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Original Investigation

Technique of Localizing the Central Sulcus under Awake Anesthesia for Treatment of Gliomas in or near Motor Areas

Wan YI[1,2], Shujun XU[2], Xingang LI[2], Xiangyu MA[2]

[1]Kowloon Hospital of Suzhou Affiliated to Shanghai Jiao Tong University, Department of Neurosurgery, Suzhou, China
[2]Qilu Hospital of Shandong University, Department of Neurosurgery, Jinan, China

Corresponding author: Xiangyu MA ✉ qilumaxiangyu@126.com

ABSTRACT

AIM: To study the protective effect on motor function of intraoperative awakening and localizing the central sulcus during surgery in patients with gliomas located in motor areas.

MATERIAL and METHODS: A total of 68 patients with gliomas in motor areas were intubated with a laryngeal mask and rapidly underwent craniotomy without scalp clips and with surgical awakening, followed by localization of the central sulcus by somatosensory evoked potential. To protect brain function, we resected the greatest degree of tumor possible, and then finished by closing the skull with the patient in an awake state or under general anesthesia.

RESULTS: All the patients underwent surgery successfully. Except for the emergence of new neurological dysfunction in six patients, most patients' neurological function did not deteriorate, or even showed improvement. In addition, there were no complications or postoperative painful memories for the patients. The resection of gliomas in motor areas with intraoperative awakening and localization of the central sulcus can ensure the largest possible resection of the tumor while protecting brain function.

CONCLUSION: Here, we describe a simple and effective surgical procedure for patients with glioma. The technique involves localizing the central sulcus under awake anesthesia, which can improve the prognosis for patients with gliomas in motor areas.

KEYWORDS: Awake anesthesia, Central sulcus, Eloquent brain region, Glioma

■ INTRODUCTION

Glioma is the one of the most common intracranial malignant tumors. Evidence-based medicine shows that its prognosis is closely related to the percentage of resection (11). However, if gliomas invade the motor areas near the central sulcus, there may be complications when attempting to achieve maximal resection of the tumor while protecting brain function (12). The single-minded pursuit of the largest resection will seriously affect the patient's postoperative neurological function and quality of life, which obviously counteracts the desired benefit of prolonged survival. A huge challenge for neurosurgeons is balancing the extent of tumor resection and nerve function protection.

Awake craniotomy and neuropsychological examinations have played important roles in the surgery of glioma in eloquent areas (2). A series of 68 patients with gliomas located in motor areas were selected from the Department of Neurosurgery of Qilu Hospital of Shandong University and underwent surgery with awake craniotomy and neuropsychological examinations, which are reported here in this study.

■ MATERIAL and METHODS

Patient Information

A total of 68 patients who met the enrollment criteria were selected from January 2014 to August 2016, including 36 men and 32 women, ranging in age from 24 to 66 years

Wan YI : 0000-0002-3933-699X
Shujun XU : 0000-0002-0229-4642
Xingang LI : 0000-0003-4534-4010
Xiangyu MA : 0000-0002-6904-0719

(average age: 52 years) (Table I). A Karnofsky performance status score was determined, ranging from 80 to 100, and produced an average score of 90.56 points. The preoperative clinical symptoms included 25 cases of headache, 10 cases of dizziness, 15 cases of epilepsy, 11 cases of limb weakness, and 7 cases of limb numbness. Preoperative brain magnetic resonance imaging (MRI) examinations confirmed that all the lesions were located near the central sulcus, including 36 cases on the left side and 32 cases on the right side. With respect to the brain layers violated, 38 cases were located in the cortical surface, whereas 30 cases were deep in the white matter. The largest tumor diameter ranged from 2.0 to 5.5 cm, with an average of 3.3 cm.

Surgical Procedure

Before surgery, the following information was provided to the patients (2,3,9):

1) The procedure of the awake craniotomy
2) The importance of the intraoperative neuropsychological examinations to the location and protection of motor areas
3) The possible risks and complications during the anesthesia and surgery
4) The possible adverse reactions during surgery, such as headache, dry mouth, and shivering.

Finally, the enrolled patients were informed of the preoperative trainings, which included tasks that needed to be completed during the surgery, such as naming and describing functions of the subject of certain images and answering questions.

