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Temporal Glioblastoma Mimicking Basal Ganglia Invasion: Distinguishing Removable and Unremovable Tumors

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■ OBJECTIVE: **Maximal safe resection prolongs the survival of patients with glioblastoma (GB). However, whether total resection of the enhanced lesion is pursued or abandoned depends on preoperative judgments based on the findings of magnetic resonance imaging (MRI). Anatomically, medial temporal tumor tends to invade toward the temporal stem, insula, and basal ganglia, representing tumor with high surgical risk. In the present study, we describe the key radiologic features of medial temporal GB to achieve extent of resection.**

■ METHODS: **We reviewed all GB cases located in the temporal lobe (tGB) treated between April 2013 and March 2018 at Kitasato University Hospital. On the basis of MRI, tGB was simply classified into 3 groups: medial tGB and nonmedial tGB, and medial tGB was further subdivided into invading type and mimicking type. We focused on the resectability of medial tGB.**

■ RESULTS: **Twenty-seven patients with tGB were identified. Twenty were included in the nonmedial tGB, and 7 were in the medial tGB. All medial tGB seemed to invade into the basal ganglia and/or the lenticulostriate arteries, but detailed examination revealed 2 types of tumor, invading type (3 cases) and mimicking type (4 cases). The invading type had true involvement of the basal ganglia and/or lenticulostriate arteries, whereas the mimicking type had no involvement of these structures. This new classification is highly effective, as the former is unresectable, but the latter is totally resectable.**

■ CONCLUSIONS: **Medial tGB is a challenging tumor for maximal safe resection, so our classification will help to identify cases of removable medial tGB.**

INTRODUCTION

Glioblastoma (GB) is a primary brain tumor with a dismal prognosis. Maximal safe tumor resection in patients with GB is well known to improve overall survival,[1,2] but not all GBs are candidates for gross total resection (GTR). Assessment of the indications for GTR of GB based on preoperative images showed that GBs presenting with extensive invasion, such as crossing the corpus callosum and uncinate fasciculus, or located in eloquent areas or the basal ganglia cannot be safely removed without causing new iatrogenic deficits.[3] However, judgments to pursue or not to pursue GTR of the enhanced lesion depend on the experience and knowledge of the neurosurgeon. Therefore these preoperative judgments are the first and most important steps to decide the extent of resection.

The present study focused on GB located in the temporal lobe (tGB). The temporal lobe contains morphologically heterogeneous cerebral cortex including allocortex, mesocortex, and isocortex.[4,5] Anatomically, the temporal lobe is connected to the insula through the temporal stem, basal frontal lobe via the limen insulae, and globus pallidus via the amygdala.[5] Therefore tumors located in the temporal lobe, especially the medial temporal lobe, occasionally present with extensive invasion toward these anatomic connections. Such tumors are defined as Schramm type D[6] and are characterized by larger tumor size, frequent

Key words
- Basal ganglia
- Extent of resection
- Medial temporal lobe
- Schramm type D
- Temporal glioblastoma

Abbreviations and Acronyms
3D: Three-dimensional
3T: 3-Tesla
GB: Glioblastoma
GTR: Gross total resection
LSA: Lenticulostriate artery
MRI: Magnetic resonance imaging
tGB: Temporal glioblastoma
TOF: Time of flight

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Citation: World Neurosurg. (2019) 130:e213-e221.
https://doi.org/10.1016/j.wneu.2019.06.035

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

*Available online: **www.sciencedirect.com***

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Table 1. Characteristics of Temporal Glioblastoma Patients with Nonmedial Type, Mimicking Type, and Invading Type

		Medial Type	
	Nonmedial Type (n = 20)	Mimicking (n = 4)	Invading (n = 3)
Average age, years	64.5	66.3	68.7
Male sex	14	3	3 (100%)
Preoperative KPS, mean (range), %	80 (20—100)	77 (60—90)	50 (30—70)
Tumor volume, average, cm^3	43.6	73.1	64.3
Extent of resection, average (range), %	98 (86—100)	95 (80—100)	89 (83—93)
LSA involvement	0	0	3 (100%)
Basal ganglia invasion	0	0	3 (100%)
MEP monitoring and subcortical stimulation	7 (35%)	1 (25%)	3 (100%)
Awake surgery	2 (10%)	0	0

KPS, Karnofsky performance status; LSA, lenticulostriate artery; MEP, motor evoked potential.

incomplete resection, and failure to control the tumor compared with Schramm types A and C, which are more localized in the medial temporal lobe.[7]

We investigated the characteristics of preoperative magnetic resonance imaging (MRI) of medial tGB, which is hardly considered as totally removable tumor due to invasion of the surrounding vital structures. Here, we propose that a certain type of medial tGB can be safely removed, which we have named *mimicking-type tGB*. We describe the key radiologic features of mimicking type to aid in the preoperative judgment of the possible extent of resection of medial tGB.

