

Topographic Mapping of Somatosensory Evoked Potentials Helps Identify Motor Cortex More Quickly in the Operating Room

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Summary: Median nerve somatosensory evoked potentials were recorded from exposed cerebral cortex during craniotomies. This technique is valuable when knowledge of the motor cortex location can influence surgical decisions about resection limits or biopsy sites. Two different recording techniques were compared: strips of electrodes and arrays of electrodes. The arrays recorded electrical potentials suitable for topographic mapping. We found that motor cortex could be identified more quickly when using the topographic mapping of SEPs from arrays. We conclude that topographic mapping of SEP from sensorimotor regions during craniotomies works well in general and can be done more quickly than the traditional electrode strip technique.

Key words: Evoked potentials; Somatosensory; Motor cortex; Surgery.

Introduction

Identification of motor cortex can be helpful during certain craniotomy procedures. These include certain cases of biopsy, debulking of tumors and epilepsy surgery in which the location of biopsy or limits of resection can be chosen in part based on the location of motor cortex. Obviously, one would prefer not to biopsy motor cortex if that can be avoided. In epilepsy surgery, limits of resections at frontal or parietal regions often are chosen specifically to spare the precentral and postcentral gyri. Occasionally in other procedures, knowledge of the location of motor cortex can guide the details of the surgical procedure.

Several different techniques are available for localization of motor cortex intraoperatively. The classical technique of cortical stimulation, popularized by Penfield and Jasper, has its limitations (Penfield and Jasper 1954; Ojemann et al. 1989). Stimulation of sites adjacent to

motor cortex can sometimes produce motor responses, and stimulation at motor cortex can fail to produce a response. Furthermore, detecting responses beneath surgical draping can be difficult. Stimulation with too much current can produce epileptic seizures. As an alternative, motor cortex can be identified anatomically as a long gyrus just posterior to the midcoronal plane extending continuously from Sylvian fissure into the interhemispheric fissure. Unfortunately, anatomical variations or distortion from pathology can interfere with use of this anatomical rule. A third approach to localization of motor cortex has been somatosensory evoked potentials. Direct cortical recording of the median nerve somatosensory evoked potential has grown in popularity during the last decade (Broughton et al. 1981; Gregorie and Goldring 1984; Nuwer 1986, 1991; Wood et al. 1988). The technique is relatively straightforward and can be done in 5-10 minutes. Improvements in this latter technique are described here. In particular, we have investigated ways in which we can help speed up this procedure by using 18 channel recordings with color coded topographic maps instead of the previous standard four channel recording technique.

Methods and Materials

Subjects

We used the new array electrodes on 25 patients, and compared this with the previous 50 patients on whom

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strip electrodes were used. All patients were tested between 1989 and 1991 at UCLA Medical Center. The two groups were evenly divided by gender. The median age of the new array techniques patients was 16 years, whereas it was 22 years for the older strip electrode technique patients. Overall ages ranged from six months to 66 years. The difference in ages between the two groups was due to an increase in surgery for intractable childhood epilepsy, which was not felt to influence the outcome of this technical comparative study. The reason for surgery in the new array technique patients was intractable epilepsy 17 (68%) and tumor 8 (32%); in the older technique, the reasons were intractable epilepsy 27 (54%), tumor 14 (28%) and arterial-venous malformations 9 (18%).

Stimulation

Stimulation was carried out at the median nerve contralateral to the tested hemisphere. Median nerve stimulation at the wrist was done with subdermal needle electrodes. One needle was placed over the median nerve at the carpal tunnel and a second needle was placed 2-3 centimeters proximally. These were taped down to avoid accidental dislodgement. Needle electrodes were considered preferable to disc with paste which can gradually dry. Needles were usually placed prior to placement of a radial arterial line, since substantial taping at the wrist may be used for that line. Stimulation was carried out with a 200 microsecond squarewave electrical pulse, with the more proximal electrode as the cathode. Stimulation rate was set to 5-7 per second. Stimulation during the case was usually carried out at a current greater than motor threshold; 20 mA stimulus intensity was used if neuromuscular junction blockade prevented direct assessment of the motor threshold. If there remained questions about whether the stimulus was adequate, the Erb's Point N9 potential was measured to assure that peripheral conduction was occurring in the expected manner.

Recording

Two types of recording electrodes were used and compared in this study. One was the traditional *strip* electrodes, generally a series of small stainless steel or platinum disc electrodes embedded in silastic. Each electrode contact was 3 mm across, separated 7 mm from each other, so that the electrodes were spaced 10 mm center-to-center. These strips, 4 to 8 electrodes long, are available with adaptor cables that can be plugged into standard EEG jack boxes out of the sterile field.

