Awake Surgery for Glioma Resection in Eloquent Areas
—Zurich’s Experience and Review—

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Abstract

Awake surgery was performed in a series of 21 patients with gliomas in eloquent areas with the use of intraoperative electrical mapping. Gross total removal was performed in 18 patients. There was no operative mortality. Postoperative findings included no change in symptoms and signs in 10 patients, improvement of the preoperative deficit in 11 patients. Four patients had improved Karnofsky performance status (KPS) scores after surgery, 17 patients were stable, and no patient had lower KPS score. Extensive radical resection of gliomas prolongs the overall survival and improves the patient's quality of life. However, surgical resection of gliomas located within the sensorimotor or language areas remains a neurosurgical challenge in reducing eloquent neurological sequelae. Awake surgery with intraoperative functional mapping is a safe approach to maximize the extent of tumor removal and to minimize the resultant neurological deficits in the treatment of glioma involving the eloquent cortex.

Key words: awake craniotomy, cortical brain mapping, glioma, language, sensorimotor cortex

Introduction

Extensive surgical resection of low- or high-grade gliomas prolongs the survival time and improves the patient's quality of life.1,12,33,42) Therefore, the surgical goal is to resect the tumors as completely as possible without additional postoperative neurological deficits. However, resection of tumors located within eloquent areas carries a high risk of inducing neurological deficits.22,48) Surgical resection of gliomas located within the sensorimotor and language areas is challenging, as anatomical landmarks and functional sites show no precise spatial correlation.

Functional mapping methods are widely used to improve the surgical results, including functional magnetic resonance (MR) imaging, magnetoencephalography, single photon emission computed tomography, somatosensory evoked potential recording, and transcranial magnetic stimulation.2,11,25,30,35) These methods can localize the eloquent cortex preoperatively by measurement of various parameters such as blood perfusion and tissue metabolism. However, pathological local hemodynamic changes may result in variations in the findings.23)

Tumor removal with the patient awake is not a new technique in modern neurosurgery. Karinthy32) had already reported the experience of awake craniotomy of Prof. Olivecrona in 1958, in which the risk of awake surgery under local anesthesia was 25% less than that under general anesthesia. Recent advances in microsurgical and anesthetic techniques have refined the surgical procedures and improved the surgical outcomes in awake surgery. Intraoperative electrical mapping is a well-established and safe technique to maximize the extent of tumor excision and minimize neurological deficits in the treatment of tumors involving the eloquent cortex.3,5,28,36)

We have treated 21 patients with gliomas in the...
eloquent cortex by awake surgery with the use of intraoperative electrical mapping, and describe the usefulness of this technique for improving surgical outcome.

Patients and Methods

I. Patient population

Twenty-one patients with gliomas in eloquent areas underwent awake surgery for functional cortical mapping using direct cortical stimulation at the department of neurosurgery in Zurich University Hospital between November 1999 and April 2003. The patients had a wide variety of clinical presentations, lesion locations, and histologies. Meningiomas or cerebral metastases with good demarcations from the eloquent areas do not need in principle such procedures with or without awake surgery. The topography of tumors was analyzed accurately by preoperative MR imaging. The hemispheric dominance was defined using neuropsychological testing and functional MR imaging before surgery. The extent of tumor removal was verified by intraoperative MR imaging or computed tomography (CT) with contrast medium performed on the day after surgery.

II. Surgical procedures

Surgery was performed under microsurgical conditions using an operating microscope. In the operating room, the anesthesiologist established intravenous access, fitted an oxygen mask, and commenced patient monitoring with noninvasive blood pressure recording, pulse oximetry, and monitoring of expiratory gas CO2 concentrations via a nasal cannula. The patient was then positioned in the supine position with careful attention to padding pressure areas and avoiding uncomfortable positioning. Surgery in the sitting position could also be performed if necessary. The Mayfield head clamp was applied under local anesthesia using 30 ml of 1% lidocaine with 0.5% adrenaline, so that the head could not be mobilized adverently or inadvertently. A small adjustable stand was positioned to keep the surgical drapes off the patient’s face and allow the anesthesiologist and examiners adequate viewing of the patient’s face. This also enabled the patient to look at the subject material during examinations.

