Correct Plane of the Sylvian Vein Dissection for Middle Cerebral Artery Aneurysm Using Indocyanine Green Videoangiography

Sung-Pil Joo, Seung-Hoon Jung, Sung-Hyun Kim, Tae-Sun Kim

BACKGROUND: Preservation of the superficial Sylvian veins (SSVs) is essential to prevent neurologic deficits during Sylvian dissection. We describe an appropriate surgical approach for unruptured middle cerebral artery (MCA) aneurysms to preserve these veins by using indocyanine green videoangiography (ICG-VA).

METHODS: Between August 2014 and August 2015, we performed microsurgical clipping for 37 unruptured MCA aneurysms in 36 patients. We classified all of the cases into 3 types according to the location between the Sylvian fissure and the SSV. We defined 3 surgical approaches (frontosylvian, intersylvian, and temporo-sylvian) based on the SSV and investigated the proper surgical approach according to the type of case.

RESULTS: In our study, most SSVs were located above the Sylvian fissure (fissure type, 64.9%). The SSV was located on the temporal lobe in 10 cases (temporal type) and on the frontal lobe in 3 cases (frontal type). The frontosylvian approach (splitting between the SSV and frontal lobe) was performed in all of the patients with temporal type; the temporo-sylvian approach (splitting between the SSV and temporal lobe) was performed in all of the patients with frontal type and single SSV of fissure type. The intersylvian approach (splitting between the frontal and temporal SSV, or among multiple SSVs) was successfully performed in the patients with double or multiple SSVs of fissure type. No venous complications occurred that were related to the surgical approach.

CONCLUSIONS: Correct dissection strategy using intraoperative ICG-VA is greatly useful to define the optimal surgical approach without vein injury.

INTRODUCTION

The Sylvian fissure is the gateway to all intracranial aneurysms around the circle of Willis, and splitting the Sylvian fissure is one of the most important surgical skills for microneurosurgeons. Superficial Sylvian veins (SSVs) are the guardians of the Sylvian fissure. In general, SSVs are mobilized to the temporal side of the fissure because they course inferiorly and bridge to the sphenoparietal sinus under the sphenoid ridge. Therefore, the Sylvian fissure has been dissected conventionally through the frontal side of the SSV with sacrifice of the frontal superficial Sylvian vein (fSSV). Sacrifice of the vein can lead to venous infarction or severe cerebral edema, and a neurologic deficit after venous complications is one of the important factors in the treatment of unruptured intracranial aneurysms. Previous studies introduced various surgical techniques to preserve the Sylvian veins.

Indocyanine green videoangiography (ICG-VA) is commonly used during cerebrovascular surgeries to determine vascular patency and obtain real-time lesional status. We applied ICG-VA to splitting of the SSV for a microsurgical approach to unruptured middle cerebral artery (MCA) aneurysms with minimal arachnoid opening; herein we describe the correct plane of Sylvian dissection to enter the fissure and preserve the SSV.
METHODS AND MATERIALS

Patient Demographic and Clinical Data
Between August 2014 and August 2015, we performed surgery on 37 unruptured MCA aneurysms in 36 patients. For each patient, demographic data, including age, sex, size, relationship between the Sylvian fissure and the SSV according to intraoperative ICG-VA findings, and postoperative complications, were evaluated. We evaluated preoperative and postoperative brain computed tomography (CT) scan to identify low-density areas, or venous complications around the Sylvian fissure. We excluded patients with subarachnoid hemorrhage because this could also cause brain damage and edema.

Acquisition of ICG-VA
We used indocyanine green twice in the operating field. Before splitting the arachnoid membrane, indocyanine green was administered intravenously as a bolus. The venous phase of ICG-VA showed the course of SSV and tributaries; therefore, we were able to determine the correct plane of dissection. After aneurysmal clipping, we could confirm the patency of the SSV and complete aneurysmal occlusion by using ICG-VA. Whenever we used indocyanine green, we injected half of the standard dose (0.2–0.3 mg/kg). No adverse effect related to indocyanine green occurred.

Craniotomy and Dural Incision
All of the patients underwent typical pterional craniotomy. Although the patient was in the supine position, the head was rotated by 15° to the opposite side of the surgical site. After frontotemporal craniotomy was performed, the lateral parts of the sphenoidal ridge were removed. The dura mater was opened in a semicircular fashion.

