 doi: 10.2176/nmc.cr2012-0361

Neurol Med Chir (Tokyo) 54, 321–326, 2014

Online October 21, 2013

Preservation of the Long Insular Artery to Prevent Postoperative Motor Deficits after Resection of Insulo-opercular Glioma: Technical Case Reports

Masaki IWASAKI,[1] Toshihiro KUMABE,[1] Ryuta SAITO,[1] Masayuki KANAMORI,[1] Yoji YAMASHITA,[1] Yukihiko SONODA,[1] and Teiji TOMINAGA[1]

[1]*Department of Neurosurgery, Tohoku University Graduate School of Medicine, Sendai, Miyagi*

Abstract

Resection of insulo-opercular gliomas carries the risk of postoperative hemiparesis caused by ischemia of the corona radiata resulting from injury to the long insular arteries. However, intraoperative identification of these perforating arteries is challenging. We attempted intra-operative motor evoked potential (MEP) monitoring under temporary occlusion of the suspected long insular artery arising from the opercular portion of middle cerebral artery in two patients with insulo-opercular gliomas. Temporary occlusion of the artery caused decrease in MEP amplitude, which recovered after release in one patient, who had no postoperative motor deficits or ischemic lesion in the corona radiata. Temporary occlusion of the artery caused no changes in MEP amplitude, so that the artery was sacrificed for tumor removal in the other patient, who had no motor deficits but ischemic lesion was present in the corona radiata in the territory of the long insular artery sparing the descending motor pathway. These cases show that great care should be taken during surgical manipulations near the posterior part of the superior limiting sulcus to preserve the perforating branches to the corona radiata, and temporary occlusion of the branches under MEP monitoring is useful to identify the arteries supplying the pyramidal tract.

Key words: glioma, infarction, insular artery, motor evoked potential, operculum

Introduction

Resection of opercular gliomas carries the risk of damage to the descending motor pathway in the corona radiata. We previously found that maximal resection of opercular glioma was associated with postoperative infarction beneath the resection cavity in all the 11 cases, and maximal resection of opercular glioma involving the descending motor pathway caused permanent motor deficit in 2 of these 11 cases.[1)] Microangiographical analysis demonstrated that damage to the long insular and long medullary arteries arising from the opercular and cortical segments of the middle cerebral arteries (MCAs) was responsible for such ischemic complications.[2)]

Motor evoked potential (MEP) is increasingly employed as a practical and reliable method for monitoring motor tract integrity during surgery. MEP is utilized to monitor both the patency of the perforating arteries of the pyramidal tract, such as the anterior choroidal artery and lenticulostriate arteries,[3)] and direct injury to the tract during resective surgery near the primary motor cortex.[4)]

We describe the application of MEP to preservation of the long insular artery supplying the descending motor pathway during resection of opercular glioma.

Methods

I. Intraoperative MEP

MEPs were recorded after "train-of-five" pulse stimulation of the pre-central gyrus. The central sulcus was identified first by recording median nerve somatosensory evoked potentials (SEPs). A platinum disc electrode array (Unique Medical Co., Ltd., Komae, Tokyo) was placed on the hand primary motor cortex anterior to the central sulcus. Two by two grid electrodes with 1.5 mm diameter and 5 mm inter-electrode distance, or two by four grid electrodes with 4 mm diameter and 10 mm inter-electrode distance were used depending on the available surgical field. Care was taken to place wet cotton patties and to apply gentle pressure to the grid, to maintain steady contact between the electrodes and the cortical surface. Five trains of constant current 2-ms square-pulse stimuli

Received October 10, 2012; Accepted January 28, 2013

were delivered at 500 Hz with reference to the extracranial lead attached to the skin above the contralateral mastoid. Surface electromyography of the contralateral flexor pollicis brevis was monitored. The stimulation and recordings were performed with a Neuromaster MEE-1200 (Nihon Kohden, Tokyo). Stimulus intensity was increased in 1 mA steps to identify the threshold required to elicit MEPs. The electrode with the lowest threshold was employed for later monitoring. Then, continuous monitoring was started at 20% intensity above the threshold.

