Cortical localization and monitoring during cerebral operations

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Cortical sensory potentials have been evoked under general anesthesia by median nerve stimulation and direct cortical stimulation of the motor cortex in 35 consecutive patients with mass lesions in the middle half of the cerebral hemispheres. The evoked potentials produce movement that is useful in localizing the pre- and postcentral gyri. Ultrasound has also been used to aid in the selection of access routes to subcortical lesions while sparing the cerebral cortex bordering the Rolandic fissure. In five of these 35 patients, the sensory evoked response was also monitored throughout selected portions of their operative procedures. Representative cases have been presented to illustrate how observations made with these methods have been used to facilitate the patient's intraoperative management in an effort to limit postoperative morbidity.

KEY WORDS • sensory evoked potential • cortical localization • intraoperative monitoring • ultrasound • operative procedure

ROBERT Bartholow first demonstrated the electrical excitability of the human motor cortex in 1874. Ten years later, Sir Victor Horsley identified the motor cortex during standard craniotomies using Faradic stimulation and local anesthesia. His purpose was to define more precisely the relationship of a subcortical lesion to the sensorimotor cortex. When he could establish a precise localization, the mortality rate was dramatically reduced. Most efforts to localize sensory and motor cortex since then have also been carried out under local anesthesia during procedures designed to relieve seizure disorders.

Jasper, et al., indicated that localization based on evoked potentials could be quickly accomplished and might prove to be a technique of practical importance for use in neurosurgery. In 1984, Gregorie and Goldberg reported their experience with the identification of the pre- and postcentral gyri using somatosensory evoked potentials and motor cortex stimulation under general anesthesia. It was their opinion that the use of this technique during the removal of neighboring lesions would favorably influence postoperative morbidity.

It is well known that the pre- and postcentral gyri cannot be identified with certainty by intraoperative inspection alone, even in an undisturbed hemisphere. Mass lesions with associated edema often displace brain tissue and further obscure identification of the pre- and postcentral gyri.

Our short-term goals in these studies have been: 1) to identify the relationship between the sensorimotor cortex and major lesions in the midportion of the cerebral hemisphere during standard neurosurgical procedures under general anesthesia; 2) to combine this localization with intraoperative ultrasonography in order to select access routes to subcortical lesions while sparing the sensorimotor cortex; and 3) in some instances, to monitor evoked responses in the sensory cortex during the removal of nearby lesions or manipulation of blood vessels supplying the sensorimotor cortex. In this report, we describe selected cases and observations made while using these techniques in an attempt to reduce morbidity associated with intracranial surgery. The recording period for sensory evoked responses usually lasted for 15 to 20 minutes. When precentral cortex was also identified, localization time could last up to 45 minutes.

Localization Techniques

Localization techniques were used during standard craniotomies in 35 patients. Initially Nicolet CA-1000 and more recently Pathfinder II equipment were employed.* Median nerve stimulation was delivered through two cutaneous disc electrodes located 2-cm

* Pathfinder II manufactured by Nicolet Biomedical Instruments, Madison, Wisconsin.
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apart and positioned across the median nerve on the wrist. A stimulus pulse of 1 msec at 3.1/sec and 10 to 20 mA was delivered in sequences of 100 repetitions. Each pulse induced a mild thumb twitch confirming that an effective stimulus had been delivered.14

Cortical recording electrodes consisted of flat platinum discs, 1 to 1.5 mm in diameter, aligned in rows and spaced at 0.5- or 1-cm intervals, and embedded in a matrix of reinforced Silastic sheeting. The matrix was aligned along what was thought to represent the postcentral gyrus. Occasionally, recordings were obtained transdurally. Evoked responses were recorded with sequential electrode combinations generally at 0.5- or 1-cm intervals. Evoked potentials were recorded using a high (5-Hz) and low (1.5-kHz) bandpass. Usually, 100 cortical evoked potentials were averaged, and various electrode combinations were analyzed in the first 200 msec following stimulation. The primary cortical waves were in the 18- to 30-msec poststimulus latency range, with phase-reversals of the early components indicating the locus of cortical activation. Averaging of more than 20 evoked responses did not introduce changes indicative of volume-conduction artifacts in the first 30 msec of these responses. The matrix was then pivoted on the most active site, and the process was repeated to seek a phase-reversal at the same cortical site to confirm that the evoked potential was not being recorded from a remote locus (Fig. 1).