Relationship Between the Sylvian Fissure and the SSV
After opening the dura mater, we used ICG-VA before we split the outer arachnoid membrane over the SSV and confirmed the location of the Sylvian fissure and the path of the SSV. We divided all of the cases into 3 types according to the location between the Sylvian fissure and SSV as follows: temporal type, where the SSV was located on the temporal lobe (Figure 1A); fissure type, where the SSV was located above the Sylvian fissure (Figure 1B); and frontal type, where the SSV was located on the frontal lobe (Figure 1C).

We also divided the SSV into 4 types according to the number of main trunks as follows: 1) no SSV; 2) single, where the SSV had a single vein with tributaries from the frontal and/or temporal lobes; 3) double, where the SSV had parallel or 2 venous stems (frontal and temporal) with tributaries; and 4) multiple, where the SSV had multiple veins with tributaries.

Intersylvian and Retrosylvian Approach
Based on the SSV, we defined an approach that split between the fSSV and temporal superficial Sylvian vein (tSSV), or among the multiple SSV as an intersylvian approach (Figure 1B). We also defined an approach that split between the SSV and the temporal lobe as a temporosylvian approach (Figure 1C). The frontosylvian approach split between the SSV and the frontal lobe (Figure 1A). We dissected all Sylvian fissures from superficial to deeper layers.

RESULTS
The patients included 29 women and 7 men, of whom 1 man underwent surgical clipping on both sides. The mean age at presentation was 59.9 years (range, 38–76 years). The mean size of the aneurysms was 5.2 mm (range, 1.5–9 mm). The MCA...
bifurcation was the most common location of the aneurysm (MCA bifurcation: n = 36, horizontal segment of middle cerebral artery [M1]: n = 1), and only 1 patient had multiple aneurysms (MCA bifurcation and insular segment of middle cerebral artery [M2]). The outcome of the 37 cases was good, with no neurologic deficit. On postoperative CT scan, we did not observe any low density around the surgical field.

Almost all the SSVs were single or double and had tributaries (83.8%). The intraoperative ICG-VA findings indicated that the single SSV had tributaries from both the frontal and temporal lobes or from one side of each lobe. The double SSVs consisted of one SSV with tributaries from the frontal lobe (fSSV) and another SSV with tributaries from the temporal lobe (tSSV). Multiple SSVs had multiple veins with tributaries. We did not identify any cases with an absence of SSSVs in our series.

In this study, most SSVs were located above the Sylvian fissure (fissure type, 64.9%). The SSV was located on the temporal lobe in 10 cases (temporal type, 27.0%) and the frontal lobe in 3 cases (frontal type, 8.1%).

The frontosylvian approach was performed in all of the patients with temporal type, and the temporo-sylvian approach was performed in all of the patients with frontal type. We performed various approaches for the fissure type cases, including both the frontosylvian and temporo-sylvian approaches. The intersylvian approach was performed in 13 fissure type cases, and almost all cases had double SSVs (11/13, 84.6%). The temporo-sylvian approach was performed in 8 fissure type cases, and all consisted of a single SSV. The relationship between the type of cases and the surgical approach is shown in Table 1.

### Table 1. Relationship Between the Type of Cases and Surgical Approach

<table>
<thead>
<tr>
<th>Type of Case</th>
<th>Temporal Type</th>
<th>Fissure Type</th>
<th>Frontal Type</th>
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<td>3</td>
</tr>
<tr>
<td></td>
<td>Double: 3</td>
<td></td>
<td>Multiple: 1</td>
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Illustrative Cases

**Case 1 (Fissure Type, Intersylvian Approach).** A 63-year-old woman was operated for an unruptured aneurysm on the MCA bifurcation. After lateral to medial dissection of the Sylvian fissure, we could see an unruptured aneurysm (5 mm in size). The aneurysm was successfully clipped by using a multiple clipping technique (Figure 2C). We identified patency of the SSV and tributaries by using the ICG-VA after aneurysmal clipping (Figure 2D). Another representative 2 cases of multiple SSVs over the Sylvian fissure were successfully split by using the same approach (Figure 3).