II. Identification of perforating arteries and temporary occlusion under MEP monitoring

The tumor was carefully aspirated using an ultrasonic surgical aspirator (Sonopet; Miwatec Co., Ltd., Tokyo) to preserve all major vessels passing over the area of removal, such as the superficial sylvian veins, MCAs, and their opercular branches. Surgery was guided by a neuronavigational system (Vector Vision; BrainLAB, Munchen, Germany). Especially great care was taken to identify the insular-opercular segments of the MCAs and the location of the superior limiting sulcus, at the origin of the long insular arteries or perforating arteries to the corona radiata. Hemostasis was achieved with fine use of bipolar electrocautery.

A temporary clip was applied to the perforating artery and the MEPs were monitored every 10 seconds to 60 seconds. If the MEP amplitude was decreased by greater than 50% from the baseline, blood flow insufficiency to the descending motor pathway was suspected, and the temporary clip was released. If no significant changes were observed in the MEP amplitude for 10 minutes, the perforating artery was judged to carry low risk for motor tract infarction, and the artery could be sacrificed as needed during tumor removal.

Indocyanine green (ICG) video-angiography was performed to check the patency of the perforating arteries after temporary occlusion. After the surgical field was cleared with hemostasis, 0.3 mg/kg of ICG was injected intravenously as a bolus. Video-angiography was monitored with the infrared 800 fluorescence mode (Carl Zeiss Co., Oberkochen, Germany).

Illustrative Cases

I. Case 1

A 47-year-old right-handed female was found to have a brain tumor after the first episode of generalized convulsive seizure. Computed tomography demonstrated a large left frontal tumor with calcification before she was referred to us from a local hospital. Three-tesla magnetic resonance (MR) imaging revealed a mass in the left insular cortex extending to the fronto-parietal operculum, appearing as high intensity on T_2-weighted imaging and low intensity with heterogeneous enhancement on T_1-weighted imaging with gadolinium (Fig. 1A–D). Functional MR imaging during verb generation tasks suggested language dominance of the left hemisphere.

Awake surgery was planned for language mapping. The surgery was started under general anesthesia with laryngeal mask ventilation. Left fronto-parieto-temporal craniotomy was performed with the patient's head positioned laterally. Median nerve SEPs were recorded to identify the central sulcus and the MEP recording was established before the patient was awakened. Direct cortical stimulation with 10-mA constant current electrical pulses at 50 Hz was performed over the exposed cortex using a bipolar electrode (5 mm spacing) (Fig. 2A, B). No disturbances in her speech were observed during the number-counting and object-naming tasks, so that no language functions were identified in the area of planned resection (negative language mapping). Laryngeal mask ventilation and general anesthesia were re-introduced before tumor removal.

The tumor was removed under guidance of a neuronavigation system, and continuous MEP monitoring was started at 10-mA stimulus intensity. All major branches of the MCAs were preserved carefully in the sylvian fissure. During the removal of the insular portion of tumor, a perforating artery was found to branch from the precentral artery, which was suspected to be a long insular artery. Temporary clipping of this branch (Fig. 2C–E) was followed by immediate and significant decrease in MEP

