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Safe Removal of Glioblastoma Near the Angular Gyrus by Awake Surgery Preserving Calculation Ability

—Case Report—

Masanori KURIMOTO, Takashi ASAHI, Takashi SHIBATA, Chiaki TAKAHASHI, Shoichi NAGAI, Nakamasa HAYASHI, Mie MATSUI*, and Shunro ENDO

*Departments of Neurosurgery and *Psychology, University of Toyama, Toyama, Toyama*

Abstract

A 67-year-old patient presented with progressive agraphia, alexia, and impaired ability to calculate persisting for 4 weeks. He showed preserved ability to do single-digit addition and subtraction. Magnetic resonance imaging demonstrated a tumor in the left parietal lobe. A malignant glioma was suspected, and awake craniotomy was performed to remove the tumor with functional cortical mapping to determine the cortices involved in calculation and language. His calculation ability was mapped on the angular gyrus, and partial resection of the tumor was achieved without deterioration of that ability. The histological diagnosis was glioblastoma multiforme. The patient's calculation ability improved dramatically after the operation.

Key words: awake surgery, glioma, parietal lobe, Gerstmann's syndrome

Introduction

Extensive tumor resection is associated with an improved prognosis for patients with malignant astrocytomas,[1,2,14-16,24,25] but the effect for patients with malignant gliomas remains controversial. Resection of malignant astrocytomas close to the eloquent areas of the brain is likely to be less radical, and tumors in such areas may progress more rapidly. Therefore, the outcome for these patients is very poor. Functional cortex and subcortical white matter may be located within the tumor or in the adjacent infiltrated brain.[26] Postoperative neurological deficits after extensive tumor resection may result from retraction, edema, and/or resection of the eloquent tissue.[19,29]

Image-guided neurosurgery, preoperative functional magnetic resonance (MR) imaging, and intraoperative functional mapping methods can facilitate maximal resection of the tumor around the eloquent brain.[11,13,15,19,22,26,27,29] Awake craniotomy is now being revived for functional brain mapping and aggressive tumor resection around the eloquent cortex.[19,26,27,29] Motor and language functions are usually mapped during awake surgery using cortical and subcortical mapping to maximize resection and minimize neurological morbidity.[19] So far, very few attempts have been made to map the calculation center during surgery.[9,21]

We describe a case of surgical resection of glioblastoma located near the left angular gyrus, using awake surgery with functional mapping of language and calculation functions.

Case Report

A 67-year-old, right-handed man presented with progressive agraphia, alexia, and impaired calculation ability persisting for 4 weeks. He showed preserved ability to do single-digit addition and subtraction. Neither right and left disorientation nor finger agnosia was observed. MR imaging demonstrated a tumor in the left parietal lobe (Fig. 1). Left carotid angiography showed a highly vascularized tumor with early venous filling (Fig. 2). The tumor appeared to be malignant and located in the dominant hemisphere. We planned extensive resection which carried the risk of Gerstmann's syndrome, aphasia, and apraxia. We provided extensive explanations to the patient and his family about the risk to the quality of life. They agreed to

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Fig. 1 T$_1$-weighted magnetic resonance images with gadolinium demonstrating a tumor in the left parietal lobe.

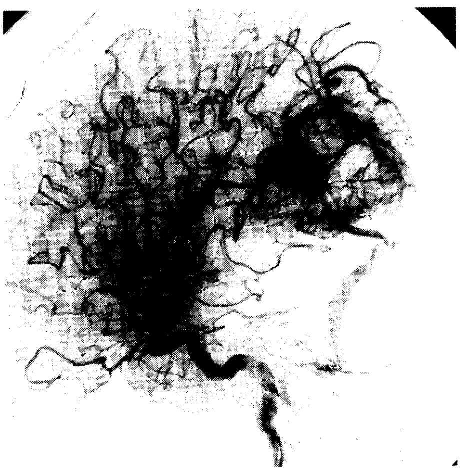

Fig. 2 Left carotid angiogram showing a highly vascularized tumor with early venous filling.