METHODS

This single-center retrospective study was based on patients with GB treated at our department, and the study protocol was approved by the ethics committee of Kitasato University School of Medicine. We retrospectively examined all patients with tGBs treated between April 2013 and March 2018 and collected data on age, sex, preoperative Karnofsky performance status, preoperative and postoperative MRI findings, preoperative and postoperative tumor volumes, extent of resection, MIB-1 labeling index, and surgical morbidity due to damage to the pyramidal tract. The preoperative and postoperative tumor volumes were calculated using OsiriX software (Pixemo SARL, Bernex, Switzerland) as previously reported. Briefly, the area of the enhanced region on axial gadolinium-enhanced T1-weighted MRI was calculated, and the tumor volume was quantified on the basis of the sums of the areas on the axial images containing the tumor.[8,9]

To achieve extent of resection of GB, we focused on gadolinium-enhanced T1-weighted MRI. On the basis of the mere enhanced lesion, we first classified tGB into 2 types: medial-type

Table 2. Characteristics of Medial Temporal Glioblastoma

Case Number	Age (years), Sex	Tumor Volume (cm^3)	Residual Tumor Volume (cm^3)	Extent of Resection (%)	Involvement of LSA/Basal Ganglia	Preoperative KPS (%)	MIB-1 Labeling Index (%)	Damage to Pyramidal Tract	Intraoperative Monitoring
Mimicking type									
1	58, Male	47.2	0	100	—	70	20	None	MEP & SCoS
2	64, Male	101.4	0	100	—	80	50	None	—
3	64, Female	120.4	0	100	—	60	30	None	—
4	79, Male	23.2	4.6	80	—	90	50	None	—
Invading type									
5	65, Male	64.3	11.1	83	+	50	30	None	MEP & SCoS
6	69, Male	51.8	3.8	93	+	70	30	None	MEP & SCoS
7	72, Male	76.9	7.4	90	+	30	35	None	MEP & SCoS

LSA, lenticulostriate artery; KPS, Karnofsky performance status; MEP, motor evoked potential; SCoS, subcortical stimulation.

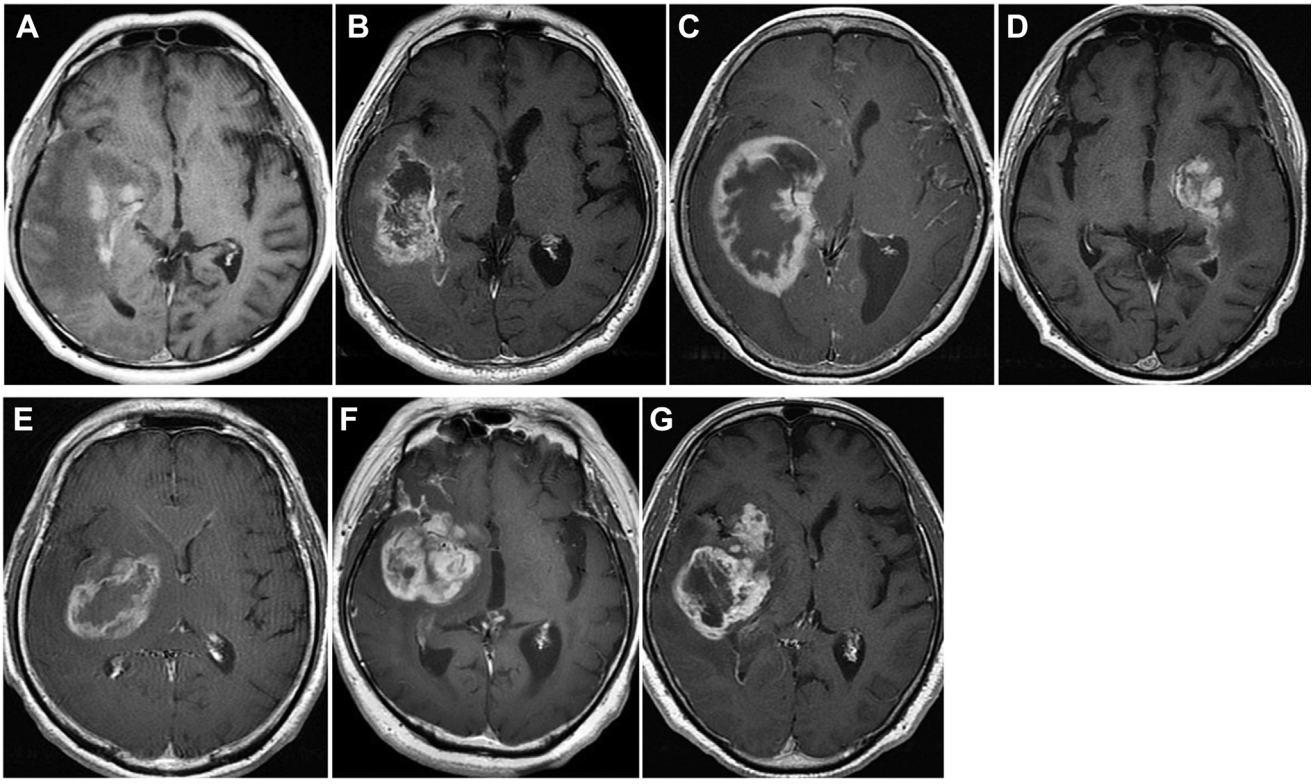

Figure 1. Preoperative axial gadolinium-enhanced T1-weighted magnetic resonance imaging (MRI) of 7 cases of medial temporal glioblastoma (tGB), all of which apparently invaded the basal ganglia. **A**—**G** show Cases 1 to 7, respectively. **A**—**D:** Mimicking type presenting pseudoinvasion toward basal ganglia. **E**—**G:** Invading type presenting invasion toward basal ganglia.