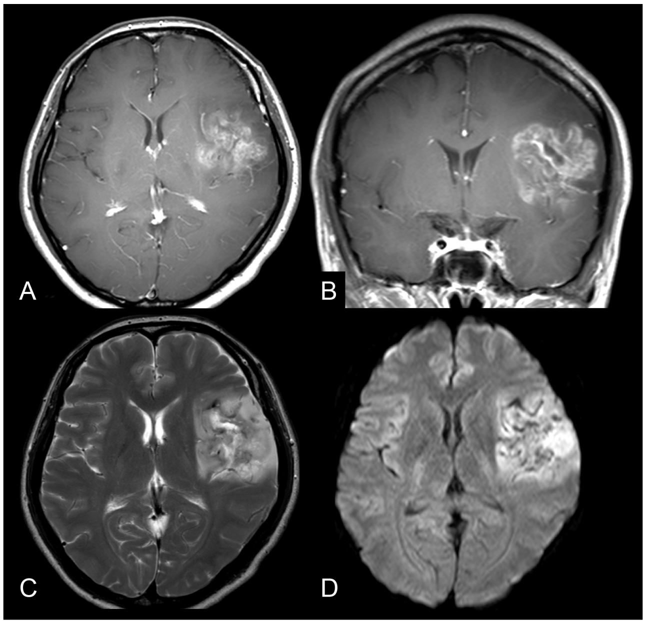

Fig. 1 **Case 1. A 47-year-old female with anaplastic oligodendroglioma. Preoperative axial (A) and coronal (B) T_1-weighted with gadolinium, axial T_2-weighted (C), and axial diffusion-weighted (D) magnetic resonance images showing an enhanced and highly cellular infiltrative tumor in the left insula and fronto-parietal operculum.**