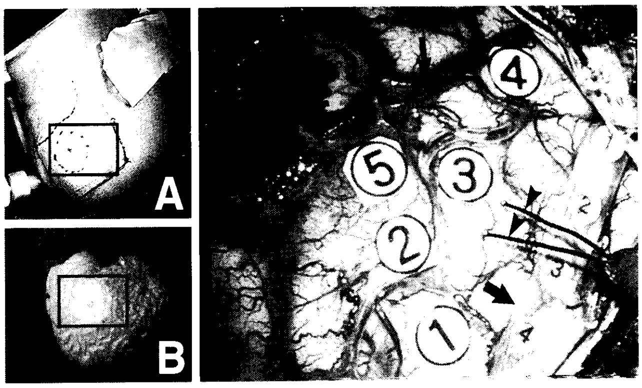

Fig. 3 Intraoperative photographs. A: Head, skin incision, and tumor location assessed by navigation. B: Three-dimensional computer graphics constructed by navigation. C: Brain surface and brain tumor (T). The number tags show the sites tested by cortical stimulation. Sites 2 and 5: calculation areas, 4: language area (Wernicke), and 1 and 3: nonfunctioning areas. *arrow*: superior temporal sulcus, *arrowheads*: electrical stimulator, *thick arrow*: electrode for electrocorticography.

our proposal to perform awake surgery with intraoperative functional mapping to remove as much as tumor possible while minimizing the risk of neurological deficits.

Anesthesia was induced with intravenous administration of propofol (1–3 mg/kg) and fentanyl (5 μg/kg). After the patient fell asleep, a laryngeal mask was inserted into the airway.[10] The patient was then placed in a lateral position. Before the head was fixed with a Mayfield head-holder, each pin site was injected with 5 to 7 ml of 0.25% bupivacaine with 0.5% lidocaine and epinephrine 1:200,000. The tumor and the skin incision were located with the aid of an image-guided device (EVANS; Tomiki Medical Instruments, Kanazawa, Ishikawa).[11] The scalp was anesthetized with the same anesthetic mixture. After the craniotomy and dural incision, propofol administration was terminated. The patient then became alert and the laryngeal mask was removed. Orientation of the cortical regions exposed was facilitated by intraoperative neuronavigation (EVANS) and the cortices were directly stimulated with a bipolar electrode using the Neuropack M1 electrical stimulator (Nihon Kohden, Tokyo). The current amplitude was progressively increased by 1 mA, beginning at 1 mA. We used a standard procedure of stimulation with biphasic square-wave pulse of 1 msec at 60 Hz, with a duration of 3 sec.

The tumor was well delineated by the surrounding sulcus on the brain surface (Fig. 3). The vein of Labbé ran anteroinferior to the tumor. The angular gyrus is anatomically defined as the gyrus surrounding the peripheral ascending ramus of the superior temporal sulcus, so the tumor was located at the inferior parietal gyrus just lateral to the angular gyrus. Therefore, the tumor had invaded the inferior part of the angular gyrus. Functional mapping was performed while the patient engaged in simple addition and subtraction, object naming, repetition, and spontaneous conversation. The largest current that permitted identification of the functional cortical sites was 5 mA. The results of the functional mapping as follows (Fig. 3). Single-digit addition and subtraction were disturbed in sites 2 and 5, suggesting the angular gyrus. Paraphasia, disturbance of object naming, and disturbance of repetition occurred in site 4. In addition to the anatomical location, site 4 was considered to be part of the

Fig. 4 Intraoperative photograph just after removal of the brain tumor.

Fig. 5 Early postoperative T_1-weighted magnetic resonance images with gadolinium revealing the remnant at the anteromedial part of the original tumor.

posterior language area (Wernicke). Writing was not performed, because the patient had agraphia. Right and left orientation and finger recognition tasks were not done due to the time limit. After the cortical mapping, a cortical incision was made around the tumor. During the resection, the patient was awake and well oriented, and was asked to give verbal responses for neurological monitoring. Finally, the tumor was partially resected to preserve calculation ability (Fig. 4).

