomography imaging to confirm that the lesion was hypermetabolic. The patient underwent a right parietal craniotomy for resection of the lesion, which was guided by intraoperative SSEP monitoring, cortical motor mapping, and frameless stereotaxy.
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A strip electrode was positioned transversely along the surface to maximize the size of the N20 (latency 23.1–24 msec). The rolandic cortex was confirmed with cortical stimulation motor mapping and the strip was then placed along somatosensory cortex (Fig. 2 center). Baseline median nerve evoked potentials were obtained and delineated well-developed N20 waveforms in Contacts 3, 4, 5, and 6 (Fig. 2 lower). The SSEPs were repeatedly monitored during the resection and were stable.

Case 3

This 48-year-old right-handed woman with Stage IV breast carcinoma developed progressive headaches, left arm and leg weakness, and gait instability. An MR image revealed a right parietal enhancing tumor with surrounding edema (Fig. 3 upper). The patient underwent a right parietal craniotomy for resection of the lesion, which was guided by intraoperative SSEP monitoring, motor mapping, and frameless stereotaxy.

Similarly, in the patient in Case 3, SSEPs were used to localize the rolandic cortex and localization was confirmed using intraoperative motor mapping. A well-developed N20 component was recorded with a latency of 22.3 msec in Contacts 4, 5, and 6 and a P22 overlying rolandic cortex is visible in Contact 7 (Fig. 3 lower left). These responses were repeated throughout the resection and were unchanged. Upon completion of the resection, the final SSEP evaluation showed a slight improvement in the amplitude of the N20 and P22 contacts (Fig. 3 lower right).
Case 4

This 18-year-old left-handed man with colonic adenomatous disease and adenocarcinoma in situ presented with an enlarging homogeneously enhancing lesion adjacent to the central sulcus on the left side (Fig. 4 upper left and right). Functional MR imaging was performed preoperatively, which localized hand motor cortex two gyri anterior to the lesion. The patient underwent a left parietal craniotomy for resection of the lesion, which was guided by intraoperative SSEP monitoring and motor mapping. Ultrasonography and frameless stereotaxy were used to delineate the lesion, which appeared to arise at the depth of the postcentral sulcus.

In the patient in Case 4, a well-developed N20 waveform was recorded in Contacts 6, 7, and 8 (Fig. 4 lower). The initial SSEP readings are superimposed on the final SSEP recordings following resection. There was a slight increase in the amplitude as well as a shorter latency following resection (25.5–23.2 msec).

Discussion

Topographical and functional localization of primary sensorimotor cortex may be discordant; therefore, intraoperative SSEP recordings have been used to localize somatosensory cortex prior to tumor resection. In addition, the sensorimotor map is confirmed intraoperatively with direct cortical stimulation–evoked motor responses. Despite the initial localization of eloquent cortex adjacent to parietal neoplasms, it is still possible to undercut important subcortical ascending fibers during the resection. The use of continuous SSEP monitoring provides a real-time assessment of sensorimotor function during the process of resection of a lesion in patients in whom general anesthesia has been induced. This technique may decrease the patient morbidity associated with resection of these lesions.

Clearly, SSEPs are extremely sensitive to the type and level of intraoperative anesthesia. These four patients all underwent surgery after induction of the general anes-
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thetic sevoflurane. The use of nitrous oxide combined with pentathol or low-dose propofol instead of halogenated anesthetic agents has been shown to improve the SSEP amplitude and shorten response latency. It is therefore critical to continue the same maximum allowable concentration level of anesthesia during the process of resection and to avoid drug boluses when recording continuous SSEPs so as not to change the amplitude of the N20. The neurophysiological monitoring team must be informed by the anesthesiologist of any changes in anesthetic during the SSEP recording session.

When confirming the SSEP localization with cortical stimulation–evoked motor mapping, it is important to remember that stimulation of motor cortex may occasionally elicit sensation in an awake patient and similarly stimulation of sensory cortex may sometimes elicit movement. Mapping through SSEP monitoring has the advantage over continuous stimulation mapping in that seizures cannot be evoked during SSEP recordings because the cortex itself is not stimulated. In our series there was 100% correlation of the localization of sensorimotor cortex by SSEPs and cortical stimulation mapping.

False-negative evoked potential responses (that is, postoperative deficit in the setting of unchanged SSEPs) may result. Although none of the patients in our series deteriorated postoperatively, it is theoretically possible that the tracts assessed by the evoked potentials may not be accessible to monitoring because of a preexisting deficit, technical problems resulting in suboptimal intraoperative monitoring, or because of a slowly progressive lesion (that is, infarct) that is not detectable during surgery. On the contrary, an improvement in SSEP N20 amplitude and shortening of latency following the resection portends a good functional outcome.

Conclusions

The use of continuous SSEP monitoring during resection of supratentorial neoplasms adjacent to functional eloquent cortex coupled with intraoperative ultrasound and frameless navigational guidance enables the surgeon to maximize surgical resection while minimizing neurological morbidity.