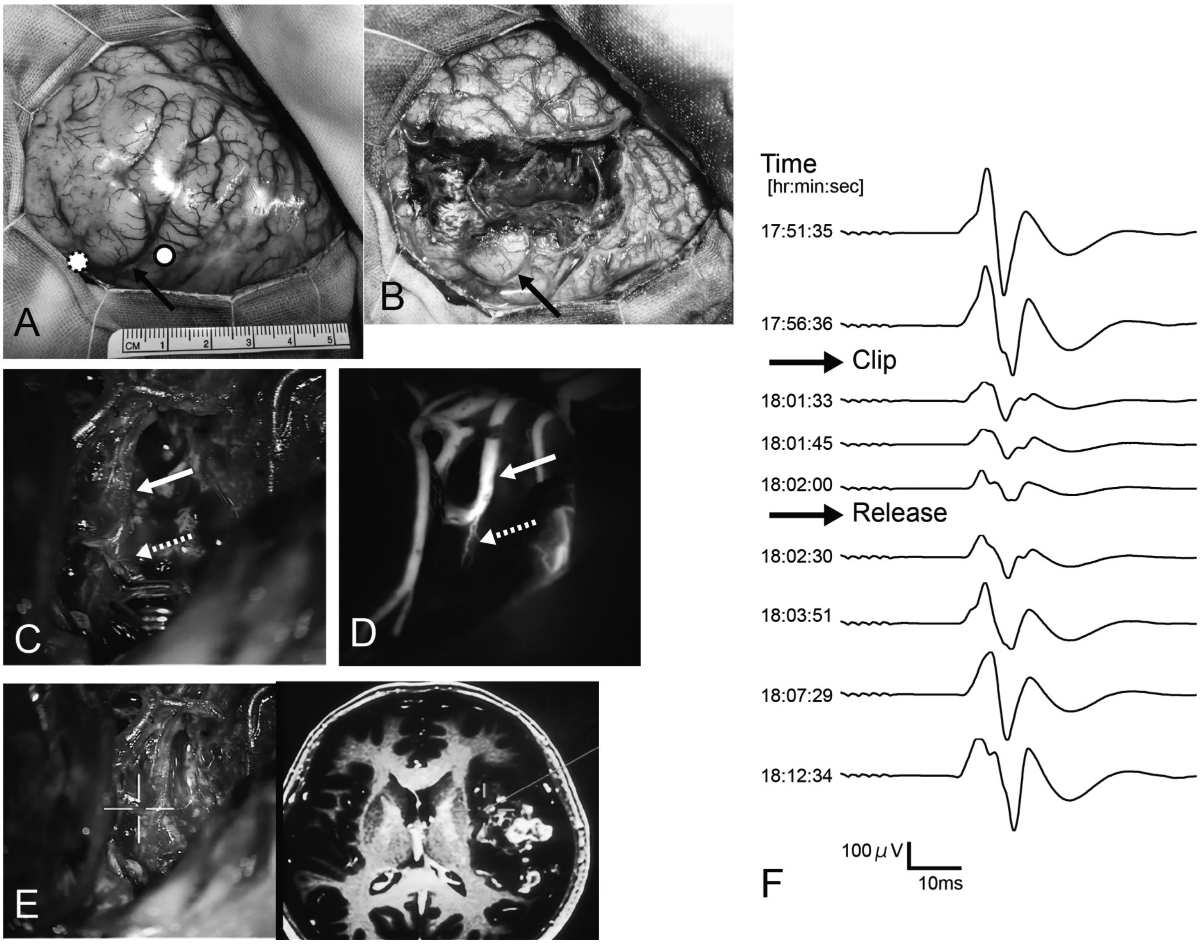

Fig. 2 Case 1. A, B: Intraoperative photographs before (A) and after (B) removal of the tumor. Direct cortical stimulation identified the right facial motor (*solid circle*) and the right hand sensory (*dotted circle*) responses. The central sulcus is indicated by *black arrows*. C: Intraoperative photograph showing the pre-central artery (*solid arrow*) and its perforating branch (*dashed arrow*) preserved during tumor removal. A temporary clip was applied to this perforating artery. D: ICG video-angiography confirming the vascular patency after release of the temporary clip. E: Intraoperative photograph showing the origin of the perforating artery (*center of cross*) localized in the upper portion of insula, confirmed by a neuronavigation system. F: MEP monitoring showing the amplitude of the MEP decreased by more than 50% immediately after temporary clipping, but normalized after release of the clip. ICG: indocyanine green, MEP: motor evoked potential.

amplitude (Fig. 2F). The MEP amplitude returned to normal after release of the temporary clip, so that the artery was judged as supplying the descending motor pathway. ICG video-angiography later confirmed patency of the vessels (Fig. 2D). Further tumor removal was limited to preserve this perforating artery.