Cortical stimulation under special anesthetic conditions was utilized to identify the precentral gyrus. The stimulus was applied to the gyrus anterior at the site of the most active evoked response and administered with bipolar silver-tipped electrodes spaced 0.3 to 0.5 cm apart. One-millisecond pulses were delivered at a rate of 50/sec for 5 to 10 seconds at 3 to 10 mA. General anesthesia was induced by preoperative atropine, 0% to 0.5% halothane, and nitrous oxide which was reduced to 20% to 40% during test intervals. Succinylcholine was administered to provide relaxation for intubation and again after the recordings were completed. Spontaneous movements were occasionally seen under these circumstances. Fentanyl citrate was occasionally given with nitrous oxide instead of halothane.

After the pre- and postcentral gyri were localized, intraoperative ultrasound was used to identify the optimum surgical approach to subcortical lesions. In selected patients intraoperative digital subtraction angiography was used to supplement the standard preoperative baseline angiograms, and was particularly useful following intraoperative embolization. In patients undergoing embolization procedures, a femoral artery catheter was placed preoperatively into the external carotid artery and withdrawn into the common carotid artery for injection of meglumine iothalamate (Conray 60). At embolization, surface vessels were selectively cannulated and embolized with isobutyl-2-cyanoacrylate (Bucrylate).

The selection of a site for a cortical incision and for resection of a cortical or subcortical lesion was based on information gained from the cortical localization and ultrasound examinations. Occasionally, intravenous administration of 2% fluorescein and a Wood's lamp were used to help in the delineation of the margin of tumor tissue within a gyrus. Access routes to subcortical lesions and margins of resection of surface lesions were designed in order to preserve sensorimotor cortex. We have recently used these techniques in five patients to monitor sensory evoked responses when lesions in close proximity to the pre- and postcentral gyri were being resected or when the blood supply to that region was being manipulated during a procedure.

During the first few months of our efforts, the recordings were not satisfactory for technical reasons in six patients. Of the remaining 29 patients, four had arteriovenous malformations (AVM's), two had abscesses, 20 had primary brain tumors, two had meta-

1† Silastic sheeting-reinforced medical grade silicone manufactured by Dow Corning Chemicals, Lansing, Michigan.
2‡ Ultrasound unit, Model DRF-1, manufactured by Diasonics Inc., Milpitas, California.
static brain tumors, and one had a middle cerebral artery aneurysm.

Cortical Localization Studies

Case presentations have been selected to illustrate observations that led us to modify our operative procedures as a consequence of using these techniques.

Case 1 demonstrated that the sensory and motor cortex may lie immediately adjacent to a lesion, the margins of which are not distinct on visual or manual inspection of the surface of the hemisphere. This 54-year-old woman had suffered left facial seizures for 1 month before admission. Computerized tomography (CT) showed a right frontal subcortical ring-shaped lesion (Fig. 2). At surgery, the surface of the hemisphere was not remarkable in appearance although there was a palpable sense of fullness in the exposed field. A small matrix of electrodes was placed over the area believed to lie above the lesion. Phase-reversal sensory evoked responses were readily demonstrated. Motor responses were elicited in the hand from the adjacent anterior gyrus. The boundaries of the subcortical lesion were outlined on ultrasound study. An incision was made in the gyrus immediately adjacent to the motor cortex, and the subcortical lesion was readily evacuated. The patient had no new neurological deficits during the immediate postoperative period.

