



Impact of the Intracranial Course of Internal Carotid Artery on Optimal Surgical Approach for Posterior Communicating Artery Aneurysms

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■ **BACKGROUND:** The anterior temporal approach (ATA) has been reported as suitable for surgical clipping of posteriorly projecting internal carotid artery (ICA) aneurysms. As the ICA follows a variable course, tortuosity of the ICA may affect visualization of the aneurysm. The aim of this study was to investigate the impact of the intracranial course of the ICA and aneurysm projection on surgical approach.

■ **METHODS:** Consecutive patients with posterior communicating artery aneurysms treated with clipping at our hospital between May 2015 and April 2018 were retrospectively reviewed. When the transsylvian approach (TSA) could not achieve adequate exposure of the aneurysm, the ATA was subsequently performed. Distance between the ICA and the anterior and posterior clinoid line, angle between the midline and the C1 segment of the ICA, and aneurysm projection were compared between ATA and TSA groups.

■ **RESULTS:** Of 52 patients (40 ruptured, 12 unruptured), 12 were in the ATA group, and 40 were in the TSA group. Mean ICA–anterior and posterior clinoid distance was significantly shorter in the ATA group than in the TSA group ($P = 0.002$), and mean midline–C1 angle was significantly larger in the ATA group than in the TSA group ($P < 0.0001$). The ATA group was associated with a greater frequency of posteriorly projecting aneurysms (12 of 12; 100%) than the TSA group (9 of 40; 22.5%) ($P < 0.00001$).

■ **CONCLUSIONS:** A low-lying, laterally projecting intracranial ICA and posteriorly projecting aneurysm are predictors of the necessity for the ATA in the surgical clipping of posterior communicating artery aneurysms.

INTRODUCTION

Despite the present endovascular era, advances in microsurgical techniques for posterior communicating artery (PCoA) aneurysm are needed, as this aneurysm was shown to carry a high risk of recurrence after coil embolization in the International Subarachnoid Aneurysm Trial and other studies^{1,2} and thus may require microsurgical treatment. The anterior temporal approach (ATA), also referred to as the tempopolar approach or combined pterional/anterior temporal approach, has been described as a modification of the classic transsylvian approach (TSA) that allows access to aneurysms of the basilar apex.^{3–5} This approach has also been reported to be suitable for surgical clipping of posteriorly projecting ICA aneurysms, as lateral and posterior views of the internal carotid artery (ICA) via the wide retrocarotid space can be achieved.⁶ However, objective definitions of aneurysm projection are lacking.⁷ Furthermore, as the ICA follows a variable course close to inferior and lateral structures, such as the anterior and posterior clinoid processes and tentorium, the tortuosity of the ICA and its proximity to fixed structures affect visualization of the aneurysm. This study investigated the impact of the intracranial course of the ICA and aneurysm projection on the optimal surgical approach for clipping of PCoA aneurysms.

Key words

- Anterior temporal approach
- Internal carotid artery
- Low-lying
- Posterior communicating artery aneurysms
- Transsylvian approach

Abbreviations and Acronyms

- APC:** Anterior and posterior clinoid
- ATA:** Anterior temporal approach
- CTA:** Computed tomography angiography
- ICA:** Internal carotid artery
- IQR:** Interquartile range
- ML:** Midline

