Intraoperative localization of the central sulcus by cortical somatosensory evoked potentials in brain tumor

Case report

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Perplexing findings of cortical somatosensory evoked potentials (SEP's) for determining the central sulcus during a craniotomy are reported in a case of brain tumor. On stimulation of the contralateral median nerve in that patient, phase-reversal of SEP waves N1 and P2 was observed not only across the central sulcus but also across the precentral sulcus. In topographic mapping of the N1-P2 amplitude, the sulcus dividing the maximum polarity was the central sulcus; this was confirmed by the cortical stimulation-evoked motor responses. For accurate localization of the central sulcus by cortical SEP's, the distribution of potentials must be analyzed with extensive exposure of the sensorimotor cortex.

KEY WORDS • somatosensory evoked potentials • functional localization • sulcus • sensorimotor cortex • stimulation-evoked motor responses

Previous reports have described the usefulness of cortical surface recording of somatosensory evoked potentials (SEP's) for the functional localization of the human cortex during surgery. Since 1985, we have recorded SEP's from the exposed cortical surface to localize the central sulcus in surgery. We have recently treated a patient who showed perplexing findings for determining the central sulcus. We report this case and describe a potential pitfall in the clinical application of cortical SEP's for functional localization of the sensorimotor cortex.

Cortical Surface Recording of SEP's

With the patient under general anesthesia with 60% nitrous oxide in oxygen and 0.5% to 1.0% enflurane, the brain surface is exposed by craniotomy and reflection of the dura. Electrical stimuli of 0.2-msec constant current pulses are delivered to the median nerve at the wrist. Stimulus intensity is adjusted to produce a small thumb twitch at a stimulus rate of five times per second. A silicone sheet holding four electrodes (10 mm inter-electrode distance) is placed on the cortical surface. An average of 250 responses is made using a frequency filter bandpass of 2500 to 3000 Hz. The cortical SEP's are recorded twice to assess reproducibility. A reference electrode is placed in the temporal muscle adjacent to the craniotomy margin. The initial negative deflection of cortical SEP's is designated N1, and the following positive deflection P2.

Case Report

This 49-year-old woman noted motor weakness of her right upper extremity beginning in July, 1988. The motor strength progressively deteriorated and she was admitted to our institution on August 25, 1988.

Examination. Examination revealed a mild monoparesis of the right upper extremity. There were no other neurological deficits and the physical examination was normal. Magnetic resonance imaging showed a well-defined lesion in the left frontal lobe (Fig. 1). Left cerebral angiography showed an avascular mass lesion in the left frontal lobe. Based on these examinations, a low-grade astrocytoma in the left frontal lobe was postulated.

Fig. 1. Magnetic resonance images showing a well-defined lesion in the left frontal lobe.
Fig. 2. Intraoperative photograph of the brain surface showing placement of electrodes for recording somatosensory evoked potentials. The continuous line indicates the location of the tumor, and the dotted line the location of the surgically removed tumor. Cortical stimulation at A elicited electromyographic responses in the right thumb and at B in the right quadriceps femoris. F = frontal lobe; P = parietal lobe.

Operation. On September 1, the patient underwent a left frontoparietal craniotomy. After incision of the dura, a silicone sheet holding four electrodes was placed on the brain surface parallel to the interhemispheric fissure to record cortical SEP's (Fig. 2). Cortical SEP's were recorded by the electrode array at points 7, 6, 5, and 4 cm lateral to the interhemispheric fissure. Thus, a 4 × 4 grid (10 mm interelectrode distance) was created. Figure 3 shows phase-reversal of cortical SEP waves N₁ and P₂ between Electrodes 2 and 3, and Electrodes 6 and 7. However, phase-reversal was also observed between Electrodes 7 and 11, Electrodes 11 and 12, and Electrodes 12 and 16. Thus, sulcus exhibiting phase-reversal of cortical SEP waves differed among these recording arrays. Topographic mapping of the amplitude of N₁-P₂ was maximum in recording arrays 7 and 6 cm lateral to the interhemispheric fissure (Fig. 4).