In circumstances such as in Case 1 these localization studies have been particularly helpful in selecting access routes and for resection of subcortical lesions that are in immediate proximity to the sensorimotor cortex.

In Case 2, the sensorimotor cortex was located at a surprisingly remote distance from the lesion. This 62-year-old woman had experienced progressive headache, a right hemiparesis, and expressive aphasia for 4 weeks. A CT scan showed a ring-shaped lesion in the left hemisphere. Her clinical symptoms cleared almost completely after several days on high-dose steroids. At surgery, the somatosensory evoked potential and motor responses were obtained transdurally from just behind the coronal suture high on the hemisphere. Preoperatively, the tumor was thought to lie in the region of the sensorimotor cortex, but transdural ultrasound clearly identified the tumor as far posterior to the sensorimotor cortex. The dural opening was limited to the region of the tumor.

On five other occasions it was reassuring to find that the sensorimotor cortex was at a site unexpectedly remote from a preferred access route to a subcortical lesion. This has allowed a greater margin of safety in selecting a site for a transcortical incision than would otherwise have been offered. In two patients the rolandic fissure was displaced so as to coincide with the coronal suture, and in three patients the somatosensory evoked potential and the motor cortex for finger or hand movement were displaced toward the vertex, and were identified 2 cm from the midline.

Case 3 illustrates that even if the sensorimotor cortex is stretched immediately over a subcortical lesion it may still be localized in the presence of profound sensory and motor deficit. This 76-year-old woman presented with dense left sensory and motor disturbances that were unresponsive to a preoperative course of high-dose steroids. A CT scan demonstrated a large central subcortical ring-shaped lesion on the right. At craniotomy, the entire exposed cortex was full and elevated. Sensory evoked potentials with phase-reversals were readily demonstrated and motor responses were elicited from the next anterior gyrus. Both of these gyri were draped immediately over the mass in the middle of the field. Ultrasound studies demonstrated a superficial, highly echogenic site behind the primary sensory cortex where the transcortical access route was planned. This patient demonstrated dramatic improvement in sensory and motor functions in the immediate postoperative period.

We had almost decided not to look for the sensory or motor cortex in this patient because of her profound hemiplegia. It was surprising to find that both the pre- and postcentral gyri could be readily identified in the middle of the operative field. We would very likely have

![Figure 2](image-url)

**Fig. 2.** Studies in Case 1. A: Computerized tomography scan demonstrating a ring-shaped lesion underlying the right prerolandic area. B: The recording electrode matrix is seen overlaying the lesion. C: Somatosensory evoked potential recordings with a phase-reversal in the upper two tracings located the postcentral gyrus indicated in D by s. D: The surface of the brain as it appeared after removal of the lesion. The dotted line indicates where the ultrasound outlined the lesion. m = Site where arm motor responses were obtained anteriorly to the site of the evoked potential at s.
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made our cortical incision into one of these gyri had we not attempted localization studies.

Case 4 demonstrates that evoked responses can provide localizing information even though a phase-reversal is not identified. This 52-year-old left-handed woman presented with a 1-month history of expressive aphasia and mild right hemiparesis. Preoperative high-dose steroids improved her speech deficit and cleared her hemiparesis within 48 hours. A CT scan demonstrated a ring-shaped lesion in the right frontal lobe (Fig. 3). Transdural recordings were obtained to determine the location of the sensory and motor cortex. Although a phase-reversal was not identified in this instance, highest amplitude evoked responses, limited to a single gyrus, indicated that the recording electrodes were near the sensory cortex. Eye twitch was evoked by cortical stimulation of the gyrus just anterior to that area, confirming the location of the motor cortex. Both observations were obtained from an area of cortex immediately over the center of the CT-localized lesion. At the margins of the lesion, ultrasound studies identified a superficial echogenic locus indicating the position of a subcortical extension of the lesion near the surface but distant from the region of the sensory and motor responses. A limited transcortical incision was made at that site, and a major evacuation of a cyst and surrounding glioma tissue was accomplished. Postoperatively, the patient had no increase in her neurological deficit.