PCoA: Posterior communicating artery

TSA: Transsylvian approach

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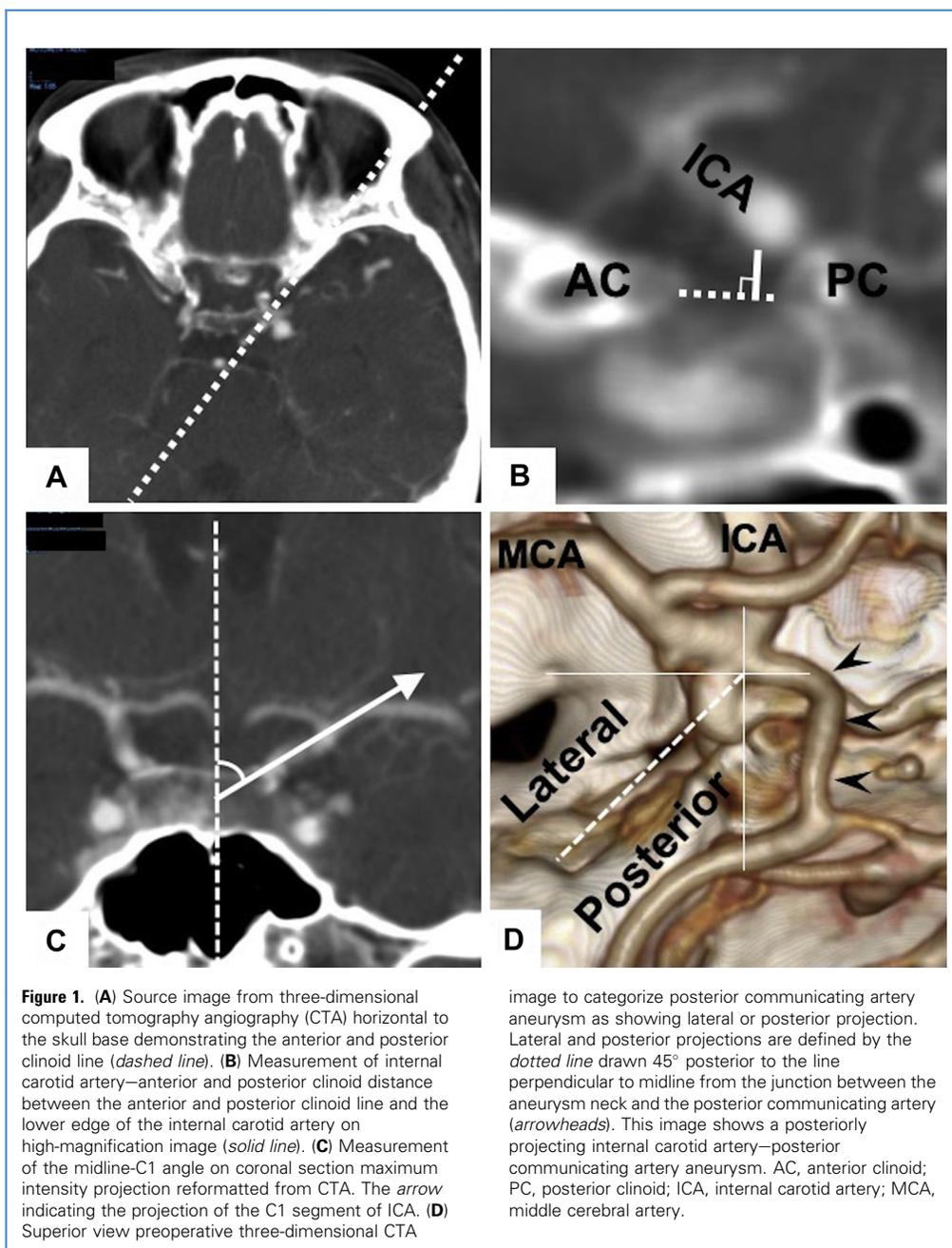
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MATERIALS AND METHODS

Institutional review board approval was obtained for retrospective review of the medical records from our hospital. The clinical records of 59 consecutive patients with ruptured or unruptured PCoA aneurysm (47 ruptured, 12 unruptured) who underwent surgical aneurysmal neck obliteration at our hospital between May 2015 and April 2018 were retrospectively reviewed. Informed consent was not required. Among these patients, 7 aneurysms projecting medially were excluded from this study, as a medial

approach from the contralateral side or fenestrated clip application from the ipsilateral side is necessary for surgical clipping.