The second type of recording electrodes was a 4-by-5 *array* of 20 recording electrodes. These were also silastic embedded metal electrodes similar to the strips.

described above, but greater in number and arranged in a two-dimensional rectangular array. These are the same commercially available arrays used for recording and stimulating in the subdural space in patients being evaluated for surgery for medically intractable epilepsy (Lesser et al. 1987, 1989; Leuders et al. 1983).

Strips and arrays were generally positioned with the long axis in an anterior-posterior direction. Occasionally they were oriented rather obliquely to cross sulci perpendicularly. They were placed on the cortex at the localization believed to be at or near the hand region of sensory and motor cortex. The surgeon tried to span the central fissure itself in initial positioning of the strip or array. A few pieces of wet cottonoid strips were used on top of the strips or array to help hold it down and in place, keeping the electrodes in good contact with underlying cortex. One strip or one array was used at a time.

Alligator clip electrodes were placed on dura or muscle at some distance away from the central region. Two such clips were used, one as a reference and the other as an isoground. Use of an isoground was considered appropriate because the recording equipment had a suitable interposed safety feature, optical isolation, that prevented this electrode from directly contacting true chassis ground.

The recording time base was usually set to 30-50 ms. The activity sought for examination usually lies around 20 ms. Filters were generally set to 30 and 3000 Hz, with the 60 Hz line filter turned off. A 5 ms prestimulus baseline was used, and baseline correction of the waveforms was made using this prestimulus interval. This helped avoid DC offsets which could substantially alter maps. Maps were made with isopotential regions color coded. The relationship between maps and the cortical electrode array is shown in figure 1.

An evoked potential was formed with 100 trials in most instances. At 7 stimuli per second, this took about 15 seconds. In some instances, adequate potentials were recorded with as few as 20 trials, requiring only 3 seconds at a 7 per second stimulation rate. Artifacts were not usually a significant problem, since recording from exposed cerebral cortex produced particularly high amplitude, well defined evoked potential tracings.

Comparison of Recording Techniques

The strip technique was compared to the array technique, assessing the speed at which testing could be accomplished. Since the time to produce an individual 100 trial evoked potential is the same for the two techniques, the two techniques were compared by counting the number of separate evoked potential runs that were needed to confidently locate motor cortex. This corresponded to the number of separate times that the surgeon places the

4 X 5 CORTICAL ARRAY FITTED TO A 21-SITE TOPOGRAPHIC MAP

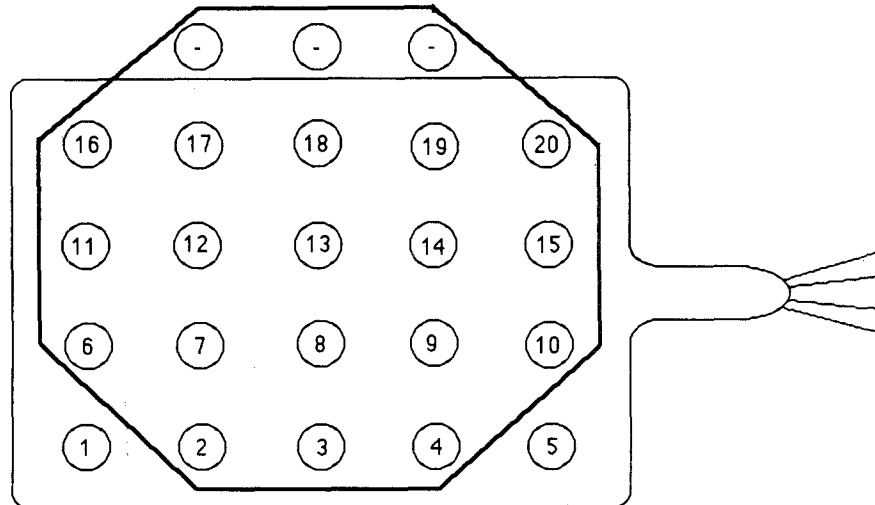


Figure 1. A 4 x 5 cortical electrode array can be fitted approximately to the shape of a traditional 21 channel topographic EEG-EP map. Since both are commercially available, this convention allows the clinician an easy way to display and measure results obtained from a cortical array. Electrodes 1 and 5 of the array do not fit, and are not used. The fronto-polar region of the map does not align with recording electrodes, and so they are electrically jumpered to the reference electrode.

strip or array at a new location, plus the number of times a second or third run was made at a location.