Table I: Clinical Characteristics

	n (%)
Age (years)	
<55	38 (56.0)
≥55	30 (44.0)
Gender	
Male	36 (53.0)
Female	32 (47.0)
Symptoms post-operation	
No change	62 (91.0)
Aggravate	6 (9.0)
Pathological type	
WHO Grade II	9 (13.0)
WHO Grade III	21 (31.0)
WHO Grade IV	38 (56.0)
Extent of surgery	
Total resection	36 (53.0)
Subtotal resection	23 (34.0)
Partial resection	9 (13.0)

The surgical procedures were performed as follows (Figure 1A-F). First, general anesthesia was provided through an intubated laryngeal mask airway to pull out easily during the intraoperative awakening; the anesthesiologist also applied nerve block anesthesia according to the site and location of the incision and head fixation. The appropriate site for the surgical incision and the patient's posture were selected according to the tumor location. Generally, the supine or lateral position was selected, with a 30-degree elevation of the upper body, and with the head appropriately rotated to the opposite side of the surgery to make sure the patient could easily complete the tasks during the awakened state. The head was fixed with a neurosurgical head frame. Conventional disinfecting of the skin around the surgical incision was applied, including laying the sterilized sheet with the anesthesia rack to set aside enough space toward the patient's facial direction, to pull out or insert the laryngeal mask conveniently for the anesthesiologist, and to observe the patient and carry out the functional tests. For the craniotomy, the surgical incision was infiltrated with a mixed liquid of lidocaine, ropivacaine, epinephrine, and physiological saline; the scalp was opened without scalp clips; the skull was exposed and the bone flap removed; and the dura mater was infiltrated with a 1% lidocaine cotton sheet for 3 to 5 minutes and incised with the figure "+" or a "U" shape. For electrophysiological localization, the anesthetist stopped the injection of propofol to wake up the patient, the laryngeal mask was pulled out, and the electrophysiological monitor (Endeavor Bravo, Nicolet, USA) was used to localize the functional areas (i.e., to place the cortex electrode on the exposed cortex and locate the central sulcus through the change of the wave peak) (12). Resection of the tumor under awake anesthesia was performed with a microscope to avoid the motion areas in front of the central sulcus: and, at the same time, the language and limb movement of the patient was monitored. After resection of the tumor, the final procedures were completed, such as hemostasis, suturing the dura, fixing the bone flap, and suturing the scalp closed. These procedures can be completed under general anesthesia.

■ RESULTS

Among the 68 patients in our group, 60 patients had their central sulcus localized with neuroelectrophysiology. Post-operative pathology showed astrocytoma World Health Organization (WHO) grade II in nine cases, WHO grade III in 21 cases, and WHO grade IV in 38 cases. Sixty-two patients had no new impaired neurological symptoms after the surgery, whereas the remaining six patients had new neurological symptoms. One month after the surgery, the emergence of new postoperative neurological symptoms disappeared in three patients, and three patients experienced postoperative relief. Six months later, among the patients with emergence of new neural symptoms, only two patients were not improved. Total tumor resection was achieved in 36 cases, subtotal resection in 23 cases, and partial resection in 9 cases.

■ DISCUSSION

The prognosis of patients with glioma is closely related to the degree of tumor resection (5,10). Resection of the maximum tumor while protecting neurofunctioning is the basic principle for the surgical treatment of glioma (7). Currently, the most widely used monitoring technologies include sensory evoked potential (SEP), motor evoked potential (MEP), brain stem auditory evoked potential (BAEP), electromyography (EMG), and intraoperative electrocorticography monitoring (ECoG) (2,3,9). Among them, SEP is often used in the localization of the central sulcus. The principle is when stimulating the peripheral nerve (e.g., the median nerve, tibial nerve) under general anesthesia, SEP could be recorded on the cerebral cortex surface. According to the phase inversion before and after the central sulcus, the sensory and motor cortex could be distinguished. The technology of intraoperative awakening with central sulcus localization technology could increase the safety of surgery and reduce injury. The goal of minimally invasive neurosurgery is not only a small incision, but also the protection of nervous system functions. The concepts of functional protection and minimal invasion should be implemented in all neurosurgical interventions. Through the individualized nervous function localization, the surgeon can achieve the largest degree of tumor resection while monitoring and protecting the patient, which could effectively avoid permanent neurological damage after surgery and significantly increase the patient's quality of life (2,3,9).