In all cases, three-dimensional (3D) computed tomography angiography (CTA) was performed preoperatively, and data were analyzed using Aquarius NET (TeraRecon, San Mateo, California, USA). Interfascial pterional (so-called frontotemporosphenoidal) craniotomy was performed, and the temporal squamosal bone was drilled inferiorly to mobilize the temporal lobe posterolaterally.⁸ After opening the dura mater, the superficial sylvian vein was



meticulously isolated toward the draining point into the sphenoparietal sinus, especially from surrounding structures, such as the superior temporal gyrus and temporal tip. Thereafter, the standard TSA was employed for the aneurysm. When the standard TSA could achieve adequate exposure of the aneurysm, surgical clipping was performed (TSA group). However, if clear exposure of the aneurysm was not achieved from the anterolateral view via the TSA, the ATA was applied subsequently (ATA group). Cutting of the arachnoid membrane lateral to the oculomotor nerve and anterior choroidal artery is the key procedure of the ATA to mobilize the temporal lobe posterolaterally and then to achieve lateral and posterior views of the ICA via the wide retrocarotid space.

Based on our clinical experience, adequate exposure of an aneurysm could not be achieved without ATA for PCoA aneurysms originating from a low-lying C2 segment or laterally projecting C1 segment according to Fischer's classification.⁹ Therefore, the distance from C2 to the anterior and posterior clinoid (APC) line and the angle between the midline (ML) and the C1 segment of the ICA (ML-C1) were measured on 3D CTA images to clarify the necessity for the ATA. ICA-APC distance was measured as described previously.¹⁰ Briefly, on a vertical plane to the skull base, the shortest distance between the anterior clinoid process and posterior clinoid process was defined as the APC line (Figure 1A). The shortest distance between the APC line and the lower edge of the ICA made on a reformatted image from the CTA dataset was then measured (Figure 1B). The ML-C1 angle was also measured on the coronal section of the maximum intensity projection reformatted from the CTA dataset (Figure 1C), as described elsewhere.¹⁰ In addition, as posteriorly projecting aneurysms seem to be impeded by the intracranial ICA via a frontolateral surgical view with the TSA approach, aneurysm projection was divided into lateral and posterior on axial plane or superior view 3D CTA (Figure 1D), as described elsewhere.⁷ Lines parallel and perpendicular to the ML were drawn posteriorly and laterally from the junction between the aneurysm and the PCoA. Another line was drawn at 45° posteriorly to the line perpendicular to the ML and defined as the axis between lateral and posterior projections

because this angle was relatively easily measured in clinical settings. Procedure-related complications were compared between the 2 approaches. Procedure-related complications were defined as symptomatic cortical or subcortical cerebral infarction or intra-operative rupture or postoperative hematoma formation.

Descriptive statistics were expressed as mean \pm SD or median value plus interquartile range, as appropriate. Mann-Whitney *U* test was used to assess differences between the 2 groups in age, sizes of the aneurysm and aneurysm neck, ICA-APC distance, and ML-C1 angle. Fisher exact test was performed to evaluate differences in sex and aneurysm projection. Sensitivity, specificity, and cutoff points of the ICA-APC distance and ML-C1 angle value for predicting the necessity for ATA were evaluated using the receiver operating characteristic curve. Statistical significance was set at $P < 0.05$.

RESULTS

The ATA group included 12 patients, and the TSA group included 40 patients (Table 1). Mean age, sex, median aneurysm size, and median aneurysm neck size did not differ significantly between ATA and TSA groups. Median ICA-APC distance was significantly shorter in the ATA group (1.1 mm [IQR 0.6–1.5 mm]) than in the TSA group (2.3 mm [IQR 1.4–3.2 mm]) ($P = 0.002$), and median ML-C1 angle was significantly larger in the ATA group (70.4° [IQR 65.8°–82.6°]) than in the TSA group (48.1° [IQR 25.6°–59.9°]) ($P < 0.0001$). For aneurysm projection, the ATA group showed a significantly greater frequency of posteriorly projecting aneurysms (12 of 12; 100%) compared with the TSA group (9 of 40; 22.5%) ($P < 0.00001$).