tGB and nonmedial-type tGB. Next, medial type tGB was divided into 2 types, invading type and mimicking type. Invading type was defined as medial-type tGB with invasive nature, resulting in involvement of the basal ganglia and/or lenticulostriate arteries (LSAs). Visualization of the LSAs used 3-dimensional (3D) 3-Tesla (3T) time of flight (TOF) MRI as previously reported.[10] Visualization of the basal vein of Rosenthal used the maximum-intensity projection images acquired from gadolinium-enhanced T1-weighted MRI. Mimicking type was defined as medial tGB with a relatively expansive nature invading the basal ganglia or including the LSAs but no evidence of true invasion or involvement. Nonmedial-type tGB included all other types.

After the craniotomy, all intracranial procedures were performed under microscope. The neuronavigation system was routinely used; however, intraoperative MRI is not available at our institution. Eleven cases underwent motor-evoked potential and subcortical stimulation to monitor the descending motor pathway. Two cases underwent awake surgery for the language mapping. Our surgical strategies toward medial tGB were based on the Schramm procedure with a combination of the transsylvian approach, anterior two-thirds lobe resection, and the transcortical approach.[6] After dissecting the sylvian fissure, the feeding arteries mainly from the anterior and middle temporal branches of the middle cerebral artery were coagulated and cut after confirmation of the distributions. The anterior temporal branch from the posterior cerebral artery running along the basal aspect of the temporal lobe was also coagulated with care taken to not damage the cortical branches supplying the posterior temporal lobe. After reducing the arterial supply to the tumor, the temporal stem was cut from the inferior limiting sulcus as far as the temporal horn of the lateral ventricle. This line of resection extended to the edge of the tentorium. After the posterior resection line was determined, the anterior two-thirds lobe resection was completed. Next, the medial part of the tGB was removed. To remove the herniated uncus and parahippocampus, the arachnoid around the oculomotor nerve was first sharply dissected. Then after vascular supplies to the anterior temporomesial area from the internal carotid artery or anterior choroidal artery (uncal arteries) were coagulated and cut, the uncus was removed. The choroidal fissure was dissected, and the hippocampal arteries to the posterior temporomesial area supplied by posterior circulation[4,11] were coagulated and cut. Then the hippocampus/parahippocampal gyrus was removed. Finally, the superior border of the tumor was removed step by step using a Cavitron ultrasonic surgical aspirator. The locations of the amygdala extending continuously to the globus pallidus and the descending motor pathway running close to the choroidal fissure must be determined. Subcortical stimulation was used to interpret