Interpretation of the Evoked Potentials

Three features were used to identify motor cortex using these evoked potentials (Leuders et al. 1983; Nuwer 1986). The first was the maximal amplitude of the major negative peak at about 20 ms, generated from the hand region of the postcentral gyrus. The second feature was a phase reversal of that 20 ms potential across the central fissure, with the negative end of the dipole on somatosensory cortex and the positive end of the dipole more anterior, often lying on motor cortex. The third identifying feature is the series of small step-like negative polarity deflections occurring on the upslope of the principal negative peak at the postcentral gyrus recording site. Sufficiently good quality of these identifying features was necessary. An experienced electroencephalographer judged this in the operating room, and recommended whether additional evoked potential runs were needed. That determined the number of times evoked potentials were run for each patient.

When all three identifying features were present, the primary somatosensory cortex location was deduced with a high degree of reliability. The motor cortex was

determined to be the gyrus immediately anterior to the postcentral primary somatosensory cortex. Once motor cortex was identified for the hand level, it could be traced anatomically more medially and more laterally. The latency of the principal negative peak varied with height, age and gender, and also was slightly prolonged due to certain anesthetic agents. However, the principal negative peak generally did occur between 18 and 24 ms. Peaks lying at 25-30 ms generally were considered incorrect peaks, since they are known to occur at sites other than the primary somatosensory cortex.

Results

Confident localization of the motor cortex was achieved in all but two patients. Both of these had preoperative evidence of substantial weakness and sensory impairment for the limb tested, due to cerebral tumors. Among the remaining patients, the strip electrodes required 5-12 individual EP runs, with a median of 7 EPs required. That number of placements plus replications was needed to confidently decide that the strip had been placed at the optimal site, both in an anterior-posterior and in a medial-lateral dimension. In contrast, the 4-by-5 electrode arrays resulted in confident motor cortex localization upon 2-4 EP runs with a median