The position of the central sulcus could be initially determined by preoperative imaging. However, during surgery, the limited bone window and insufficient brain exposure make it difficult to distinguish the central sulcus through the discontinuous cortex. As a result, the protection of the motor areas cannot be achieved (8). Intraoperative neurophysiological monitoring can provide more reliable localized information, which can avoid injury to the function areas caused by the surgeon's subjective judgment (Figure 2A-D). Resection of tumors near the central sulcus and with a deep location has been the neurosurgeon's eternal hydra in the surgical treatment of glioma (5,11). Intraoperative awakening with central sulcus localization can design a cortex surgical approach (Figure 3A-I). Among the enrolled 68 patients, 8 patients had failure to position the central sulcus, and previously, there were reports about the failure to localize the central sulcus. Through analysis, Cedzich et al. attributed this to the brain shift caused by the occupied effect of the tumors or sensorimotor cortex deviation from the normal anatomical position caused by brain tissue edema (1).

As for the cerebral cortex, damage to white matter fiber bundles could also lead to obvious neural dysfunction. Therefore, a mastering of the walking direction and degree of compression by the tumor on the fiber bundle is of great importance in designing the proper surgical treatment and judgment of the resection degree (4). Neuroimaging techniques, brain white matter tractography techniques, the basis of diffusion

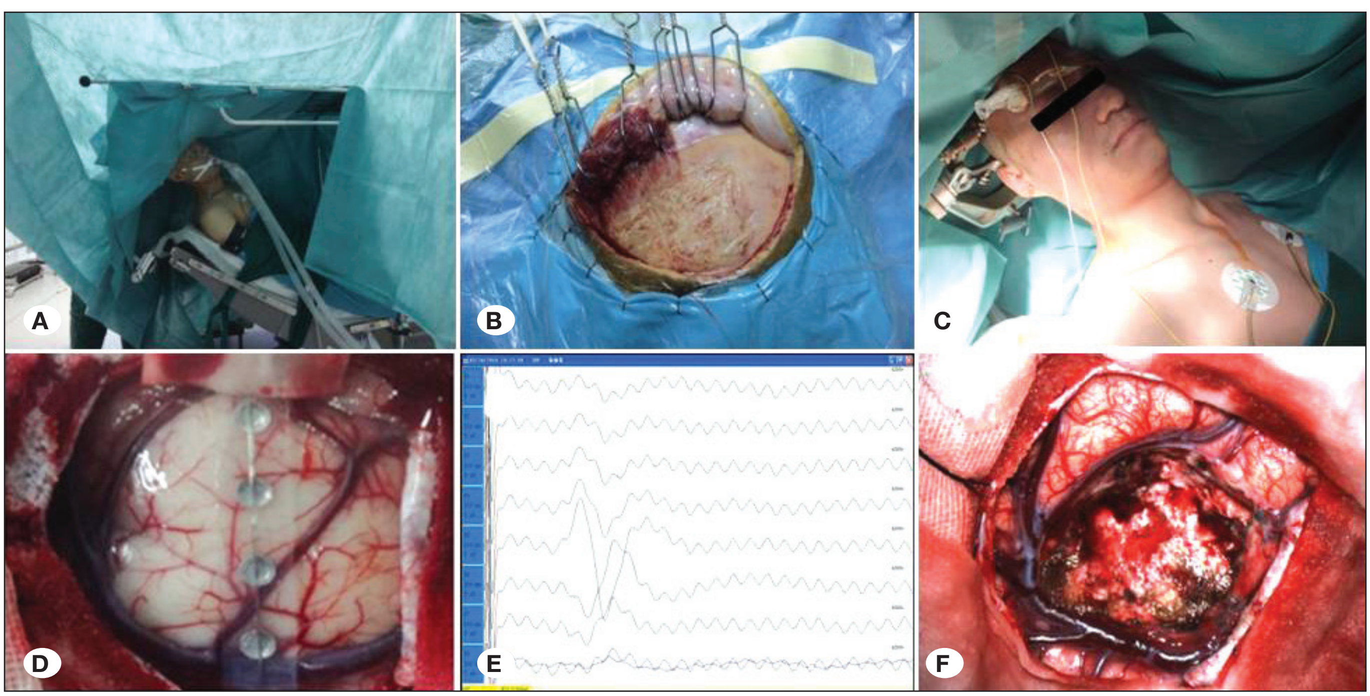

Figure 1: The procedure of the intraoperative awakening surgery with resection of glioma in a motor area. **A)** Taking a supine position and 30-degree elevation of the upper body, the patient's head was fixed with operating racks. Enough space directed to the face was retained to make sure the anesthetist could smoothly finish extubation, and the patient could easily complete tasks during the awake state. **B)** Craniotomy without scalp clip. **C)** When the patient was awakened, the anesthesiologist was asked to unplug the laryngeal mask. **D,E)** Electrophysiological monitoring. Cortical electrodes were placed in the exposed cortex. Localization of the central sulcus by the phase inversion of the crest. **F)** Resection of the tumors under microscope to avoid injuring the motor areas in front of the central sulcus.