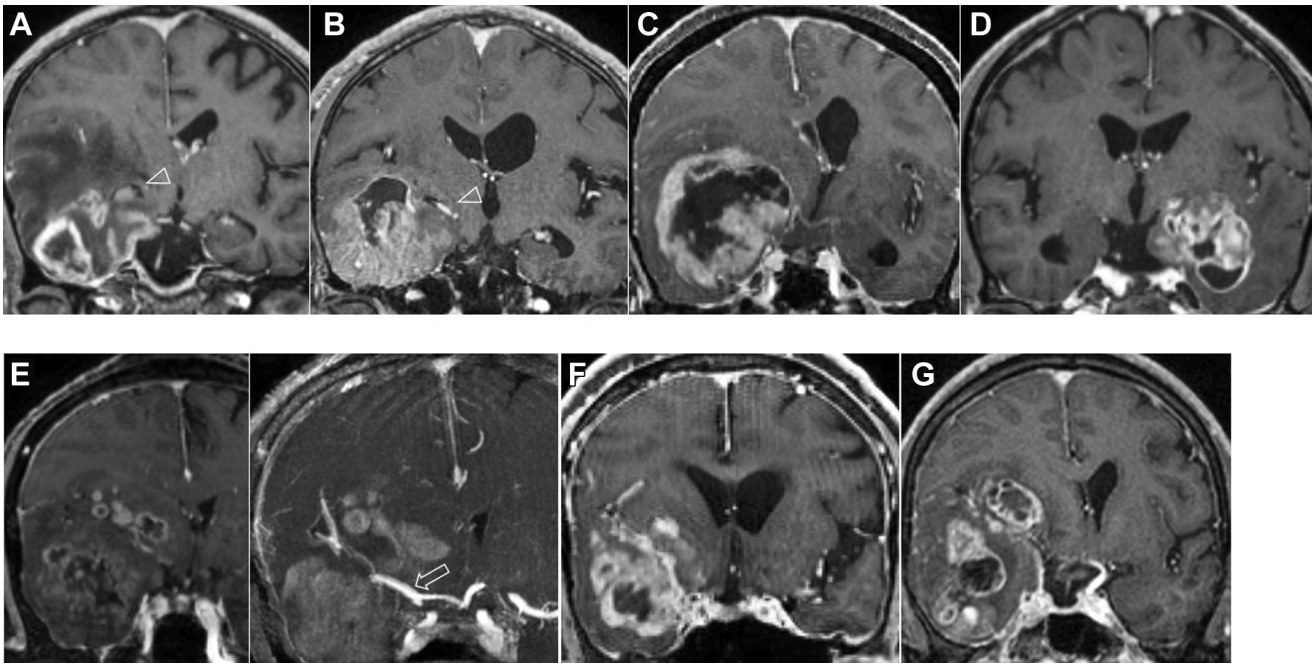

Figure 2. Preoperative coronal axial gadolinium-enhanced T1-weighted magnetic resonance imaging of 7 cases of medial temporal glioblastomas. **A**–**G** show Cases 1 to 7, respectively. **A**–**D:** Mimicking type causing upward displacement of the temporal horn (**A** and **B**, *blank triangle*). Temporal horns of **C** and **D** are not obviously visible. **E**–**G:** Invading type causing enhanced lesion above the temporal stem and middle cerebral artery (**E**, *blank arrow*), indicating invasion into the basal ganglia and involvement of the lenticulostriate arteries (LSAs).

the distance to the pyramidal tract,[12] and then the border structures facing the basal ganglia were removed. The preoperative judgment whether GTR should be pursued or not is critical to this final procedure. All the surgeries were performed by the first (I. S.) and senior author (T. K.)

RESULTS

We treated 29 consecutive cases of tGBs during the study period. Two cases presented with diffuse tumor infiltration involving at least 3 cerebral lobes, so they were omitted from this analysis. The age, sex, and preoperative Karnofsky performance status of patients are shown in **Table 1.** All medial tGBs were large and had invaded the surrounding structures. Consequently, 20 cases were classified as nonmedial-type tGB and 7 cases as medial-type tGB. All cases of medial type tGB are shown in **Table 2**. Four cases were the mimicking type, and 3 cases were the invading type. Tumor volume was 43.6 cm^3, and extent of resection was 98% in the nonmedial type, 73.1 cm^3 and 95% in the mimicking type, and 64.3 cm^3 and 89% in the invasive type. No statistical analysis was possible due to the small numbers in each group.

Preoperative and postoperative gadolinium-enhanced T1-weighted MRI of the 7 cases of medial-type tGBs are shown in **Figures 1**–**6**. All axial images showed that the tumor extended toward the basal ganglia (see **Figure 1**), so the axial images are not suitable for the judgment of resectability. Coronal images were the simplest to differentiate mimicking from invading type. First, identify the highly elevated temporal horn and confirm the absence of tumor above the temporal horn (**Figure 2A** and B). Second, tumor extension above the MCA can be determined as the invading type (**Figure 2E**). The temporal horn is often collapsed due to the mass effect of tGB within the uncus and hippocampus/parahippocampal gyrus. Therefore identification of structures such as the choroid plexus within the temporal horn or basal vein of Rosenthal running along the brainstem and choroidal fissure on thin-slice gadolinium-enhanced T1-weighted MRI is a strong indicator of mimicking type.

Figure 3 demonstrates the basal vein of Rosenthal on axial, coronal, and sagittal images, as well as the elevated temporal horn on coronal images. Both gadolinium-enhanced T1-weighted MRI and coronal T2-weighted MRI are useful to identify these 2 key structures. The basal vein of Rosenthal and temporal horn run above the upper border of the tumor in **Figure 3A**–**E** (Case 4), indicating mimicking type, whereas the basal vein of Rosenthal runs within the tumor in **Figure 3F**–**I** (Case 7), indicating invading type.

Another key indicator was the correlation between the LSAs and the tumor (**Figure 4**). Coronal, axial, and sagittal 3D 3T TOF MRI depicted a clear gap between the LSAs and the tumor border in **Figure 4A**–**C** (Case 3), so this tumor could be resected totally. In contrast, the LSAs ran within the tumor in **Figure 4D**–**F** (Case 6), so the region of LSA involvement could not be resected. **Figures 5** and **6** show the postoperative axial and coronal gadolinium-enhanced T1-weighted MRI. GTR was