The peak amplitudes of these responses were remarkably high and varied between 50 and 150 μV. The highest-amplitude evoked responses may be well localized as in this instance and may identify nearby sensory cortex even though a phase-reversal cannot be demonstrated. In three instances clear-cut phase-reversals were not recorded but the highest-amplitude sensory evoked responses were localized within a 2-cm area, and in each instance a motor response was identified nearby.

Case 5 demonstrates that a sensory evoked response may also be recorded from the primary motor cortex. This 28-year-old left-handed male anesthesiologist suffered a focal seizure in 1980 and two more in 1984. Sensory and motor components were limited to the left

FIG. 3. Studies in Case 4. A: Computerized tomography scans demonstrating an enhancing ring-shaped lesion underlying the right precentral area. B: Transdural intraoperative ultrasound scan illustrating the location of the echogenic lesion near the surface at the site marked by the dotted circle in D. C: Somatosensory evoked responses were high in amplitude indicating that the sensory cortex was nearby (at Tab “3” in D). μV.L.T = microvolt. D: Surface of the brain showing the site (Tab “4”) at which stimulation evoked eye twitching anterior to high-amplitude evoked potentials at Tab “3”. The dotted line represents the site of the cortical incision.
arm and left side of the face. On one occasion he lost consciousness. A CT scan demonstrated a small lesion in the midportion of the hemisphere. We were uncertain as to the nature of the disorder, but were aware of his previous exposure to tuberculosis. A small recording electrode matrix was placed over the appropriate portions of the hemisphere. Phase-reversals of early elements of the evoked response were readily obtained. Ultrasound studies identified the subcortical echogenic locus of the lesion beneath the next gyrus posteriorly, which appeared to be normal on inspection and palpation. A second phase-reversal, somewhat slower in onset and less well defined, was identified more anteriorly, and motor responses were elicited from that gyrus. A sterile abscess was removed from the gyrus just posterior to the sensory cortex, without postoperative deficit.

In two other cases a sensory evoked response was recorded from the gyrus anterior to the primary sensory cortex. In one of those instances a motor response could not be elicited.

Case 6 illustrates that high-amplitude sensory evoked responses may be elicited from the suprasylvian gyrus. This 35-year-old man had a 9-month history of frequent focal seizures in the left arm following a sensory aura and associated weakness of the left hand. A CT scan demonstrated a nonenhancing mass lesion located posteriorly just above the Sylvian fissure. At surgery, the surface of the hemisphere appeared normal. The sensory evoked response demonstrated a reversal of delayed elements only when it was recorded from the suprasylvian gyrus. A phase-reversal of the early components was not clearly reproducible. The high-amplitude evoked response, however, was readily identified and well localized within a region approximately 1.5 cm in diameter. This response could not be recorded further toward the vertex or lateral to the Sylvian fissure. The motor cortex was identified by stimulation in the next gyrus anteriorly which elicited a facial twitch. The lesion was identified as an occult AVM which was removed through the precentral gyrus lateral to the site from which motor responses were elicited. There were
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no neurological deficits.

In four cases, suprasylvian high-amplitude somatosensory evoked responses have been elicited, with a phase-reversal in two instances. The highest-amplitude responses were limited to the suprasylvian gyrus. No evoked potential was elicited in these cases from the next adjacent gyrus across the sylvian fissure or toward the vertex.

**Monitoring Sensory Evoked Potentials During Craniotomy for Hemispheric Lesions**

As an extension of the localization studies, we have monitored sensory evoked potentials during resection of selected lesions in five cases. These operations involved resection of subcortical lesions in close proximity to the internal capsule or its projections to the sensory and motor cortex, resection of cortical lesions immediately adjacent to or within the pre- or postcentral gyri, or resection of lesions positioned such that the blood supply to the motor or sensory cortex might be compromised while gaining access to or removing a lesion deep in the hemisphere. The following cases represent examples of circumstances in which monitoring of cortical evoked potentials was undertaken.