Sensitivity and specificity of the ICA-APC distance for predicting use of the ATA were 83.3% and 72.5%, respectively, for cutoff points close to the left upper corner of the receiver operating characteristic curve (ICA-APC distance = 1.6 mm) (Figure 2A). Sensitivity and specificity of the ML-C1 angle for predicting use of the ATA were 91.7% and 77.5%, respectively, for cutoff points close to the left upper corner of the receiver operating characteristic curve (ML-C1 angle = 60.0°) (Figure 2A). For a cutoff ICA-APC distance equal to 2.5 mm and for a cutoff ML-C1 angle equal to 50.4°, sensitivity and negative predictive values for using

Table 1. Clinical Characteristics of 52 Cases with Internal Carotid Artery–Posterior Communicating Artery Aneurysm

Variable	Surgical Approach		P Value
	ATA (12 Patients)	TSA (40 Patients)	
Age, years	66.5 \pm 13.6	70.5 \pm 11.8	0.4089
Male sex	3 (25)	2 (5)	0.0779
Aneurysm size, mm (IQR)	6.95 (6.50–7.50)	6.80 (6.30–7.20)	0.671
Aneurysm neck size, mm (IQR)	4.9 (4.25–5.10)	4.6 (4.20–5.00)	0.330
ICA-APC distance, mm (IQR)	1.05 (0.61–1.48)	2.29 (1.42–3.15)	0.0019
ML-C1 angle, ° (IQR)	70.4 (65.8–82.6)	48.1 (25.9–59.9)	<0.0001
Posterior projection	12 (100)	9 (22.5)	<0.00001

Data are presented as mean \pm SD, number of patients (%), or median (IQR).
ATA, anterior temporal approach; TSA, transsylvian approach; IQR, interquartile range; ICA, internal carotid artery; APC, anterior and posterior clinoid; ML, midline.