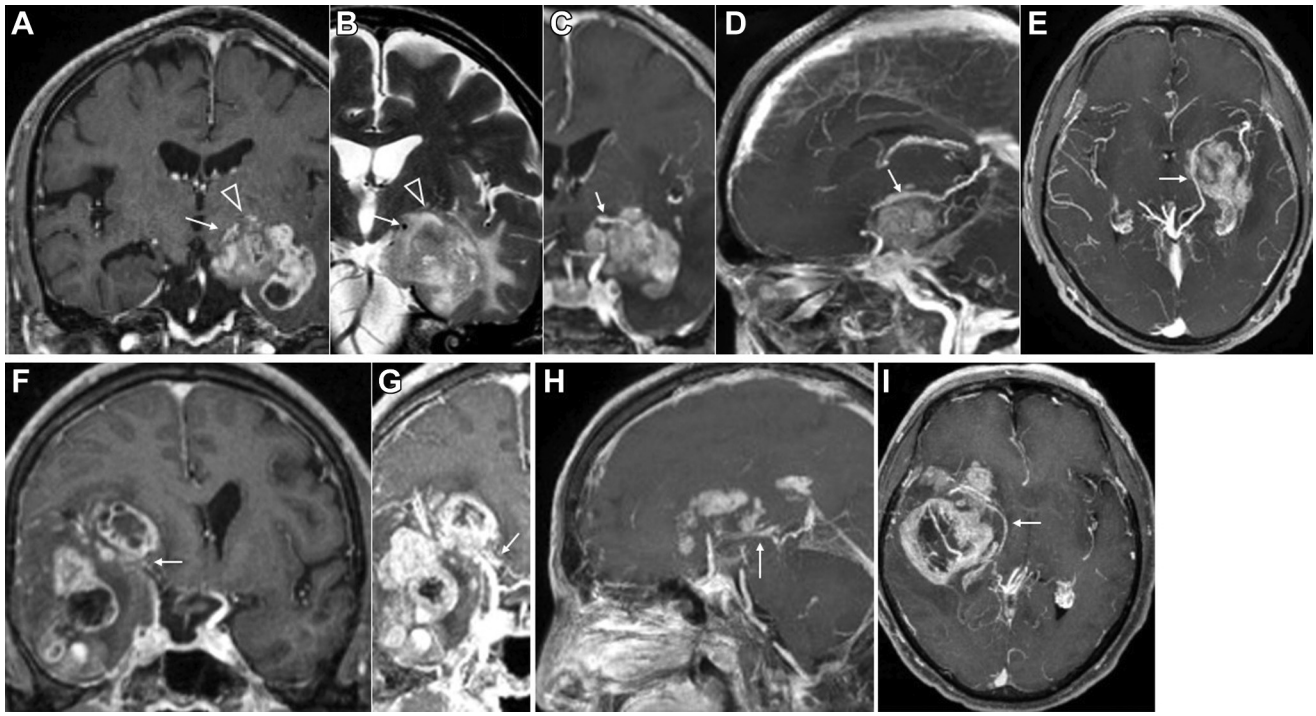

Figure 3. Representative magnetic resonance imaging (MRI) of the basal vein of Rosenthal in both mimicking and invading type. *Arrow* indicates the basal vein of Rosenthal, and *blank triangle* shows the temporal horn. (**A**–**E**) Case 4, mimicking type. Coronal gadolinium-enhanced T1-weighted MRI (**A**). Coronal T2-weighted MRI (**B**) showing the basal vein as a flow void and the temporal horn as a hyperintense region. Coronal (**C**), sagittal (**D**), and axial (**E**) maximum intensity projection (MIP) images demonstrating the basal vein of Rosenthal running along the inner-upper border of the tumor. (**F**–**I**) Case 7, invading type. Coronal gadolinium-enhanced T1-weighted MRI (**F**). Coronal (**G**), sagittal (**H**), and axial (**I**) MIP images showing the basal vein of Rosenthal running within the tumor.

possible in Cases 1, 2, and 3. Preoperative MRI (see Figure 3A–E) indicated that Case 4 was the mimicking type, so it was supposed to be totally removable. However, we misinterpreted the preoperative MRI as unremovable, resulting in residual tumor in the medial temporal lobe and resection of only 80% (see Figures 5D and 6D). Cases 5, 6, and 7 had residual tumor in regions of the LSAs and/or basal ganglia, which we judged preoperatively as unremovable (Figures 5E–G and 6E–G). No surgical morbidity occurred due to damage to the pyramidal tract. In addition, 6 of the 7 tumors were in the nondominant hemisphere, so no aggravation of verbal function due to resection was experienced.

DISCUSSION

Generally, the preoperative gadolinium-enhanced T1-weighted MRI findings are used to determine whether the enhanced lesion is totally resectable or not. If the judgment is that the tumor is unremovable, GTR is never attempted. Our experience is that tumor predicted to be totally removable sometimes results in residual enhanced lesion on postoperative MRI. However, tumor predicted to be unremovable never results in GTR. Therefore careful interpretation of the preoperative MRI is the first step for maximal and safe resection, but such judgments are not always easy.

The present study examined our cases of medial tGBs, and demonstrated 2 variations, named as mimicking and invading types. Mimicking type is totally removable, but examination of the preoperative axial MRI tends to suggest that the tumor had invaded the basal ganglia, leading us to think that the tumor is unremovable. The key point to differentiate mimicking from invading type is identification of the LSAs, temporal horn, basal vein of Rosenthal, and choroid plexus. Mimicking type elevated the temporal horn and temporal stem upward compared with the contralateral structures on axial imaging, as if the upper part of the tumor was located at the level of basal ganglia. The temporal horn was sometimes collapsed, so structures such as the choroid plexus and basal vein of Rosenthal were helpful to identify the upper border of the tumor. In addition, 3D 3T TOF MRI was used to visualize the LSAs.[10]

In Case 3 (see Figure 1C; Figure 2C; and Figure 4A–C), a representative of the mimicking type, the tumor and LSAs were clearly separated, so the tumor could be resected without damaging the LSAs. The representative case of misinterpretation was Case 4 (see Figure 1D; Figure 2D; and Figure 3A–E), a mimicking type, which was not identified preoperatively as