Postoperatively, the patient had no motor weakness or language deficits. MR imaging revealed subtotal removal of the tumor (Fig. 3A) and no ischemic lesions in the corona radiata (Fig. 3B, C). A small gadolinium-enhanced remnant was left in the upper insular subcortex (Fig. 3A, *arrow*), which was not removed to preserve the long insular artery. The histological diagnosis was anaplastic oligodendroglioma, and additional radiochemotherapy was administered.

II. Case 2

A 43-year-old man presented with transient sensory disturbance of the left side of the face. He was neurologically intact when referred to us for treatment of brain tumor. Three-tesla MR imaging revealed a mass in the right insula and frontal operculum, appearing as high intensity on T_2-weighted imaging and non-enhanced low intensity on T_1-weighted imaging with gadolinium (Fig. 4A–D). Functional MR imaging during verb generation tasks suggested language dominance of the left hemisphere.

Surgery was performed under general anesthesia. Right fronto-temporo-parietal craniotomy was performed. Median nerve SEPs were recorded to identify the central sulcus and continuous MEP monitoring was started at 8 mA. Tumor removal was guided by a neuronavigation system

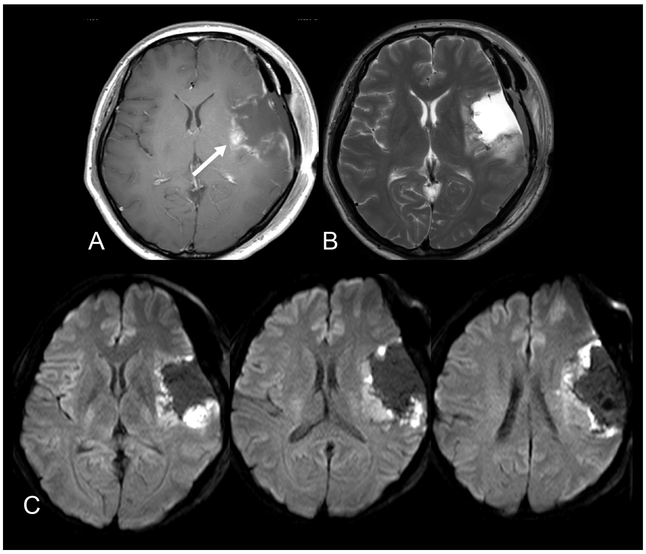

Fig. 3 Case 1. Postoperative axial T_1-weighted with gadolinium (A), T_2-weighted (B), and diffusion-weighted (C) magnetic resonance images showing subtotal resection of the tumor. A small enhanced remnant tumor (*arrow* in A) was left in the insular cortex. High intensity lesions were seen around the resection cavity, but not in the corona radiata or the territory of long insular artery (C).