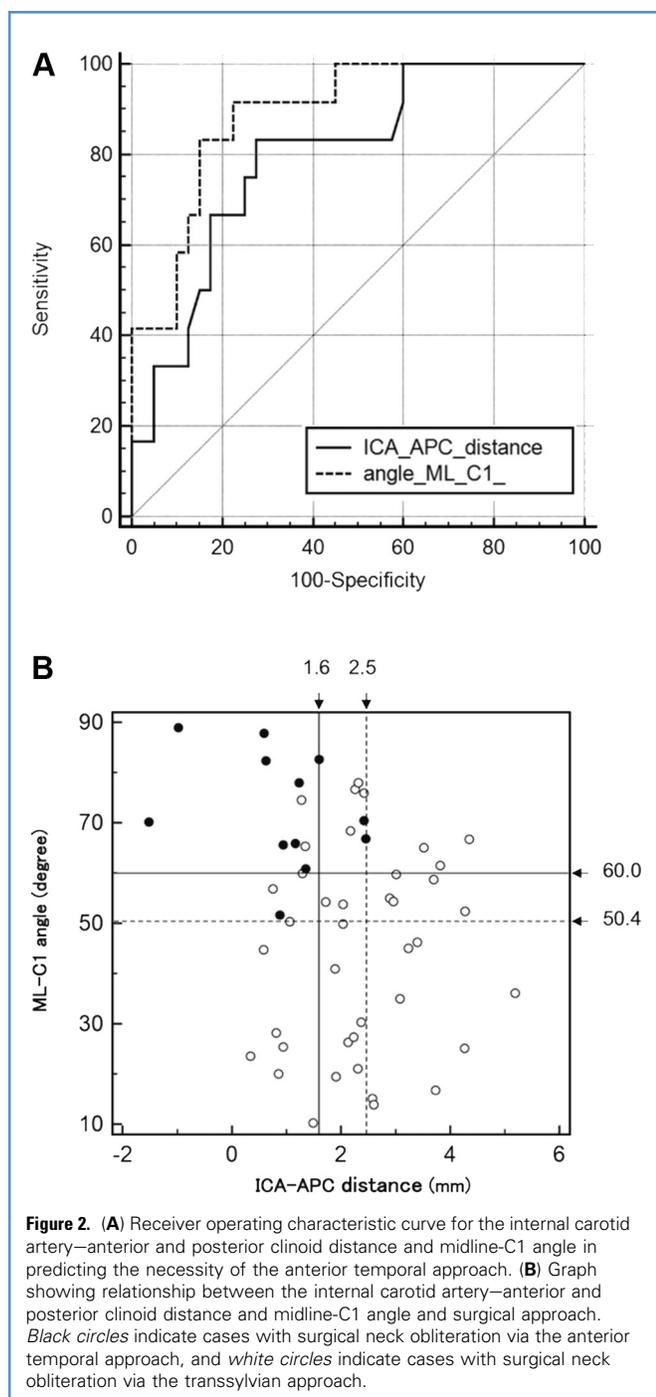


Figure 2. (A) Receiver operating characteristic curve for the internal carotid artery–anterior and posterior clinoid distance and midline-C1 angle in predicting the necessity of the anterior temporal approach. (B) Graph showing relationship between the internal carotid artery–anterior and posterior clinoid distance and midline-C1 angle and surgical approach. Black circles indicate cases with surgical neck obliteration via the anterior temporal approach, and white circles indicate cases with surgical neck obliteration via the transylvian approach.

the ATA were both 100%. The relationship between ICA-APC distance and ML-C1 angle and surgical approach is shown in **Figure 2B**. When the ICA-APC distance was short and the ML-C1 angle was simultaneously large, the surgical approach tended to be the ATA. In other situations, the surgical approach tended to be the TSA.

Procedure-related complications were observed in 2 of 52 (3.8%) surgical clippings for ICA-PCoA aneurysms. In the ATA group, 1 patient experienced venous infarction of the temporal lobe 6 days after surgery without morbidity. In the TSA group, 1 patient experienced intraoperative rupture. No cases of postoperative oculomotor palsy were encountered in this series. The number of cases was too small to reveal any findings of statistical significance.