After routine head shaving, skin preparation, and draping, the site of the skin incision was infiltrated with an adequate dose of local anesthetic not exceeding 100 ml to prevent lidocaine toxicity. A small adjustable stand was positioned to keep the surgical drapes off the patient’s face and allow the anesthesiologist and examiners adequate viewing of the patient’s face. This also enabled the patient to look at the subject material during examinations.

After routine head shaving, skin preparation, and draping, the site of the skin incision was infiltrated with an adequate dose of local anesthetic not exceeding 100 ml to prevent lidocaine toxicity. After making the burr holes, the dura was infiltrated by placing cottonoids soaked with 1% procaine. During the incision and craniotomy, the patient was generally kept deeply anesthetized with an intravenous drip of low-dose propofol (100 mg/kg; Diprivan; Stuart Pharmaceuticals, Wilmington, Del., U.S.A.) and bolus injections of 0.5 to 1 ml fentanyl citrate/droperidol (Innovar; Janssen Pharmaceutica Inc., Titusville, N.J., U.S.A.). The effect of these agents is rapidly reversible within 5 to 20 minutes of discontinuation of the drip. If the dural incision caused discomfort to the patient, especially near the skull base, dural infiltration with 1% lidocaine was performed with a hypodermic needle in combination with dural immersion using 1% procaine-soaked cottonoid.

The patient was then allowed to awaken after the dura was opened. Tumor location was identified using ultrasonography (B & K Medical, Norderstedt, Germany) or open MR imaging (Odin Pole Star N-10; Odin Medical Technologies, Ltd., Yokneam, Israel). Electrocorctigraphy was also used to indicate the location of the tumors at the site of depressive waves. Monitoring of hemodynamic and respiratory parameters was used to adjust the depth of conscious sedation for the comfort of patients.

III. Direct cortical stimulation and electrocorctigraphy

Intraoperative cortical mapping was performed as previously described. Cortical stimulation was performed in all patients using a portable stimulator (model OCS-1; Radionics, Burlington, Mass., U.S.A.) with a bipolar probe consisting of electrodes 1 mm in diameter and spaced 5 mm apart (model OCS-P; Radionics) or the grid electrodes for the corctigraphy as shown in Fig. 1. The probe was connected to a constant current generator to produce bipolar square-wave pulses of 1 to 4 msec at 50 to 60 Hz. In addition, electrocorctigraphy was sometimes used coupled with the cortical stimulation to attempt maximum resection of epileptogenic tissue. The cortical stimulation was initiated with a current of 2 mA. If no responses were elicited at the 2 mA level, the current was gradually increased to as high as 10 mA in 0.5 mA steps. A trained observer was present to monitor carefully the response of the patient’s hands, face, and feet. The stimulation was performed in a systematic manner adjacent to the lesions. All sites were tested, marked with a sterile numbered label, and photographed for documentation. From the photographs, the positive and negative stimulation points were transferred to the schematic brain section.

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After completion of tumor resection, patients were resedated for closure of the craniotomy. Additional administration of local anesthetic agents was seldom necessary during closures of 4 to 5 hours duration. Postoperatively, the patient was generally awake and could be examined prior to leaving the operating room. The patient was usually kept in the intensive care unit overnight.

IV. Sensorimotor stimulation

Awake surgery allowed more sensitive information to be obtained, as the patients could also give subjective information, sometimes prior to the objective signs of twitching commonly seen as a positive response of cortical stimulation. As the stimulator probe was applied to the postcentral cortex for 1–2 seconds, the patients were asked to notify the examiners when or where paresthesias or abnormal sensations were experienced. Motor stimulation was initiated in the immediate suprasylvian motor cortex and proceeded towards the midline, sequentially identifying the pharynx, tongue, lips, thumb, hand, arm, and leg areas. Any evoked seizures were typically focal in nature and usually terminated within seconds. Iced Ringer solution was used to irrigate the stimulated cortex for 5–10 seconds. Prolonged seizures were to be controlled with intravenous injection of anticonvulsants, and the anesthetic team was ready for intubation. Fortunately, no prolonged seizures were experienced in our group of patients. As lesion resection proceeded, the subcortical motor fibers were identified by stimulation. Resections were extended to the cerebral areas showing stimulation-evoked movements, indicating the functional tissues that should be spared.