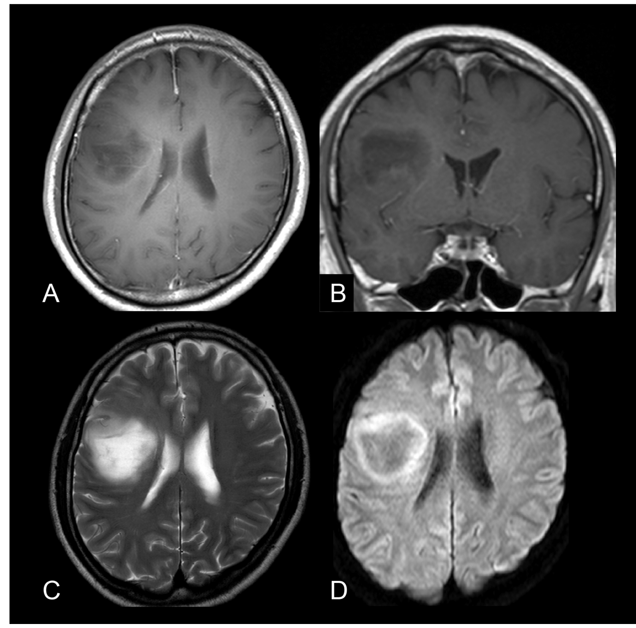

Fig. 4 Case 2. A 43-year-old man with oligo-astrocytoma. Preoperative axial (A) and coronal (B) T_1-weighted with gadolinium, axial T_2-weighted (C), and axial diffusion-weighted (D) magnetic resonance images showing a non-enhanced right insular and frontal opercular tumor.

and three "fence-post" tubes inserted at the anterior, posterior, and superior limits of planned resection (Fig. 5A, B). All major branches of the MCAs were preserved carefully at the insula and frontal operculum. A perforating artery was found to branch from the central artery at the superior limiting sulcus, which was suspected to be a long insular artery (Fig. 5C–E). Temporary clipping of the branch for more than 10 minutes was followed by no changes in the MEP amplitude (Fig. 5F). ICG video-angiography confirmed patency of the vessels after temporary clipping (Fig. 5D). This perforating artery was not judged to supply the descending motor pathway, so that the artery was cut and further tumor removal was possible (Fig. 5B).

Postoperatively the patient experienced no neurological deficits. MR imaging confirmed subtotal removal of the tumor (Fig. 6A, B). Ischemic changes were found in the corona radiata sparing the descending motor pathway (Fig. 6C–E). The anatomical distribution was consistent with the territory of the long insular artery, so was suspected to result from cutting of the perforating artery. The histological diagnosis was oligo-astrocytoma, associated with loss of 1p19q heterozygosity. Adjuvant chemotherapy was performed in an outpatient clinic.

Discussion

The present two cases illustrate that intra-operative identification and preservation of the long insular arteries supplying the descending motor pathway are possible based on temporary occlusion of the suspect arteries under continuous MEP monitoring. However, careful preparation of the related arteries is essential. This technique is useful to maximize resection of insulo-opercular glioma while preserving critical motor function. In Case 1, decrease in MEP amplitude indicated that the perforating artery supplied the descending motor pathway. Consequently, remnant tumor was left unresected, but no ischemic sequela was observed because of the preservation of this artery. On the other hand, in Case 2, no changes were observed in MEP amplitude, so that the perforating artery was sacrificed. No motor deficits occurred but ischemic lesion was detected in the corona radiata outside the pyramidal tract. These findings show that the long insular arteries supplying and not supplying the descending motor pathway can be differentiated using this MEP monitoring technique.