ILLUSTRATIVE CASE

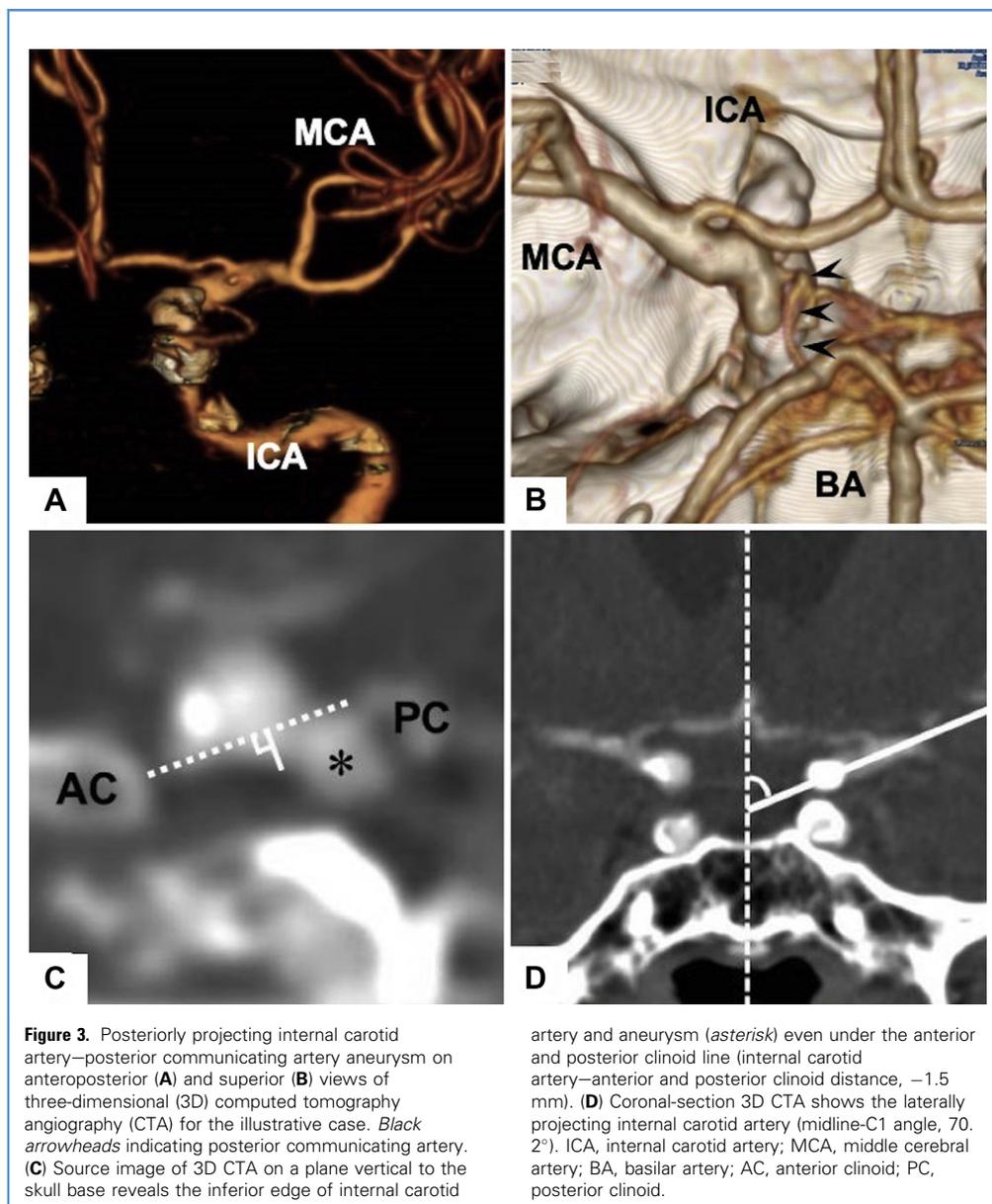
An 81-year-old man with severe headache and subsequent loss of consciousness was admitted to our hospital. No focal neurologic abnormalities were noted. Initial computed tomography showed findings typical of subarachnoid hemorrhage in the basal cistern. A saccular aneurysm could not be identified on anteroposterior view 3D CTA (**Figure 3A**). Superior view 3D CTA showed posteriorly projecting saccular aneurysm (**Figure 3B**). ICA-APC distance was -1.5 mm, and ML-C1 angle was 70.2° (**Figure 3C** and **D**).

The aneurysm was approached via the standard TSA but could not be well visualized because the greater part of the aneurysm was hidden behind the ICA (**Figure 4A** and **B**). Therefore, the ATA was applied to achieve more lateral views of the aneurysm and ICA. The ATA allowed the surgeon to approach the aneurysm even along the inferior wall of the ICA and to expose the aneurysm neck (**Figure 4C** and **D**). The aneurysm was successfully obliterated with a bayonet-shaped titanium clip (Yasargil titanium clip; Aesculap AG, Tuttlingen, Germany). Complete aneurysm occlusion and patency of both the PCoA and the anterior choroidal artery were confirmed intraoperatively by indocyanine green angiography. Postoperative 3D CTA revealed disappearance of the aneurysm (**Figure 4E** and **F**). The postoperative course was uneventful, and the patient was discharged with no neurologic deficits.