The immediate postoperative course was uneventful. Early postoperative MR imaging revealed the remnant anteromedial part of the tumor (Fig. 5). The patient underwent radiochemotherapy. Neuropsychological examination 1 month after the operation revealed improved calculation ability. The patient's ability to calculate extended to multiplication and division in addition to difficult addition and subtraction. His alexia and agraphia were slightly improved. Postoperative Karnofsky performance status was 70% and the patient did well for 13 months, taking care of himself at home. However, the patient abruptly became delirious and MR imaging demonstrated subarachnoid tumor dissemination. He died 14 months after the operation.

Discussion

The inferior parietal regions in the dominant hemisphere are strongly involved in mental calculation. Acalculia may be associated with other cognitive dysfunctions, such as aphasia, alexia, and apraxia, depending on the location of the left parietal lesion, such as the angular gyrus and the supramarginal gyrus. The combination of finger agnosia, right and left disorientation, acalculia, and agraphia is well known as Gerstmann's syndrome.[4,12] Recent advances in functional MR imaging and positron emission tomography studies have provided more detailed and complex topographical knowledge of mental calculation. The bilateral intraparietal sulci, angular gyrus, and the precentral gyrus are involved in the mathematical process.[7,21] This widespread involvement can be explained by the fact that calculation ability represents a multifactor skill that integrates verbal, spatial, memory, body knowledge, and executive function abilities.[3]

Studies of patients with damage to the left parietal brain revealed that arithmetic impairment often affects multiplication more severely than subtraction.[5–7,17,20] On the other hand, several cases showed subtraction to be more severely affected than multiplication.[8,18,28] This complex phenomenon seems to depend on the involvement of the surrounding brain tissues, especially the intraparietal sulcus and the supramarginal gyrus. Our patient also presented with more severe impairment of multiplication than of subtraction and addition. In addition, he had alexia with agraphia, which was caused by involvement of the angular gyrus. Interestingly, angular alexia with agraphia may be the result of damage to the adjacent lateral occipital gyri.[23] In the present case, the lesion was located in the posterolateral part of the angular gyrus and extended toward the lateral occipital gyri.

Only few attempts have been made to localize the calculation center in the left parietal lobe.[9,21] A left parieto-occipital glioma invading the angular gyrus was successfully removed using calculation task monitoring without deterioration of the calculation ability.[9] Gerstmann's syndrome was demonstrated by direct stimulation of the left angular gyrus and is often associated with various types of aphasia, depending on the stimulation sites or lesions of the cortical areas in the left parietal lobe.[21] The six monitoring tasks included standard naming, reading, calculation, finger recognition, color naming, and writing. In the present case, simple addition and subtraction, object naming, repetition, and spontaneous conversation were used during the awake cortical mapping to prevent both aphasia and deterioration of ability to calculate. In fact, the calculation center was localized in the angular gyrus and was preserved. The patient's calculation ability dramatically improved postoperatively. We assumed that complex tasks are time consuming and should be avoided during awake surgery.

Despite recent advances in therapeutic modalities, the prognosis for patients with malignant astrocytomas remains poor. Therefore, the postoperative quality of life is very important. Language and motor functions usually improve in patients with intracranial tumors in the eloquent areas after resection surgery with careful assessment using functional mapping.[19,29] Even in patients with glioblastoma near the eloquent areas, as much of the tumor as possible should be removed without causing deterioration of the brain functions. The survival period may be improved by only a few months by extensive tumor resection, so good performance status should be the most important factor for patients with glioblastoma. MR imaging-guided stereotactic surgery provides better delineation of the tumor margins. The combination of neuronavigation with awake functional mapping is the best approach to extensive resection of tumor in the eloquent brain.

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Address reprint requests to M. Kurimoto, M.D., Department of Neurosurgery, University of Toyama, 2630 Sugitani, Toyama 930–0194, Japan.
e-mail: kuri3312@ms.toyama-mpu.ac.jp