Cortical stimulation (10 to 15 mA, 0.2 msec duration, 50 Hz trains applied bipolarly) was then carried out. Electromyographic recordings were made from the right thumb and the right quadriceps femoris. We determined the central sulcus and motor cortex from those stimulation-evoked motor responses. The sulcus dividing the maximum polarity of cortical SEP's was the central sulcus. The brain surface of the superior and middle frontal gyri and the precentral gyrus was pale; this was thought to be the location of the tumor. The precentral gyrus was preserved during tumor removal. Neuropathological study revealed a grade I astrocytoma.

Postoperative Course. The patient exhibited a moderate right hemiparesis during the 1st week after surgery. However, the hemiparesis improved and recovered to the preoperative state. She was discharged on September 20.

Discussion

Wood, et al., reported that N₁0-P₂0 of cortical SEP's did not necessarily show phase-reversal across the central sulcus at locations away from the hand area. Woolsey, et al., demonstrated in their Fig. 7 that the hand representation area was 6 to 7 cm lateral to the interhemispheric fissure; however, they stated that the receptive fields were not completely defined. Gregorie and Goldring reported the importance of functional localization because lesions and their associated edema could displace the central sulcus.

Lueders, et al., hypothesized the generation of cortical SEP wave N₁ by a horizontal dipole produced...
Pitfall of functional localization by cortical SEP's

The region of zero-potential (areas 3, 1, 2, and 4 in the sensorimotor cortex), however, they stated that the field of distribution of the precentral P2 was consistent with a horizontal dipole in the central sulcus, possibly in its anterior bank (areas 4 and 3a). Wood, et al., reported that the on-axis line connecting the maximum cortical potentials of 20- and 30-msec fields formed an angle of about 70° with a line parallel to the central sulcus line. Their on-axis line implied the direction of the horizontal dipole generated in the central sulcus, and pointed to the frontal midline.

Our hypothesis to explain the SEP findings in the present case is shown in Fig. 5. The tumor in this case displaced the central sulcus posteriorly, and the direction of the horizontal dipoles producing N1 and P2 was shifted. The on-axis line pointed to the parietal midline. The zero-potential line dividing the negative and positive polarity pointed to the frontal midline and crossed the precentral sulcus at a location away from the generation of horizontal dipoles in the central sulcus. In this portion, phase-reversal of N1 and P2 was observed across the precentral sulcus. The zero-potential line also passed between Electrodes 7 and 11, and Electrodes 12 and 16. Therefore, phase-reversal of N1 and P2 was observed between those electrodes. Another explanation for those widely distributed potentials and perplexing phase-reversal is that there are multiple representations of the body in the primary sensory cortex, as has been demonstrated in the primate. However, SEP's could be recorded widely around the sensorimotor cortex, and phase-reversal findings were observed not only across the sulcus but also in the gyrus (Electrodes 7 and 11, and Electrodes 12 and 16 in our case).

We believe that localization of the central sulcus might be incorrect when the sensorimotor hand representation area is incompletely exposed. Cortical stimulation-evoked motor responses might provide misleading information on the localization of the motor cortex.

**Fig. 4.** Topographic maps of amplitudes of N1 (left, 2.3 μV/step) and P2 (right, 1.8 μV/step) of cortical somatosensory evoked potentials. The continuous line indicates the location of the tumor and the dotted line indicates the location of the surgically removed tumor. CS = central sulcus; PreCS = precentral sulcus; LS = lateral sulcus. Cortical stimulation at A elicited electromyographic responses in the right thumb and at B in the right quadriceps femoris. Numbers indicate the locations of the electrodes.

**Fig. 5.** Diagram explaining the phase-reversal of potentials in the precentral sulcus (PreCS) at the location away from the horizontal dipoles. The on-axis line connects the maxima of the N1 and P2 somatosensory evoked potential waves. The zero-potential line divides the positive and negative polarity. The region of the largest N1 waveform is indicated by horizontal hatching, and that of the largest P2 waveform by vertical hatching. The tumor is indicated by stippling. CS = central sulcus; IHF = interhemispheric fissure.
Wood, et al., reported that the stimulation of motor cortex sometimes elicited sensations, and the stimulation of sensory cortex sometimes elicited movements. In our patient, the motor function deteriorated during the 1st week after surgery due to the surgical manipulation. However, the area of surgical intervention was not the precentral gyrus because hemiparesis recovered to the preoperative state. To identify precisely the central sulcus, the distribution of SEP's must be studied in and around the sensorimotor cortex with cortical stimulation-evoked motor responses.

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References


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