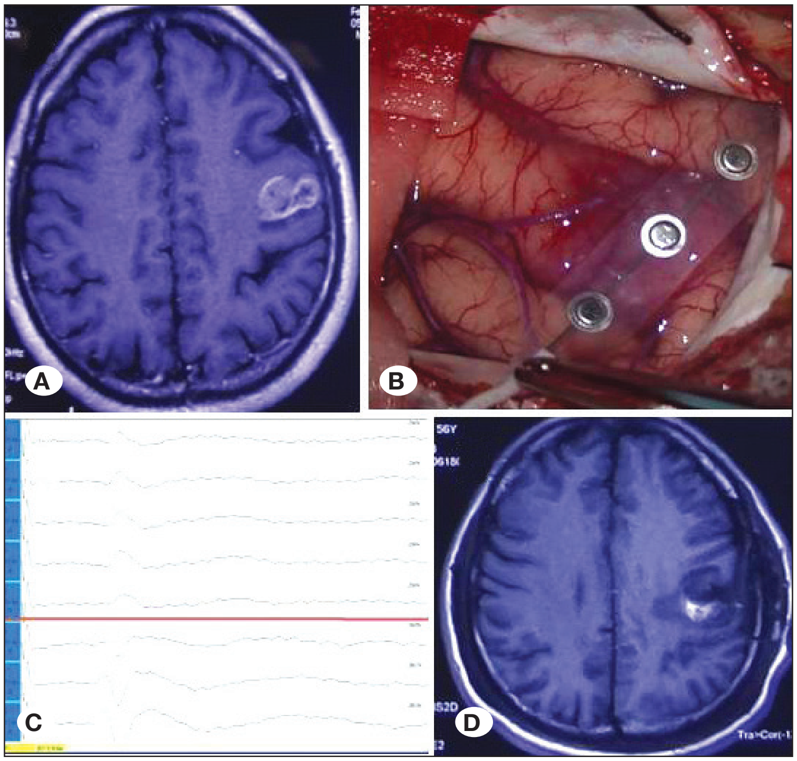

Figure 2: Tumor resection area with the application of the central sulcus localization technology.
A) Brain MRI showed the lesion was located in the left frontal lobe with enhanced MRI scan showing obvious heterogeneous enhancement. Preoperative MRI showed the lesions suspiciously involved the anterior central gyrus, which contradicted the patient's symptoms of right facial numbness.
B,C) With the technology of localization of the central sulcus, the lesions were proven to be located in the postcentral gyrus, which ensured the largest resection of tumors and protection of the precentral gyrus. The red line shows the central sulcus boundary.
D) Postoperative brain MRI showed the lesion totally removed, and the patients have no movement disorder of the limbs.