**Case 7**

This 18-year-old woman presented with increasing psychomotor seizures over 9 months and progressive dystonic movements of the left upper extremity of 2 weeks' duration. Magnetic resonance imaging and CT studies demonstrated an unusual mass lesion in the right operculum; however, angiography was normal. The lesion was located between the middle cerebral artery candelabrum, the internal capsule, and the basal vein of Rosenthal (Fig. 4).

Evoked sensory potentials were used to monitor the dissection through the candelabrum of the middle cerebral artery and into the operculum where biopsy for diagnosis and decompression of the lesion was planned. We also wished to monitor any adverse change secondary to manipulation of the internal capsule on the medial side of the lesion and were prepared to terminate or alter the procedure if the monitored evoked potentials diminished. At surgery, the recording matrix was well secured beneath the dura and was not moved once monitoring was started. At no time during the resection did the amplitude of the evoked potential diminish. Instead, the potential gradually increased to twice the original amplitude during the debulking of the lesion. Twenty-four hours postoperatively the patient's upper-extremity deficit was substantially improved, and within a week her hand had nearly normal function.

**Case 8**

This 19-year-old man presented with headaches and intractable focal seizures of major magnitude. Angiography demonstrated an AVM in the left parietal region (Fig. 5). At surgery, the primary sensory cortex was identified in the gyrus immediately adjacent to the anterior edge of the lesion. The highest-amplitude re-
responses were identified at the crest of the gyrus. The
electrode matrix was moved slightly anteriorly in order
to facilitate access to some of the arterial feeders at the
posterior edge of that gyrus. High-amplitude evoked
responses were readily recorded at that site. Intraoper-
ative digital subtraction angiography was used during
the procedure. The arterial feeders were temporarily
occluded and cannulated, and angiography was
performed with contrast material injected through the
cannulated vessels into the AVM. The vessels were then
segmentally cleared with dextrose and embolized with
Bucrylate, and the lesion was removed. There was no
change in the position of the recording electrodes or in
the configuration of the evoked potential. The posterior
portion of the gyrus had been infused with Bucrylate
and subsequently became pale (Fig. 6); Bucrylate had
extended into the posterior portion of the postcentral
gyrus over a distance of 3 to 4 cm. Twenty-four hours
postoperatively, the patient was found to have no neu-
rological deficit on fine parietal sensory testing in the
right hand. With the onset of postoperative edema, he
developed a transient hemiparesis, which later cleared.

Case 9

This 51-year-old man presented with expressive
aphasia and slowing; he also had clumsiness of fine
repetitive distal movements in the right hand. A CT
scan showed a superficial glioma near the precentral
gyrus. At surgery, a 2% fluorescein injection and a
Wood's lamp were used to visualize the infiltration of
the tumor into the precentral gyrus. While the sensory
evoked potential from the adjacent postcentral gyrus
was being monitored, the fluorescent portion of the
anterior bank of the precentral gyrus was carefully
resected. There was no change in the monitored re-
sponse from the postcentral gyrus. The resection ex-
tended to within 3 to 4 mm of the recording electrodes,
indicating that manipulation of the cerebral cortex very
close to the electrodes need not disturb the evoked
response recordings. No additional motor deficit was
apparent the day after the resection, although increasing
motor deficit was evident during the next few days.

Discussion

Several of the observations that were made in the
course of these examinations were not anticipated. In
many patients, surgical procedures were modified as a
result of information gained by intraoperative locali-
ization of the sensory motor cortex.