V. Speech monitoring

Prior to surgery, all patients were examined for language function, to exclude patients with marked language deficits, and to train and familiarize the surgical candidates with the language tests to be performed during awake craniotomy. The patients were shown a series of slides each containing a simple diagram. During surgical procedures, the same series of slides was shown to the patients and each selected cortical area was stimulated. The patients were asked to read aloud a phrase, and to name the object during the stimulation period of 4 seconds. The stimulation grid electrode was routinely placed on the surface of the temporal and frontal lobes, allowing stimulation of the superior temporal gyrus and the inferior frontal gyrus (Fig. 1). The language cortex was identified by blocking the ability to perform any language task such as naming objects. Areas where intraoperative stimulation evoked speech arrest were marked with indicating letters, and were subsequently spared during tumor resection.

Results

I. Clinical presentation

The clinical characteristics of the 21 patients are summarized in Table 1. The series consisted of 17 males and four females, ranging in age from 32 to 79 years (mean 52.6 years). All patients were right-handed. Awake surgery was performed for primary tumor in 14 patients and recurrent tumors in seven patients. Presenting symptoms were seizures in seven patients without neurological deficit, progressive mild deficit in 11 patients (4 motor deficits, 6 language disturbances, and 1 visual disorder), and
intracranial hypertension in two patients. One patient had no symptoms. Nineteen patients (90%) had a Karnofsky performance status (KPS) score of ≥80. Preoperative MR imaging showed 21 supratentorial brain lesions located on the right in one patient and on the left in 20 patients. The tumors were located as follows: five in paracentral areas, three in the insular cortex, nine in the temporal lobe, and four in the inferior frontal or temporal gyri. Histology was as follows: low-grade gliomas in eight patients (1 gemistocytic astrocytoma, 3 fibrillary astrocytomas, 3 oligodendrogliomas, and 1 oligoastrocytoma) and high-grade glioma in 13 patients (2 anaplastic astrocytomas, 1 anaplastic oligodendroglioma, 10 glioblastomas).

II. Extent of tumor removal

Postoperative surgical results are summarized in Table 2. All patients underwent awake open surgery with the goal of gross total resection. All patients were positioned in the supine position except for one patient in the sitting position. Surgery was performed using open MR imaging in four patients to confirm the extent of tumor removal intraoperatively. Gross total removal was performed in 18 patients, and subtotal removal in three patients because the tumor had invaded functionally

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### Table 1 Clinical presentation of 21 patients who underwent awake surgery for glioma removal

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age/Sex</th>
<th>Side</th>
<th>General location</th>
<th>Location in detail</th>
<th>Preoperative symptoms</th>
<th>Intraoperative monitoring</th>
<th>Open MR imaging</th>
<th>Functional MR imaging</th>
<th>Histology (WHO grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49/M</td>
<td>lt</td>
<td>T</td>
<td>middle temporal gyri</td>
<td>epilepsy, aphasia</td>
<td>speech</td>
<td>–</td>
<td>+</td>
<td>AAC (III)</td>
</tr>
<tr>
<td>2</td>
<td>41/M</td>
<td>lt</td>
<td>T</td>
<td>temporopolar</td>
<td>aphasia, hemianopia</td>
<td>speech</td>
<td>–</td>
<td>–</td>
<td>OLG (II)</td>
</tr>
<tr>
<td>3</td>
<td>32/F</td>
<td>lt</td>
<td>T</td>
<td>inferior frontal gyri</td>
<td>epilepsy</td>
<td>speech</td>
<td>+</td>
<td>+</td>
<td>AC (II)</td>
</tr>
<tr>
<td>4</td>
<td>61/M</td>
<td>lt</td>
<td>T</td>
<td>medial temporal gyri</td>
<td>aphasia, alexia</td>
<td>speech</td>
<td>–</td>
<td>+</td>
<td>GBM (IV)</td>
</tr>
<tr>
<td>5</td>
<td>51/M</td>
<td>lt</td>
<td>T</td>
<td>medial temporal gyri</td>
<td>epilepsy, aphasia</td>
<td>speech</td>
<td>+</td>
<td>+</td>
<td>GBM (IV)</td>
</tr>
<tr>
<td>6</td>
<td>54/M</td>
<td>lt</td>
<td>T</td>
<td>middle temporal gyri</td>
<td>epilepsy, aphasia</td>
<td>speech</td>
<td>–</td>
<td>–</td>
<td>OLG (II)</td>
</tr>
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<td>7</td>
<td>45/M</td>
<td>lt</td>
<td>T</td>
<td>insular</td>
<td>headache, aphasia</td>
<td>speech</td>
<td>–</td>
<td>+</td>
<td>OLG (II)</td>
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<td>8</td>
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<td>inferior frontal gyri</td>
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<td>speech</td>
<td>–</td>
<td>+</td>
<td>AAC (III)</td>
</tr>
<tr>
<td>9</td>
<td>79/M</td>
<td>lt</td>
<td>T</td>
<td>inferior temporal gyri</td>
<td>memory disturbance, aphasia</td>
<td>speech</td>
<td>–</td>
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<td>GBM (IV)</td>
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</table>