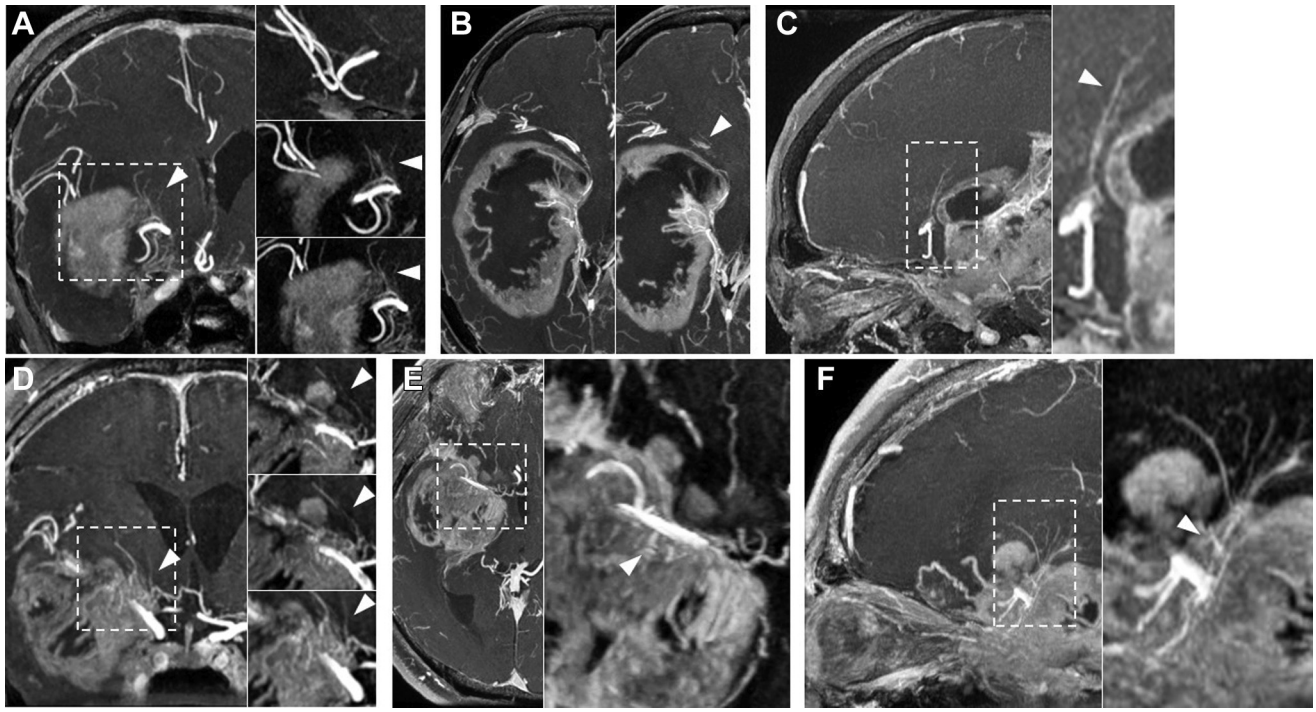

Figure 4. Representative 3-dimensional 3-Tesla time-of-flight magnetic resonance imaging of the lenticulostriate arteries (LSAs) in mimicking and invading types. *Triangles* indicate LSAs. Images with *dashed rectangle* have larger images on the right. Coronal images (**A** and **D**), axial images (**B** and **E**), and sagittal images (**C** and **F**). (**A**–**C**) Case 3, mimicking type. There was a gap between the LSAs and tumor. (**D**–**F**) Case 6, invading type. LSAs running within the tumor.

mimicking. Therefore we presumed that the tumor could not be resected totally, resulting in residual enhanced rim at the upper border. We treated this case early during the study period, when we did not understand the difference between mimicking and invading types. We first understood that the tumor extended toward the basal ganglia via the amygdala, which turned out to be incorrect on the basis of detailed images of **Figure 3A–E**. Although we could not resect the tumor totally, the residual tumor was partly located in the amygdala, in the region of involvement of the LSAs. Therefore resection in this region needed caution even if the preoperative judgment had been the mimicking type. In contrast, coronal gadolinium-enhanced T1-weighted MRI showed an enhanced lesion above the temporal horn in the invading type, indicating invasion toward the basal ganglia. In addition, 3D 3T TOF MRI showed the LSA running within the tumor.