Safe removal of insulo-opercular glioma requires that the surgeons should be aware of the anatomy of the insular arteries and utilize techniques including MEP, ICG video-angiography,[5] and temporary occlusion to preserve the critical perforating arteries. Previously, we reported that radical resection of opercular gliomas resulted in postoperative infarction beneath the resection cavity, followed by permanent motor deficit in 2 of 11 cases.[1] The long insular arteries and long medullary arteries arise from the opercular and cortical segments of the MCAs, and supply the corona radiata.[2] The long insular arteries

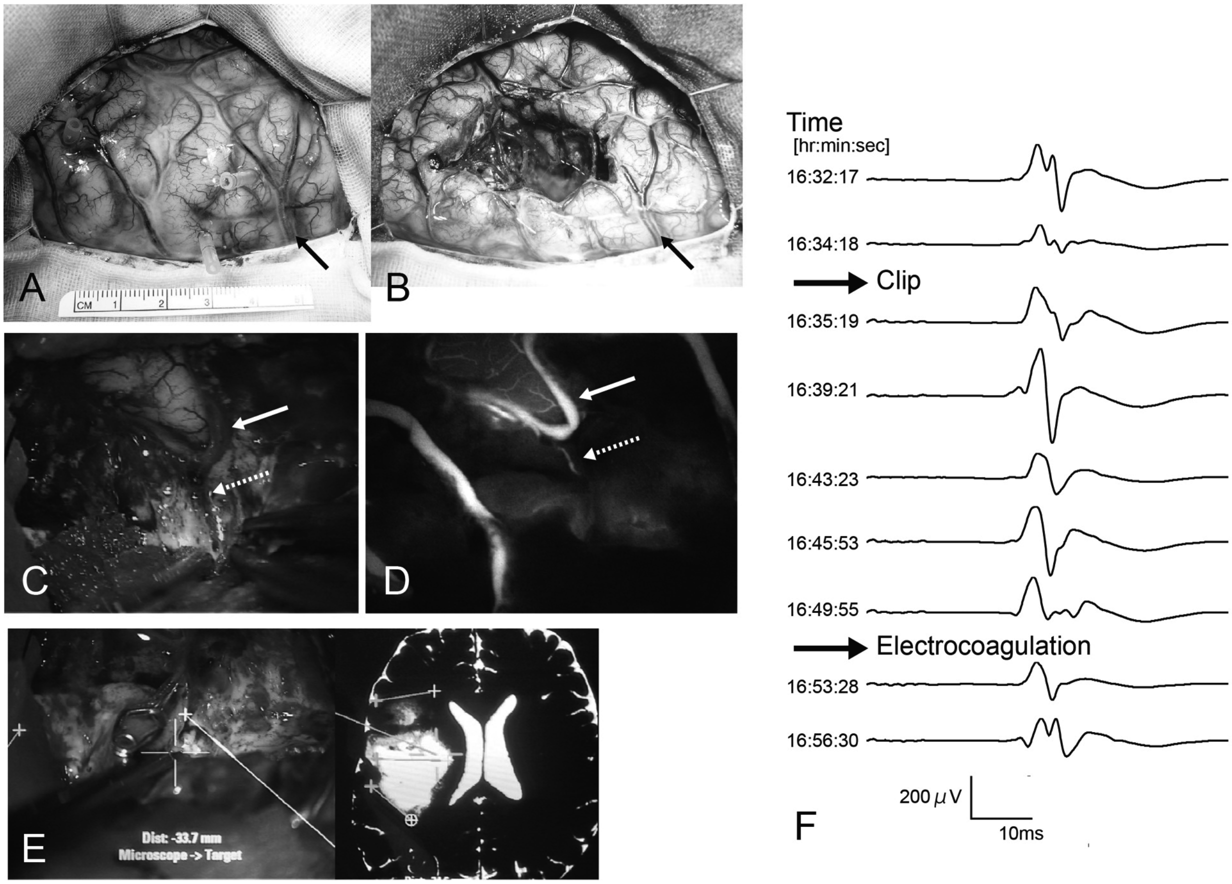

Fig. 5 Case 2. A, B: Intraoperative photographs before (A) and after (B) removal of the tumor. The central sulcus is indicated by *black arrows*. C: Intraoperative photograph showing the central artery (*solid arrow*) and its perforating branch (*dashed arrow*) preserved during tumor removal. A temporary clip was applied to the perforating artery. D: ICG video-angiography confirming the vascular patency after release of the temporary clip. E: Intraoperative photograph showing the perforating artery (*center of cross*) localized in the bottom of tumor close to the corona radiata, confirmed by a neuronavigation system. F: MEP monitoring showing the amplitude of the MEP not changed during temporary clipping of the perforating artery for 10 minutes. The artery was cut for further removal of tumor. ICG: indocyanine green, MEP: motor evoked potential.

comprise 3% to 5% of the insular arteries that are long enough to supply the corona radiata.[6] The long insular arteries are located primarily in the posterior region of the insula, most commonly on the posterior half of the central insular sulcus and on the long gyri.[6,7] This location overlaps zone II of the Berger-Sanai classification system for insular gliomas, i.e. the area above the line of the sylvian fissure and posterior to a perpendicular plane crossing the foramen of Monro.[8] The extent of resection is limited in this location because of the proximity to the Rolandic cortex, inferior parietal language sites, and the posterior limb of the internal capsule. Thus, great care should be taken during surgical manipulations near the posterior part of the superior limiting sulcus to preserve the long insular arteries. The present method of temporary occlusion of the suspected branches under MEP monitoring is useful to identify the vessels supplying the pyramidal tract.

Practically, our technique would be useful to confirm arterial branches that supply cortical region in order to carry tumor resection safely. However, several cautions should be pointed out. First, not all arterial branches observed on the insular cortex supplies the corona radiata. Moreover, identification and preservation of medullary branches originating from the MCAs are still technically difficult compared with the long insular arteries. Second, temporary clipping carries a certain, but unknown, risk for vasospasms or permanent occlusion of the clipped artery. Application of temporary clipping to small perforating arteries has not systematically been reported, but is probably associated with higher risk for secondary vasospasms. It would be important to confirm vessel patency after the procedure with ICG video-angiography. Third, considering the above technical demands and risks, this technique should be used at the final stage of tumor resection when the amount of resection could be