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### Table 2 Surgical outcome of 21 patients who underwent awake surgery for glioma removal

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Extent of removal</th>
<th>Clinical results</th>
<th>KPS score</th>
<th>Follow-up term (months)</th>
<th>Recurrence</th>
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<td></td>
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<td>Post</td>
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<td>90</td>
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<td>80</td>
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<td>T</td>
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<td>90</td>
<td>100</td>
<td>30</td>
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<td>80</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
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<td>T</td>
<td>unchanged</td>
<td>80</td>
<td>80</td>
<td>3</td>
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<td>100</td>
<td>100</td>
<td>12</td>
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<tr>
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<td>improved</td>
<td>90</td>
<td>90</td>
<td>12</td>
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<tr>
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<td>19</td>
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<td>20</td>
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<tr>
<td>21</td>
<td>T</td>
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</table>

important motor/speech areas as identified by intraoperative cortical stimulation.

III. Postoperative clinical course
There was no operative or postoperative mortality. Postoperative findings included no symptom changes in 10 patients, improvement of the preoperative deficit in 11 patients. Four patients had increased KPS scores after surgery, 17 patients were stable, and no patient had lower KPS scores.

IV. Representative cases
Case 5: A 51-year-old right-handed male had experienced partial seizures for 1 month with aphasia. Preoperative MR imaging showed a tumor located in the left superior and middle temporal gyri with ring-like enhancement (Fig. 2A–C). Awake surgery with language mapping was performed to minimize the risk of neurological sequelae (Fig. 2G, H). The postoperative course was uneventful with neither motor nor language deficit. The histological diagnosis was glioblastoma (World Health Organization [WHO] grade IV). Postoperative radiation therapy and adjuvant chemotherapy were performed. Three months after the first operation, follow-up MR imaging showed tumor regrowth in the same loca-

Fig. 2 Case 5. A–C: Preoperative coronal (A), sagittal (B), and axial (C) T1-weighted magnetic resonance (MR) images with contrast medium showing a left temporal lesion with ring-like enhancement located within the superior and middle temporal gyri. D–F: Postoperative coronal (D), sagittal (E), and axial (F) T1-weighted MR images with contrast medium showing total tumor removal. The patient showed no clinical worsening. G, H: Intraoperative photographs obtained before (G) and after resection (H) indicating the functional sites (numbers). The resection was restricted using the functional boundaries.

Neurol Med Chir (Tokyo) 45, October, 2005
Fig. 3 Case 11. A–C: Preoperative axial (A), coronal (B), and sagittal (C) T1-weighted magnetic resonance images with contrast medium showing a left insular tumor manifesting as episodes of speech arrest. D, E: Postoperative computed tomography (CT) scans without (D) and with contrast medium (E) after awake surgery showing total tumor removal. Histological examination indicated glioblastoma multiforme. F: Follow-up CT scan with contrast medium 8 months after surgery revealing no recurrence.

Case 11: A 55-year-old male presented with partial seizures without other signs of neurological abnormality. Preoperative MR imaging showed a left insular tumor with ring-like enhancement (Fig. 3A–C). Awake surgery with language mapping was performed. The postoperative course was uneventful. Postoperative CT showed gross total removal of the tumor (Fig. 3D, E). The histological diagnosis was glioblastoma (WHO grade IV). Postoperative radiation therapy and adjuvant chemotherapy were performed. Eight months after surgery, follow-up CT with contrast medium revealed no recurrence (Fig. 3F). Two years after the first operation, follow-up MR imaging showed tumor regrowth in the same location (Fig. 4A, B). Consequently, the same surgical procedure was performed. Total removal was performed (Fig. 4C). The patient showed no clinical worsening and lives a useful life independently.