Invading type is unremovable due to the involvement of the basal ganglia and LSAs. The basal ganglia, consisting of the caudate nucleus, putamen, globus pallidus, and claustrum, is located deep within the brain and surrounded by critical structures such as the internal capsule and perforating arteries. Therefore, any lesions located in the basal ganglia are challenging to remove. Vascular lesions such as arteriovenous malformation, cavernous angioma, and intracerebral hemorrhage located in the basal ganglia can be surgically removed.[13,14] Tumor involvement of the basal ganglia is associated with incomplete resection.[15] A case report of oligodendroglioma located in the basal ganglia underwent biopsy.[16] However, a case of ganglioglioma in the basal ganglia was successfully removed through the transdistal sylvian approach.[17] In addition, low-grade gliomas invading the nondominant striatum are also removable.[18] Some expanding lower-grade gliomas or vascular lesions in the basal ganglia can be resected, but we think that GB invading toward the basal ganglia can generally be as unremovable.

tGB accounts for around 28%–34% of all GBs, almost as frequent as frontal GB ranging from 30%–37%.[19-21] Most cases (74% in our series) are categorized in nonmedial tGB, in which GTR can be simply achieved. The overall survival of patients with tGB varies at 24 months, 11 months, and 9 months after supramaximal resection, gross total resection, and subtotal resection, respectively.[22] Some cases of nonmedial tGBs can be good candidates for supramaximal resection. In contrast, fewer cases are medial tGBs (only 26% in our series). A large series of 224 cases of tGBs did not mention medial tGB,[23] so the incidence of

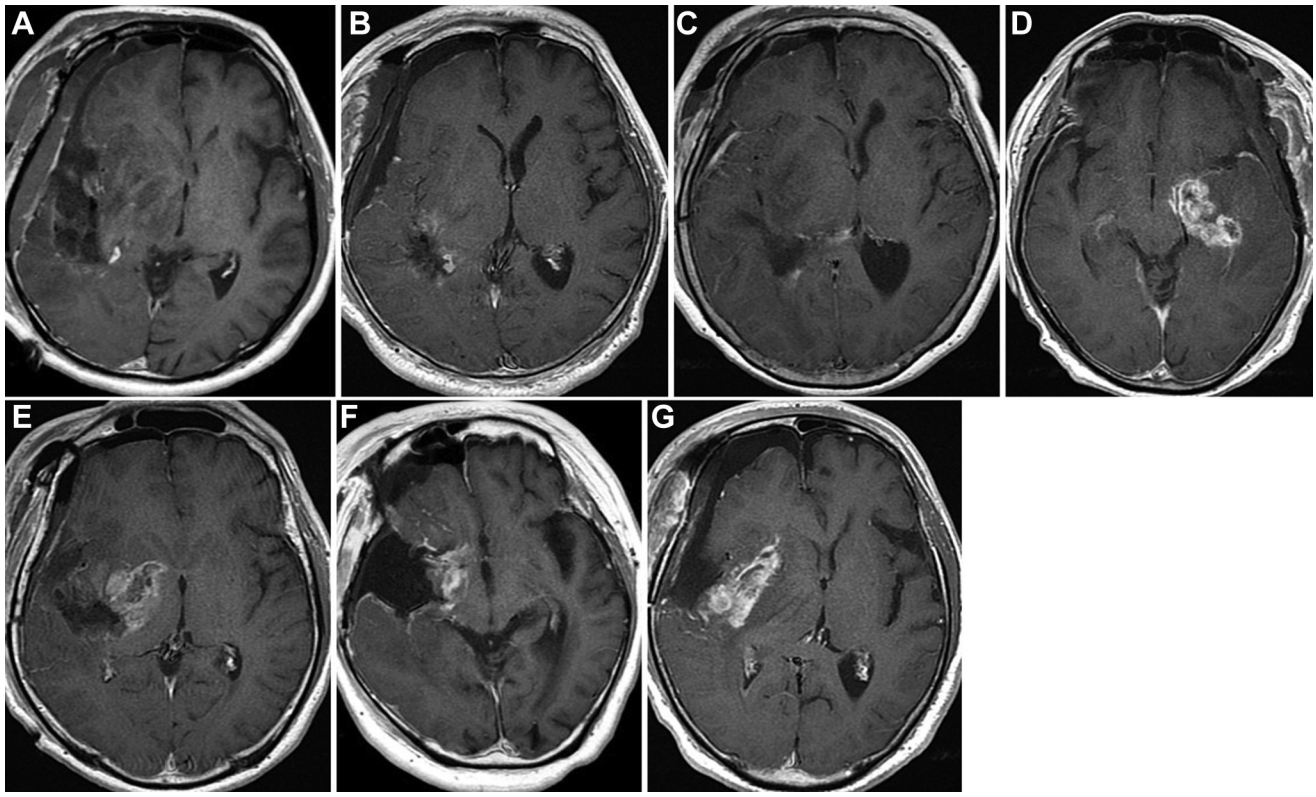

Figure 5. Postoperative axial gadolinium-enhanced T1-weighted magnetic resonance imaging of 7 cases of medial temporal glioblastomas. (**A**–**G**) Cases 1 to 7, respectively. (**A-D**) Mimicking type allowing extensive resection. Case 4 (**D**) showed residual tumor in the medial temporal region. (**E**–**G**) Invading type with residual tumor in the basal ganglia/lenticulostriate artery region.

medial tGB was unknown. Another series of 50 cases of medial temporal glioma included 18 cases of medial tGBs.[24] Their preoperative tumor volume based on gadolinium-enhanced T1-weighted MRI was 19.9 ± 13.0 cm^3, whereas ours was 68.7 cm^3. We assume that they did not have cases of large tumor volume, which are hard to differentiate removable from unremovable. Therefore the frequency of invading and mimicking types remains unclear.