DISCUSSION

This study demonstrated that PCoA aneurysms originating from a low-lying C2 segment and laterally projecting C1 segment were significantly associated with use of the ATA. Moreover, PCoA aneurysms projecting $\geq 45^\circ$ posteriorly to the line perpendicular to the ML were also associated with use of the ATA. The intracranial course of the ICA will influence the operative view as follows: 1) a lower-lying C2 segment narrows the retrocarotid space and can result in inadequate visualization of the aneurysm from the anterolateral view via the TSA; 2) a laterally projecting C1 segment interferes with aneurysm visualization via the TSA and also narrows the retrocarotid space. The ATA thus needs to be adopted, as this approach allows exposure of aneurysms along the lateral and posterior wall of the ICA.

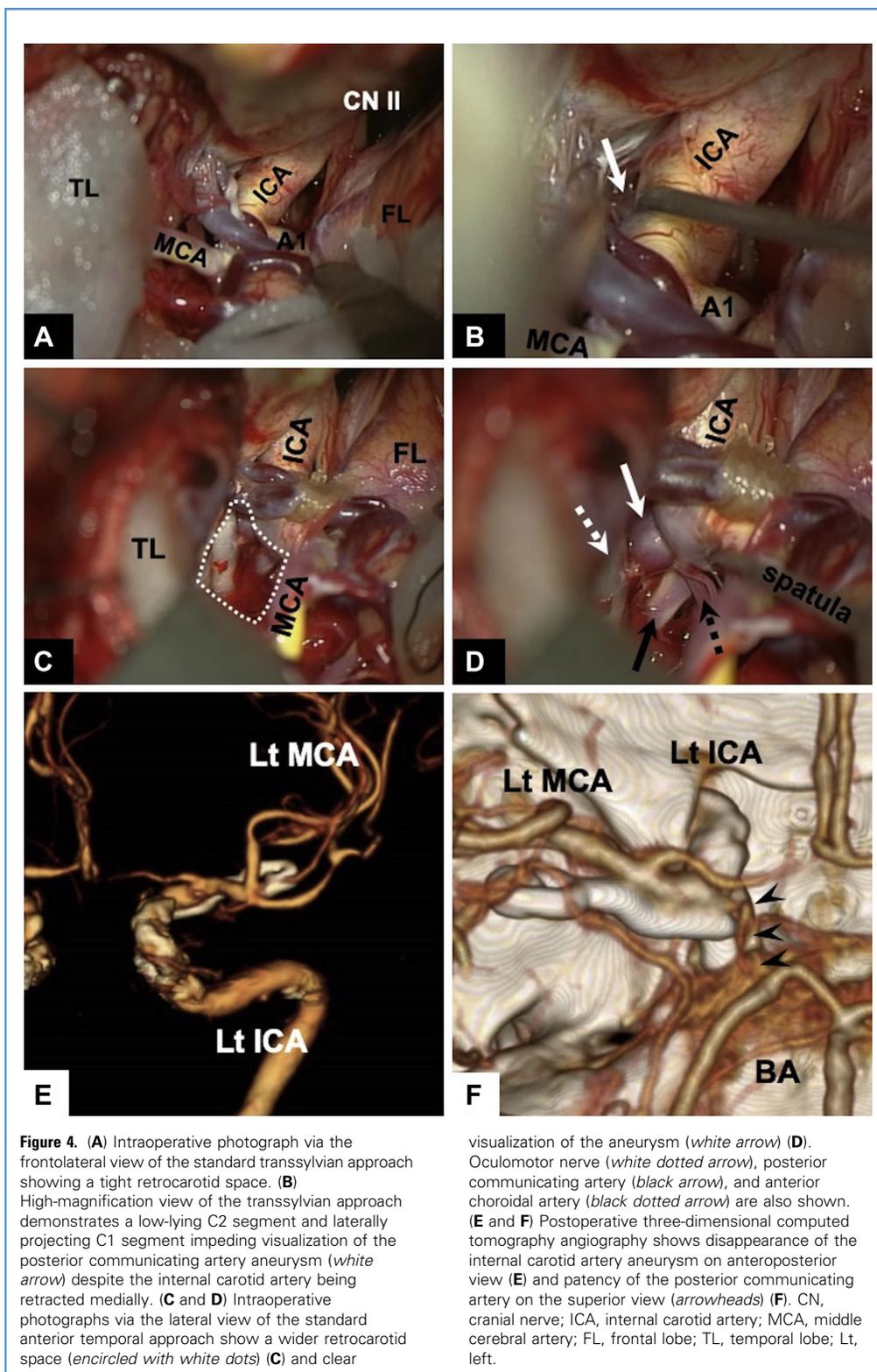
PCoA aneurysms with posterior projection showed a higher risk of procedure-related complications of surgical clipping than aneurysms with other projections.⁷ Kazumata et al.⁶ reported the utility of the ATA for safe clipping of PCoA aneurysms with posterior projection. However, no consensus has been reached regarding objective definitions for posterior projection. Therefore, we defined posteriorly projecting aneurysms as those projecting $\geq 45^\circ$ from the line perpendicular to the ML, as this