Discussion

Cortical stimulation can evoke local excitation, inhibition, or activation of fiber tracts leading to distant excitation or inhibition, suggesting that cortical stimulation affects a focal cortical area and depolarization will evoke certain responses particular to specific cortical regions. Direct cortical stimulation during awake surgery allows the precise location of functional sites intraoperatively, and has improved postoperative functional results. In our series, gross total removal was performed in 18 patients, and subtotal removal in three patients, but no patient showed clinical worsening during the postoperative course.

The cortical language sites are difficult to determine during general anesthesia, because the classical concept of the constant localization was...
Fig. 4 Case 11. A, B: Axial (A) and sagittal (B) T1-weighted magnetic resonance images with contrast medium 2 years after the first operation showed recurrent tumor manifesting as speech disturbance, which improved markedly with high dose dexamethasone. Arrow indicates the primary operative field (B). C: Postoperative computed tomography scan with contrast medium showing gross total removal of the recurrent tumor without neurological deficits.

proven to be untrue. The spatial localization of language areas shows large individual differences. The essential language area is organized in discrete mosaics that occupy a much smaller area than described by the traditional language maps. Cortical stimulation identified wide variations in localization of language area, and showed that the language sites are located within 3 cm of the temporal lobe tip in the superior and middle temporal gyri. The superior temporal gyrus contains significantly more language sites than the middle temporal gyrus. Therefore, the resection margin from the nearest language site (more than 1 cm) may be the most important variable in determining postoperative language deficits.

The insular cortex is a complex anatomical structure that participates in sensory-motor functions, limbic integration, and auditory-vestibular functions. Recent studies suggested that the dominant insular cortex constitutes an essential language area, particularly implicated in speech coordination and verbal working memory. Electrophysiological studies have also shown that the dominant insular cortex is important in language. Consequently, cortical stimulation mapping should aid in maximizing the extent of tumor removal in insular structures. In our series, two patients had tumors located within the insular cortex including Case 11 (Figs. 3 and 4). These patients showed no clinical worsening and postoperative CT showed gross total removal. Therefore, we suggest that sensory-motor function and speech function should be monitored in the awake condition during resection of tumor in the insular cortex.

The supplementary motor area (SMA) is located rostral to the primary motor cortex and occupies the medial surface of the superior frontal gyrus. The SMA can be subdivided into the pre-SMA (anterior part) and the SMA (posterior part). The SMA is also involved in the initiation of speech, speech timing, and control of phonation. The pre-SMA is activated early in the preparation period, whereas the SMA is activated only with movement execution. SMA syndrome, confirmed as transient contralateral weakness and aphasia after surgical resection of tumors involving the SMA, is well known. A recent study recommended awake surgery with cortical mapping of motor and speech function to resect tumors involving these areas. The topography and severity of the postoperative neurological deficits correlate to the extent of the SMA resection. In addition, a permanent motor deficit rather than transient SMA syndrome is likely to develop if the posterior resection line is less than 5 mm from the precentral sulcus or from positive stimulation points. However, the mechanisms of expression and resolution of SMA syndrome still remain obscure. Further investigation will be needed to establish the method to prevent this syndrome.

Prediction of functional organization using classical anatomical criteria is not reliable. The individual variability caused by the mass effect and functional reorganization provides a mechanism of compensation in slow growing lesions due to the recruitment of parallel networks. Interestingly, recent studies suggest that functional reshap-
ing or brain plasticity might be induced intraoperatively by surgical resection of the tumors.\textsuperscript{17,21} The surgical procedure itself could induce GABAergic inhibition and N-methyl-D-aspartate receptor-mediated excitation that support synaptic plasticity, previously described in brain injury.\textsuperscript{49} Different approaches may be useful for preoperative functional mapping as mentioned above.\textsuperscript{2,11,25,30,35} However, considering intraoperative functional reshaping, the results may not be identical in pathological conditions. Therefore, we suggest that intraoperative functional mapping with cortical stimulation is mandatory to perform tumor resection in eloquent areas.