There are several limitations. First, the sample size is small. A previous report demonstrated that stepwise improvement in overall survival of patients with GB was observed within the 95%–100% range.[1] In the study, they examined 500 consecutive patients with GB, including those located at eloquent brain. Thus the extent of resection resulted in a clinically significant outcome regardless of the tumor location. We could not provide survival analysis due to sample size; however, our classification provides additional evidence for maximal safe resection in medial tGB, which may ultimately contribute to prolonged survival. Second, the retrospective nature of this study is a limitation. Therefore further studies with larger number of patients including survival analysis is warranted. Third, one may argue that there is no difference between mimicking and invading types in terms of resectability. Due to invasive characteristics of GB, tumor cells may exist at the nonenhanced region of the basal ganglia even in the mimicking type; thus complete resection of GB is never possible. Positive correlation between the extent of resection in GB and prolongation of survival was based on a gadolinium-enhanced lesion on MRI.[1] Therefore our proposal helps preoperative judgment and increases resectability in medial tGB.

CONCLUSION

The present study identified 2 types of medial tGBs: mimicking and invading. Our findings demonstrate that the mimicking type can be totally and safely resected. Thus misjudgment as the invading type will lose the opportunity for GTR. Furthermore, our classification is useful because the key radiologic features for the judgment of resectability can be visualized by routine MRI.

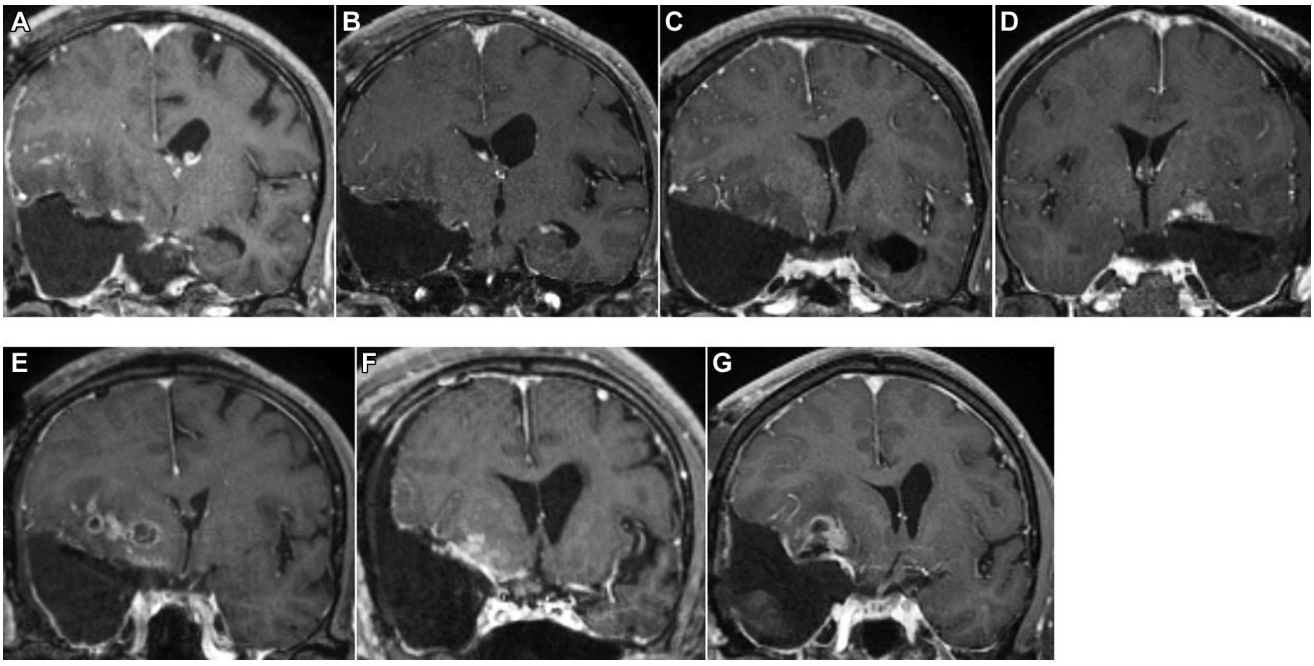

Figure 6. Postoperative coronal gadolinium-enhanced T1-weighted magnetic resonance imaging of 7 cases of medial temporal glioblastomas. (**A**—**G**) Cases 1 to 7, respectively. (**A**—**D**) Mimicking type allowing extensive resection and opened temporal horn on the resection side appearing as high as the contralateral temporal horn. Case 4 (**D**) showed residual tumor at the upper border of the medial temporal region. (**E**—**G**) Invading type with enhanced lesion above the sylvian fissure and middle cerebral artery, indicating invasion of the basal ganglia and lenticulostriate arteries.

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Conflict of interest statement: This work was supported in part by KAKENHI (Grants-in-Aid for Scientific Research), grant Number 18K16569 and Ichiro Kanehara Foundation.

Received 7 February 2019; accepted 3 June 2019

Citation: World Neurosurg. (2019) 130:e213-e221.
https://doi.org/10.1016/j.wneu.2019.06.035

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery***

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