definition seemed simple and practical for use in clinical settings. In the present study, posteriorly projecting aneurysms treated via the ATA, as defined here, were treated without significant procedure-related complications. This definition of aneurysm projection may also affect the safety of surgical clipping of posteriorly projecting aneurysms as well as predicting the utility of the ATA.

The ATA is a variation of the standard TSA but offers 2 major advantages compared with the standard TSA.^{3,7} The first is the provision of a wide operative window of the retrocarotid space. The second is that the ATA allows a more lateral line of vision, eliminating the need for medial retraction of the ICA with its attendant potential for aneurysmal rupture. These advantages

translate to improved visualization and thus safer treatment of the aneurysm arising from the low-lying, laterally projecting intracranial ICA, despite the narrow retrocarotid space. On one hand, although the subtemporal approach can also provide a more lateral line of vision than the standard TSA, the subtemporal approach requires different and complicated surgical procedures and often leads to temporal lobe injury owing to excessive temporal retraction.⁶ On the other hand, although posterolateral retraction of the temporal lobe is necessary when the ATA is adopted, temporal lobe injury is preventable by isolation and preservation of the superficial sylvian vein.⁵ Furthermore, although experienced vascular neurosurgeons may use keyhole craniotomy for a posterior projecting PCoA aneurysm, the



limited narrow viewing angles and coaxial control of the surgical microinstruments through a small cranial opening do not seem to achieve the optimal angle of attack for dissection, clipping, and troubleshooting, especially in cases with a narrow retrocarotid space.¹¹ The utility of anterior petroclinoid fold resection or anterior clinoidectomy in the treatment of aneurysm arising from a low-lying, short intracranial ICA via the standard TSA has been reported.^{12,13} These techniques allow the surgeon to expose the proximal intracranial ICA or aneurysmal neck without changing the surgical trajectory. However, the utility of these techniques may be limited in cases where the ICA does not impede the view of the aneurysm from the frontolateral view in the TSA. In addition, endoscopes and small mirrors may help with inspection of the aneurysm before and after clip application, although these devices cannot improve the adequacy of the available space during clip application in cases with a narrow retrocarotid space.¹⁴ Safe and complete clip application thus may not be facilitated by these devices.

The ATA is limited for medially projecting aneurysms, as the surgical corridor is even worse via this approach. In such cases, because neither the ATA nor the standard TSA allows sufficient visualization of the aneurysmal neck, application of a fenestrated clip via the standard TSA seems necessary.¹⁵⁻²⁰

CONCLUSIONS

The present results demonstrated that a low-lying C2 segment, laterally projecting C1 segment, and posteriorly projecting PCoA aneurysm are predictors of the need for the ATA in surgical clipping of PCoA aneurysms. We believe that operators can readily assess the necessity of the ATA for surgical clipping of PCoA aneurysms by focusing on the intracranial course of the ICA and aneurysm projection on 3D CTA. As this was a small study with nonrandomized patients analyzed in a retrospective manner, further investigation is warranted in future studies to confirm the present findings.

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