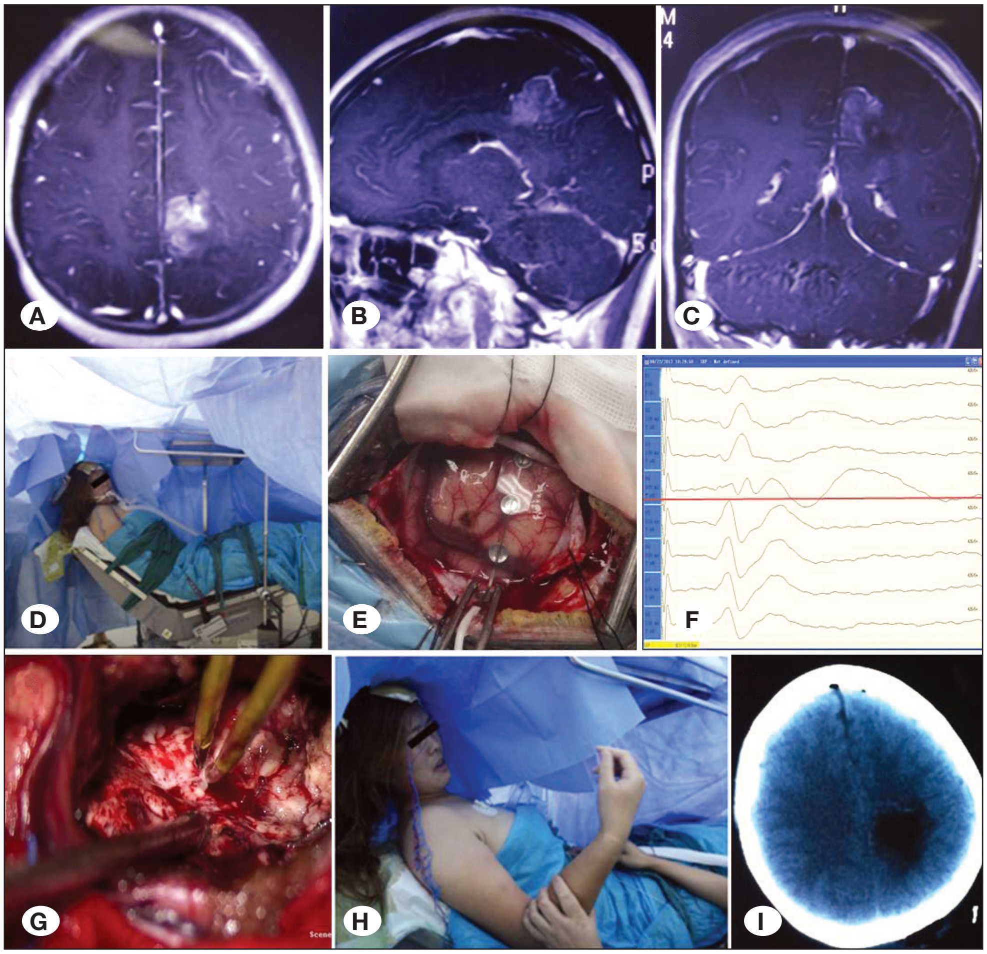

Figure 3: Choose a relatively safe surgical approach with the application of central sulcus localization.
A-C) Sagittal, axial, and coronal MRI scans showed the lesion located in the parietal lobe. Due to its short distance to the motor areas, damage to the limb movement function is difficult to circumvent without localization of the central sulcus.
D) The patient takes a supine position with the head inclining to the contralateral side of the lesion.
E-F) The central sulcus localized between the 4 and 5 electrode (the red line). As a result, the exposed cortex in bone window was located posterior to the postcentral gyrus.
G-H) Total resection of the tumor under microscope. The patient was asked to move the right limbs intraoperatively and maintain an awakened state.
I) Postoperative CT showed the tumor totally resected, and the patient maintained good activity of the limbs.

tensor imaging technology, and the three-dimensional shape structure of the white matter tracts to the T2-weighted image graph can clearly display the position of the tumor and guide the relatively safe resection of the tumor (6). In this group of patients, cerebral magnetic resonance diffusion tensor imaging and brain functional MRI were performed in patients with preoperative imaging that showed tumors dispersed or deep in the white matter. Combined with the intraoperative central sulcus positioning, tumors were guided to be resected without damaging the motor areas.

The successful surgery using awakening anesthesia needs cooperation between the neurosurgeon and the anesthesiologist. The anesthesiologist plays an important role in mastering the degree of anesthesia, judging when to extubate, and monitoring and controlling vital signs of the patient. With regard to the components that the anesthesiologist needs to monitor, a unified standard does not presently exist. In our surgery, key factors that will influence the localization of the function areas, such as the patient mood, sedation state, reaction to pain, and intracranial pressure state, are the highlights of our monitoring.

Intraoperative incision is the main source of pain during the awake state. Using ropivacaine for nerve block, incision infiltration not only achieves good analgesic effect and lower toxicity, but the long duration could also have short-term analgesic effects after the surgery (6). The local anesthetic formulations of Qilu Hospital of Shandong University consist of 20 mL of 2% lidocaine, 10 mL of 75 mg ropivacaine, 0.5 mg of epinephrine, and 30 mL of physiological saline. All 68 patients in this group underwent fast craniotomy with no Raney clips, and the total length of opening and closing the skull (including the process of suturing the dura water tightly) was less than an hour. Thus, craniotomy without Raney clips can significantly improve the quality of craniotomy, shorten the time, avoid lasting entrapment of the scalp, and reduce the pain from the surgical incision.

Although the technique mentioned in our article is not new and actually has been widely adopted by neurosurgeons across the world, we describe a process of intraoperative awakening and central groove location. An additional benefit to the patient is reduced medical expenses.

■ CONCLUSION

Intraoperative awakening combined with electrophysiological monitoring can offer a relatively safe surgical approach and rational plan for tumor resection by determining the position of the central sulcus and motor areas, which could achieve the greatest tumor resection while protecting the patient's nervous functions. The authors describe a simple and effective surgical procedure for the surgery of the central sulcus and awakening during the operation. This technique can be used for reference in the Department of Neurosurgery without brain mapping conditions.

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