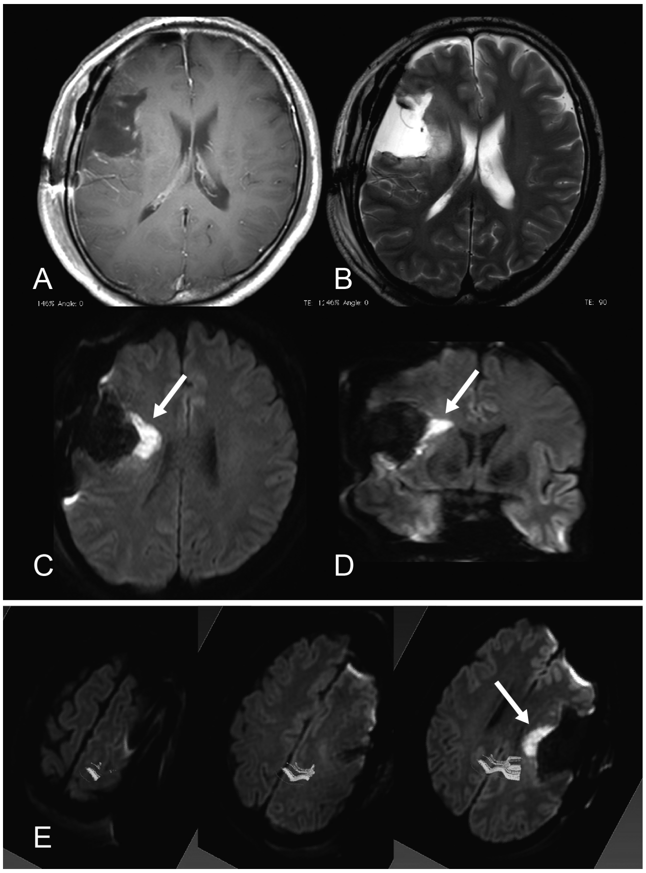

Fig. 6 **Case 2. A, B: Postoperative axial T_1-weighted with gadolinium (A) and T_2-weighted (B) magnetic resonance images showing gross total resection of tumor. C, D: Axial (C) and coronal (D) diffusion-weighted images (DWIs) showing ischemic changes in the corona radiata with wedge-shaped extension to the lateral ventricle, which is typical of long insular artery infarction. E: Fiber tracking of the pyramidal tract is overlaid and three-dimensionally presented on the DWIs. The pyramidal tract is spared from the infarction (*arrows*). Diffusion tensor images acquired with 15 gradient directions were analyzed with MRtrix software (http://www.brain.org.au/software). Image overlay on the DWI was performed with AVIZO software (VSG®; Burlington, Massachusetts, USA).**

maximized by removing the residual part deeper than perforating arteries. Certainly, more case experience is necessary to definitively establish the clinical usefulness of our methods. Careful surgical manipulation and continuous MEP monitoring remain essential to avoid postoperative motor deficits caused by surgery to remove insulo-opercular gliomas.

Conclusion

Careful investigation of the fine arteries in the posterior region of the insula, most commonly on the posterior half of the central insular sulcus and on the long gyri, based on temporary occlusion of suspected long insular arteries under continuous MEP monitoring, can help to preserve motor function during resection of insulo-opercular gliomas.

Conflicts of Interest Disclosure

All the authors have already declared COI status to the Japan Neurological Society. This manuscript has no COI that should be disclosed.

References

1) Kumabe T, Higano S, Takahashi S, Tominaga T: Ischemic complications associated with resection of opercular glioma. *J Neurosurg* 106: 263–269, 2007
2) Kumabe T, Kanamori M, Saito R, Nagamatsu K, Sonoda Y, Higano S, Takahashi S, Tominaga T: Ischemic complications associated with resection of opercular gliomas, *in* Takahashi S (*ed*): *Neurovascular Imaging: MRI & Microangiography*. London, Springer-Verlag, 2010, pp 305-318
3) Suzuki K, Kodama N, Sasaki T, Matsumoto M, Konno Y, Sakuma J, Oinuma M, Murakawa M: Intraoperative monitoring of blood flow insufficiency in the anterior choroidal artery during aneurysm surgery. *J Neurosurg* 98: 507–514, 2003
4) Krieg SM, Shiban E, Droese D, Gempt J, Buchmann N, Pape H, Ryang YM, Meyer B, Ringel F: Predictive value and safety of intraoperative neurophysiological monitoring with motor evoked potentials in glioma surgery. *Neurosurgery* 70: 1060–1070; discussion 1070–1071, 2012
5) Kim EH, Cho JM, Chang JH, Kim SH, Lee KS: Application of intraoperative indocyanine green videoangiography to brain tumor surgery. *Acta Neurochir (Wien)* 153: 1487–1495; discussion 1494–1495, 2011
6) Türe U, Yaşargil MG, Al-Mefty O, Yaşargil DC: Arteries of the insula. *J Neurosurg* 92: 676–687, 2000
7) Tanriover N, Rhoton AL, Kawashima M, Ulm AJ, Yasuda A: Microsurgical anatomy of the insula and the sylvian fissure. *J Neurosurg* 100: 891–922, 2004
8) Sanai N, Polley MY, Berger MS: Insular glioma resection: assessment of patient morbidity, survival, and tumor progression. *J Neurosurg* 112: 1–9, 2010

Address reprint requests to: Toshihiro Kumabe, MD, Department of Neurosurgery, Tohoku University Graduate School of Medicine, 1-1 Seiryo-machi, Aoba-ku, Sendai, Miyagi 980-8574, Japan.
e-mail: kuma@nsg.med.tohoku.ac.jp.