MOTOR CORTEX LOCALIZATION

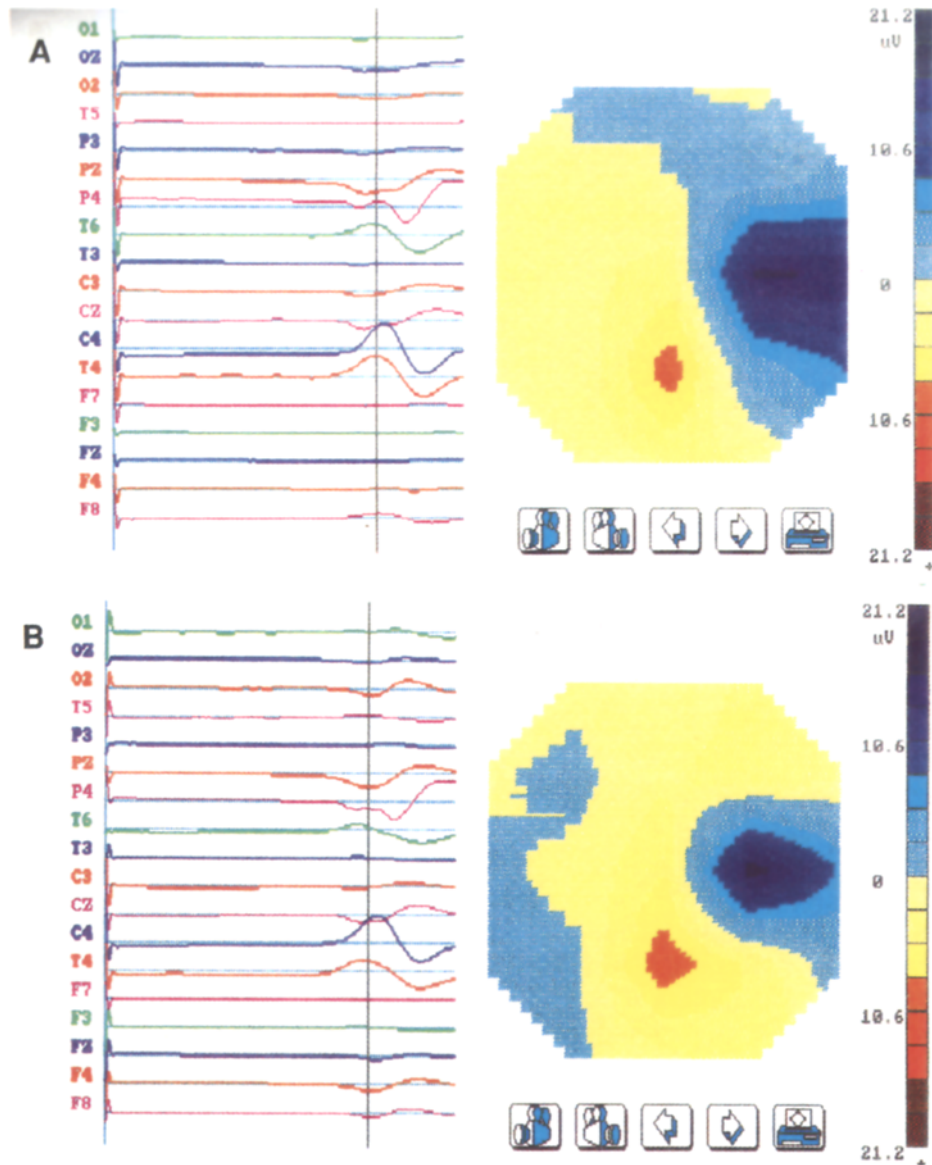


Figure 2. Two views of the topographic SEP map for the N20 primary cortical potential in one patient. The array was oriented about 30 degrees obliquely, with the anterior (left) end slightly more medial (higher) than the posterior end. The nose is to the left. The hand level of sensory cortex lies at array site 14, seen here as blue (negative). Motor cortex was deduced to be the gyrus immediately anterior to the sensory cortex. The motor cortex included array site 8, seen here as red (positive). The central sulcus lay halfway between these two maximums. The data are shown two ways: with a reference electrode at dura (A) and using a digital nearest-neighbor source derivation reference technique (B; Hjorth 1975). The latter makes the topographic polarity regions more compact, which sometimes aids quick localization. The 10-20 system site names, shown at the left of the EP traces, help to identify where each trace fits into the map.

of three runs needed. In many instances, the final placement was used only to produce aesthetically improved colored maps with the central sulcus in the center of the map. Figure 2 illustrates the SEP map of a patient with a

tumor anterior to the motor cortex.

Overall, the array cut the time needed by more than one-half, as well as providing attractive, easily interpreted colored displays of the localization results. Ar-

rays were felt to be a useful clinical tool for this purpose.

Discussion

The principal problem at hand here is one of topographic localization. It is no surprise then that topographic mapping of the early potentials are able to substantially reduce the number of placements, and therefore the amount of time required in the intraoperative setting.

In terms of minutes, we note that with well trained personnel each placement takes approximately two minutes now, beginning with placing the array, to application of wet cottonoid, to running the potentials, and subsequently using a cursor to identify the latencies to the peaks, followed by communicating the results back to the surgeon and deciding on the next step to be taken. Using two minutes as the average amount of time per cycle of testing, the arrays can produce adequate localization in about six minutes, contrasted with the strip technique which required a median of about 14 minutes.

In addition to reducing the amount of time spent on the procedure, the topographic maps are able to communicate more effectively the localization of peaks to operating room personnel who are not specialized in electrophysiology. The color coded maps, especially those showing phase reversal, can be visually related directly to the cortical electrode array. Such improved understanding and communication seem to be a benefit that is not easily quantified.

Topographic mapping of EEG and evoked potentials has been received in the medical community with rather mixed reviews (Nuwer 1988b, 1989, American Academy of Neurology 1989). Many mapping techniques offer no advantage over routine EEG or EP recording in many individual clinical settings. The techniques also carry with them significant risks of artifacts, confounding clinical issues and statistical problems which are resolved, if at all, only with difficulty and expertise on the part of the users (Nuwer 1988a; Kahn et al. 1988; Fisch and Pedley 1989). In contrast, the application of evoked potential topographic mapping as described here seems to be relatively straightforward. The issue of anatomical localization lends itself well to the topographic mapping method. Users still need to be knowledgeable about the possibility of artifacts, need for baseline correction, and interpretation paradigm. The direct relationship between the topographic maps and a 4-by-5 array is definitely advantageous. In this way, 18-20 channel recordings could be handled in a way much more easily understood than by traditional line format displays of evoked potential traces in so many channels.

In a more general way, the technique of motor cortex localization using somatosensory evoked potentials is

itself a technique which has merit in well selected cases. When it is necessary to locate motor cortex, this certainly is a straightforward technique, especially when compared to the potential for confusion when relying solely on anatomical clues or the more lengthy and occasionally misleading procedure of identifying motor cortex through direct cortical stimulation. The use of topographic mapping with 18-20 channel recordings will reduce the time needed for this procedure to 5-10 minutes in most cases.

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