The recording of high-amplitude sensory evoked po-
tentials from a 1- to 1.5-cm region of a single gyrus
close to the vertex or close to the sylvian fissure sug-
gested initially that the sensory homunclus might be
shifted higher or lower on the hemisphere than we had
expected. High-amplitude potentials restricted to a sin-
gle gyrus on the lip of the sylvian fissure, however, have
been observed in four patients, suggesting that we may
have been recording from secondary sensory cortex
close to the sylvian fissure. Sensory evoked potentials
in the secondary sensory cortex under general anesthes-
tia have not been reported previously in man. Penfield
and Boldrey clearly established the occurrence of sec-
ondary sensory cortex responses in man under local
anesthesia along the superior bank of the sylvian fissure.
We have not yet had the occasion to record from the
length of the postcentral gyrus in order to identify two
discrete loci of sensory evoked potentials from primary
and secondary sensory cortex in the same patient.

Sensory evoked potentials have previously been re-
corded from the precentral gyrus under general anes-
thesia. On three occasions we have recorded sensory evoked potentials from both pre- and postcen-
tral gyri. Others have observed that sensory evoked
responses recorded from the precentral gyrus are com-
mon and differ in conduction time and component
waveform from the response recorded from the post-
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central gyrus.11,12,15 Our techniques differ substantially from those used in some other studies.16,17,19,20 We have not yet been able to identify a consistent difference in our recordings from the two gyri. If a motor response was elicited from the more anterior gyrus, then any uncertainty as to the location of sensory and motor cortex was resolved. We have never elicited a motor response by stimulating what appeared to be sensory cortex under general anesthesia although this response has been reported under local anesthesia.21

In Case 8, the posterior bank of the postcentral gyrus was substantially infarcted with Bucrylate, although the sensory evoked potential recorded from the crest of that gyrus was unaltered. The patient had no neurological deficit 24 hours after surgery. The lack of observable functional change may be related either to an ability of the more anterior bank of the gyrus to rapidly compensate for the damaged posterior part 10,11,15,16,20,21 or to the possibility that the volume of tissue affected was insufficient to lead to demonstrable functional changes. A more likely interpretation is that the infarcted portion of the posterior bank of the gyrus was not contributing to the anatomical substrate essential to the sensory evoked potential or to sensory events demonstrable by careful clinical testing. We have explicitly avoided resection of the locus from which sensory evoked responses were recorded or the posterior wall of the motor cortex.

In Case 9, a glioma infiltrated the anterior half of the precentral gyrus and was removed just ahead of the somatosensory hand area without inducing a demonstrable change in hand function. Similar questions may then be raised concerning manipulations of the anterior bank of the precentral gyrus. From a clinical point of view, however, one would wish to avoid resection of more than the most anterior portion of the precentral gyrus, and that can only be assured if the precentral gyrus has been precisely identified.

In subhuman primates the motor cortex has a dual representation on the anterior and posterior surfaces of the precentral gyrus.24-26 The electrophysiological localization of multiple representations in primary motor and premotor cortex that have been recently described in primates22,24-26 have not been well defined in man (P Strick, personal communication, 1986).

It was surprising to note in two monitored cases (one with and one without preoperative clinical sensory deficits) that, as a subcortical lesion was “debulked,” the amplitude of the sensory evoked response gradually increased. Whether this reflected a change in cerebral perfusion, as seems more likely, or decomposition of elements of the internal capsule projecting to the somatosensory cortex beyond the lesion was not clear. We have not seen amplitude changes of similar magnitude associated with presumed stable anesthetic states or as random events in other circumstances. Movement of the electrodes seems an unlikely explanation for the changes since maximum amplitude loci were chosen for monitoring sites prior to debulking, and the waveforms, while increasing in amplitude, did not change in their temporal characteristics or component elements.

Motor responses to cortical stimulation have been somewhat more difficult to elicit and more time-consuming than the sensory evoked potentials, as others have noted.9 Presumably, anesthesia plays a major role in this regard. When movements were elicited they were not always the fine clonic distal movements seen in patients under local anesthesia. In five patients the movements were more proximal, slower, and more sustained, suggesting that responses initiated by cortical stimulation under general anesthesia can be substantially different from those characteristically seen under local anesthesia. At times, motor cortex stimulation under general anesthesia seemed effective only at widely separated loci. Within a 2- to 3-cm distance along the precentral gyrus, at times no movements were elicited, even on careful stimulation and with various stimulus characteristics. Stimulating the next centimeter adjacent to such a silent region could initiate movements of limited intensity, range, and complexity. We are not certain as to what variables may contribute to these differences in the movement patterns we have seen. They may reflect changes in motor cortex responsivity secondary to the neighboring pathological process, general anesthesia, or both.