**Case 2 (Temporal Type, Frontosylvian Approach).** A 76-year-old woman was admitted with an unruptured aneurysm on the MCA bifurcation. At surgery, we identified parallel SSVs with tributaries on the temporal lobe (temporal type, double SSV) by using ICG-VA, similar to case 17 (Figure 4A). Because the SSVs were located on the temporal lobe, and the Sylvian fissure was located to the frontal side of the SSV, we split between the fSSV and frontal lobe (conventional approach). After dissecting between the fSSV and frontal lobe without injury to tributaries, aneurysm clipping was successfully performed. ICG-VA showed the fully occluded aneurysm sac and patency of the SSV and tributaries (Figure 4C).

**Case 3 (Frontal Type, Temporo-Sylvian Approach).** A 63-year-old woman was operated for an unruptured aneurysm on the MCA bifurcation. ICG-VA showed a single SSV with tributaries on the frontal lobe (frontal type, single SSV) (Figure 5A). We identified prominent tributaries from the frontal lobe and decided to split between the single SSV and temporal lobe. No SSV tributaries were observed along the plane of dissection (Figure 5B). We easily found an unruptured aneurysm by using the temporo-sylvian approach (Figure 5C) and confirmed no compromising veins by using ICG-VA (Figure 5D).

### DISCUSSION

Sylvian dissection is a basic technique for neurovascular surgeons, but normal variations of the SSV and Sylvian fissure are often puzzling. In modern neurosurgery, preservation of the vein is essential to decrease morbidity; therefore, surgeons should try to preserve SSVs. In the conventional frontal-sided Sylvian split, all of the inferolateral frontal tributaries of the SSV are often pruned away, which may lead to neurologic complications.1,4 Bruce et al. reported that injury to the SSVs and adjacent venous structures strongly correlated with cerebral edema and hemorrhage.5 We believe that the Sylvian fissure should no longer be dissected through the frontal side of the SSV with sacrifice of the tributaries in unruptured MCA bifurcation aneurysms. The
Sylvian fissure should be dissected according to the course and tributaries of the SSV. Previous studies recommended that the dissection plane should depend on the course of the SSV. Therefore, splitting between the fSSV and tSSV is the proper dissection plane in some cases, and splitting between the brain and vein is correct in others.

The courses of SSVs and tributaries should be identified to prevent vein compromise. Almost all neurosurgeons make a dissection plane through the microscopic view with no specific device. The Sylvian vein structure can be identified with the naked eye in many cases. However, SSVs are interposed between the 2 layers of the arachnoid membrane, and the opaque outer

Figure 2. Intersylvian approach. (A) Indocyanine green videoangiography (ICG-VA) image showing 2 stems of the superficial Sylvian veins with tributaries. The Sylvian fissure is located just below the superficial Sylvian veins. (B) The superficial Sylvian veins are split between the frontal and temporal superficial Sylvian veins. An unruptured aneurysm is exposed on the Sylvian fissure. (C) The aneurysm is successfully clipped by using multiple clipping techniques. (D) ICG-VA image showing patency of the superficial Sylvian veins and complete aneurysmal occlusion. F, frontal lobe; T, temporal lobe.