Cortical stimulation methods cannot prevent postoperative transient neurological worsening if the tumor resection is pursued close to the functional networks (1 patient in this series). Such worsening might be caused by postoperative edema, vascular damage, or hemodynamic perturbations. Other possible causes of transient deficit may involve damage to white matter tracts beneath the eloquent cortex. Gliomas usually show infiltrative progression along the white fibers.\textsuperscript{27} Neurological deficits may occur after tumor removal because of surgical damage to pathways running through the white matter.\textsuperscript{11,13,34} Despite developments in functional mapping methods, the actual mapping of white fibers remains impossible for technical reasons. More recently, intraoperative electrical subcortical mapping was useful to resect gliomas located within eloquent areas in a series of 103 patients.\textsuperscript{18} There was no postoperative neurological deficit due to the interruption of the white fibers. Further investigations will determine the efficacy of these methods to preserve white fibers during the resection of gliomas.

The advantages of awake craniotomy include a low complication rate due to the avoidance of general anesthesia. Awake craniotomy can reduce the infection rate, operation time, and cost for postoperative intensive care monitoring because there is no loss of consciousness or endotracheal intubation.\textsuperscript{7,53} On the other hand, many neurosurgeons might think that these procedures are too difficult for patients to tolerate. Several studies have suggested that there were no anesthetic complications or intraoperative problems with airway maintenance, ventilation, hypertension, or brain swelling.\textsuperscript{14,15} In these series, about 50% of the patients had no complaints, and 25% expressed minor difficulties during awake craniotomy. The most painful part of the procedure is the placement of the head frame, which may be due to the anxiety at the very beginning of the procedure. We should be very careful to achieve adequate local anesthesia of the wound in this part of the operation. In addition, the patients tend to complain of pain or discomfort during sawing away of the bone flap with the craniotome, breaking the bone flap at the time of removal, especially during these procedures at the skull base, and surgical manipulation at the proximal parts of the sylvian fissure. This part of procedure may be better tolerated with conduction anesthesia by blocking the gasserian ganglion. Every effort should be made to make the patients as comfortable as possible and to obtain the most favorable access to the patient for intraoperative testing and anesthetic care during awake surgery.

Awake craniotomy with intraoperative cortical mapping results in excellent surgical outcome after the removal of gliomas located in eloquent areas. It is important to realize that this technique should be undertaken with special precautions and that perioperative interdisciplinary preparation is mandatory. Further investigations and experience will improve the surgical outcome and better comfort for the patients.

Acknowledgment

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Commentary

The authors have to be congratulated for their good results in their difficult surgery at the neighbourhood of eloquent (sensory-motor or speech) areas. As a matter of fact, anatomical, if not oncological, gross total removal of the tumor was achieved in 18 of the 21 cases. No patient was worsened. We find this paper useful as it demonstrates the importance of having awake surgery for mapping functional areas with direct cortex stimulation in the current armamentarium for brain surgery. Also, the authors emphasize the interest to apply the technique not only to the gliomas.
near the motor and the speech areas but also the insular and SMA regions. Besides, anesthetic procedures and the technique of stimulation with the appropriate parameters are clearly described.

The authors were fortunate not to have provoked prolonged seizures. Not only seizures can be dangerous, due to acute brain swelling, but also hamper the reliability of the method by inducing a refractory period to further stimulations, the more so as cooling of the cortex has to be done for stopping the fits. In their discussion, authors are wise to mention the limitation of cortical stimulation that does not concern the white matter subcortical tracts. But fiber tracking is at present in the research and development process; little doubt that this will be available in a reliable way, soon, at least for motor fibers. To finish with, we have to keep in mind that a “non-responding” area to stimulation can be, at least partly, a “silent” (but reversibly) functional area, especially in the vicinity of a mass lesion.

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The study aim of this article is kind. Authors hope to provide a new useful surgery way to make patients comfortable, and to reduce the infection rate, operation time, and cost for postoperative intensive care monitoring by no loss of consciousness or endotracheal intubation, during therapy of glioma resection. Therefore, the “awake surgery” was mentioned. However, there are some problems in this manuscript as bellows. 1. No obvious view to bring new ideas. “Awake surgery” was mentioned by Karinthy F etc. in early 1958. 2. It will be much better if showing the electrocorticography maps, sensorimotor stimulation information recorder data, etc. in this manuscript. 3. No control or comparison during mentioning the advantages of awake craniotomy, between with and without awake surgery.

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