Because the identification of the primary motor cortex can be time-consuming, it has usually seemed more efficient to find the sensory evoked potential first and then seek hand, arm, or face movements in the next gyrus anteriorly. This sequence has been particularly important when sensory evoked potentials have been recorded with phase-reversals on two adjacent gyri, and their specificity with respect to pre- and postcentral gyri cannot be differentiated by their waveforms or latency.14,19,20

None of the patients in this series who were free of neurological deficit preoperatively demonstrated neurological deficits in the immediate postoperative period. Most patients with preoperative neurological deficit showed improvement in the immediate postoperative period, two were unchanged, and one patient with minimal hemiparesis preoperatively was hemiplegic postoperatively. She had an extensive glioma infiltrating the sylvian fissure and thrombosis of the middle cerebral artery after surgery.

Conclusions

We are still not certain as to the most appropriate indications for further application and development of these observations. In reviewing the material reported here, it has been suggested that the surgeon’s intraoperative decision-making process was probably influenced to some degree by the results of the studies in 26 of the 29 patients with successful investigations. Only one patient in this group had an additional clinical deficit immediately postoperatively. Of course, our good fortune in this regard may not be sustained as these
techniques are adapted to more challenging circumstances. It seems appropriate, however, to extend this experience in order to better define the circumstances in which these observations may be helpful in controlling postoperative morbidity and in further developing our understanding of the functional characteristics of the cerebral cortex in man.

It would be valuable to know the functional characteristics of any portion of the cerebral cortex that requires resection, whether it be association-, sensory-, motor-, or language-related, or of the cortex contributing to more complex elements of higher brain function. Newer techniques may allow further pursuit of that long-term goal.

While pursuing our short-term goals, however, each of several observations modified both our intraoperative management of the patients we have studied and our appreciation of patterns of responsibility of human cerebral cortex that can be elicited under general anesthesia. Our observations are as follows:

1. Sensory evoked cortical potentials have been readily elicited under general anesthesia. Motor responses have been somewhat more difficult to initiate, even under “light” general anesthesia.

2. Focal high-amplitude sensory evoked potentials may be elicited along the posterior superior bank of the sylvian fissure without distortion of the postcentral gyrus by mass lesions. These may represent secondary somatosensory cortex responses.

3. Infarction of the posterior wall of the postcentral gyrus or resection of the anterior wall of the precentral gyrus have not necessarily been predictive of demonstrable functional neurological deficits.

4. Sensory evoked potentials have increased in amplitude as subcortical lesions were gradually debulked. Rapid improvement in preoperative sensory and motor deficits have been associated with that observation.

5. Sensory evoked potentials elicited from the precentral gyrus have not been discriminated from those arising from the postcentral gyrus in these studies.

6. The sensorimotor cortex has been displaced by mass lesions as far anteriorly as the coronal suture. Well-localized median nerve stimulation evoked potentials may, in other instances, be recorded from the postcentral gyrus within 2 cm of the midline when the postcentral gyrus has been displaced by mass lesions. The somatosensory cortex has been identified at sites unexpectedly remote from a mass lesion, adjacent to a mass lesion, draped over a mass lesion, and lying beneath a mass lesion.

7. Localization of the pre- and postcentral gyri by these techniques combined with ultrasound studies has facilitated the selection of routes of access to subcortical lesions that preserve the primary, sensory, and motor cortex.

8. Sensory evoked potentials and motor responses have been elicited despite profound preoperative deficits. Even in such cases, functional impairment can improve postoperatively if the sensorimotor cortex has been identified and preserved.

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