Figure 3. Multiple superficial Sylvian veins are located over the Sylvian fissure (A), and we chose the intersylvian approach to preserve the tributaries (B). We were able to proceed to the aneurysm easily and preserve the superficial Sylvian veins (C). F, frontal lobe; T, temporal lobe.
arachnoid membrane often makes it difficult to identify the course of the veins, especially for inexperienced neurosurgeons. In those cases, we introduced the ICG-VA to visualize the pattern of the SSVs and evaluated the usefulness of ICG-VA in Sylvian dissection. We have been using ICG-VA before splitting the outer arachnoid membrane. Moreover, ICG-VA helped surgeons decide which way to split the vein in cases where the naked eye could not clarify the venous structure. Feindel et al. 7,8 were the first to apply the concept of fluorescence angiography to the intraoperative visualization of cerebral microcirculation in patients undergoing neurosurgical procedures, and ICG-VA is widely used in cerebrovascular surgery. We recently published our experience of using...
ICG-VA for various cerebrovascular surgeries; ICG-VA is simple and provides real-time information on the patency of vessels within the field of microscopy.\textsuperscript{9} SSVs vary in size and number among patients and between sides in the same person.\textsuperscript{3} In our study, one patient had different numbers of SSVs on each side (single and multiple). In previous literature, SSVs were schematically of 4 subtypes as follows\textsuperscript{1,2}: absence of SSV, single SSV, 2 SSVs, and multiple SSVs. Kazumata et al.\textsuperscript{2} reported that SSVs were present in 90% of their cases; we identified SSVs in all of our cases. Among the 4 subtypes, 2 SSVs are generally identified, which we named double SSVs in this study.\textsuperscript{11} In 16 of our 37 cases, double SSVs were observed, followed by a single SSV in 15 cases. Maekawa and Hadeishi\textsuperscript{3} introduced several technical tips to preserve the SSVs. They said that the Sylvian fissure should be split between the fSSV and tSSV in double SSVs because each SSV usually receives blood from either the frontal or temporal side of the fissure. We agreed with this and selected a surgical approach that could save all tributaries when SSVs were located over the Sylvian fissure; we referred to these as the fissure type in this study. We dissected almost all double SSVs over the Sylvian fissure via the intersylvian approach (11/12, 91.7%) (Table 1). Almost all single SSVs over the Sylvian fissure were split by using the tempo-sylvian approach (8/10). We identified prominent tributaries from the frontal lobe in 8 cases and performed a tempo-sylvian approach to save these tributaries. Two cases of a single SSV over the Sylvian fissure had prominent tributaries from the temporal lobe, and less prominent tributaries from the frontal lobe. Therefore, we dissected between the single SSV and tributaries from the frontal lobe. All of the cases had SSVs in our study, but injury of the deep middle cerebral vein should be avoided during Sylvian dissection in such cases.

The location of the Sylvian fissure based on the SSVs is also important in deciding the surgical approach. When SSVs were over the Sylvian fissure, we made a dissection plane to save all of the tributaries. However, when the SSVs were not over the Sylvian fissure, we opened the outer arachnoid membrane near the Sylvian fissure. When the SSVs were located on the frontal lobe (frontal type), we selected a tempo-sylvian approach (3/3), and splitting the arachnoid membrane near the Sylvian fissure facilitated dissection without injury to the tributaries. When the SSVs were located on the temporal lobe (temporal type), we chose the frontosylvian approach for easy Sylvian dissection (10/10). In these cases, the intersylvian and/or tempo-sylvian approaches can damage the superior temporal gyrus, and damage to the superior temporal gyrus increases the risk of postoperative epilepsy.\textsuperscript{10}

We saved all the tributaries from the frontal lobe and acquired an adequate surgical corridor with the correct dissection plane and surgical instruments throughout the frontosylvian approach. Previous studies showed that a wide Sylvian opening was not needed for clipping aneurysms,\textsuperscript{11,12,15} and we also did not need a wide opening for management of unruptured MCA aneurysms. This means that frontal tributaries of SSV are not always sacrificed in the conventional approach, and the Sylvian fissure can be accessed through the space between the tributaries. Frontal tributaries could be detached from the frontal lobe and mobilized by using microscissors and bipolar cautery, and we could obtain a sufficiently wide working space without sacrificing the tributaries. Sylvian veins generally course inferiorly and continue to the sphenoparietal sinus. Deep aneurysms are dissected along the frontal side of the vein to preserve the Sylvian vein, such as in an anterior communicating artery aneurysm. Therefore, application of this technique to deep aneurysms is not suitable except for unruptured MCA bifurcation aneurysms.

CONCLUSIONS
We could identify the course of SSVs and tributaries by using ICG-VA and perform Sylvian dissection easily and effectively without sacrificing the SSVs, even with minimal arachnoid opening. The proper surgical approach should be selected according to the location between the Sylvian fissure and the SSV and the course of the SSV.

REFERENCES

Conflict of interest statement: This study was supported by the Chonnam National University Hospital Biomedical Research Institute (CRI16040-21). Received 20 July 2016; accepted 29 September 2016 Citation: World Neurosurg. (2017) 97:453-458. http://dx.doi.org/10.1016/j.wneu.2016.09.128 Journal homepage: www.WORLDNEUROSURGERY.org Available online: www.sciencedirect.com 1878-8750/$ - see front matter © 2016 Published by Elsevier Inc.