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Modified extradural selective anterior clinoidectomy leaving the optic canal unopened for internal carotid aneurysms: A technical note

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ABSTRACT

Background: Anterior clinoidectomy is an established procedure used to decompress the optic nerve, mobilize the internal carotid artery (ICA), or enlarge the retrocarotid space. However, its use carries the risk of optic nerve injury. In certain surgeries, such as those for internal carotid aneurysms, propose modification to the anterior clinoidectomy for enlarging the retrocarotid space, especially in operations for ICA aneurysms.

Methods: After the anterior clinoid process (ACP) is sufficiently exposed, the internal cancellous bone or pneumatization can be removed through a small window created at its lateral edge to reveal the compact bone of the optic canal. Since the compact bone of the inferior surface facing the ICA is absent or very thin, the ACP can be removed by drilling through the anchoring compact bone with the optic canal in direct sight.

Results: In 10 consecutive internal carotid aneurysm cases, the ACP was successfully removed without opening of the optic canal to enlarge the retrocarotid space.

Conclusions: Anterior clinoidectomy can be performed to enlarge the retrocarotid space without opening the optic canal from outside the dura.

1. Introduction

Anterior clinoidectomy is useful for treating lesions around the internal carotid artery (ICA) and optic nerve. Using anterior clinoidectomy, the surgeon can decompress the optic nerve, mobilize the ICA by incising the distal dural ring, and obtain wider access to the posterior fossa. However, the risk of morbidity accompanies anterior clinoidectomy, including heat or mechanical injury of the optic nerve. Fortunately, opening the optic canal may not be necessary in all cases, mainly when the purpose of the anterior clinoidectomy is to widen the retrocarotid space. Here we present a modification of extradural anterior clinoidectomy that can widen the retrocarotid space and expose the proximal portion of the intradural ICA. In this method, the optic canal is left unopened, reducing the potential risk of optic nerve injury.

2. Material and methods

2.1. Patients

From November 2017 to May 2022, we used our modified extradural anterior clinoidectomy approach in 10 cases of ICA aneurysm, nine of which were internal carotid–posterior communicating (IC-Pcom) artery aneurysms (Table 1). We removed the anterior clinoid process (ACP) in cases of ICA aneurysms that were large or lacked cancellous bone or pneumatization.

2.2. Surgical procedure

Before the operation, the size of the ACP and the thickness of the cancellous bone were evaluated by the thin slice image of the CT, or the original images of the CT angiography. The presence of pneumatization and its connection to the paranasal sinuses were also evaluated.

After a standard frontotemporal craniotomy was performed, the dura propria of the temporal lobe was dissected from the superior orbital fissure and the temporal lobe retracted posteriorly to expose the ACP. The frontal dura was dissected until the posterior edge of the optic canal was identified (Fig. 1A). A small 4-mm window was created near the lateral edge of the ACP with a high-speed drill to reveal the cancellous bone inside (Fig. 1B), which was removed using a robust blunt dissector (Fig. 1C). Given that the lateral wall of the optic canal consists of hard

Abbreviations: ACP, anterior clinoid process; CT, computed tomography; ICA, internal carotid artery; IC-PCom, internal carotid posterior communicating; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging; SAH, subarachnoid hemorrhage.

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Table 1
Clinical profiles.

Age	59.1	(±12.2)
Female	6	
Size	5.5	(±1.7)
left side	4	
Aneurysm location		
IC-Pcom	9	
IC-bifurcation	1	
Ruptured	8	

compact bone, this procedure does not injure the optic nerve. The compact bone of the optic canal was medially identifiable by removal of the compact bone around the window (Fig. 1D). The compact bone that constituted the superior and lateral walls of the ACP was then drilled away with the optic canal under direct visualization (Fig. 1E). At this point, as the inferior wall facing the ICA is absent or very thin in most cases, the ACP was connected to the medial structure by hard compact bone at the posterior edge and lateral wall facing the superior orbital fissure. Therefore, these hard, compact bony parts were thinned and the ACP selectively fractured. The ACP hanging over the ICA was dissected from the surrounding dura and extracted (Fig. 1F). The optic canal did not require opening.

3. Results

In all cases, the ACP was removed from the outside of the dura without optic canal opening. No visual deficit or other complication occurred due to this procedure. By anterior clinoidectomy, the intradural portion of the ICA was exposed more, which contributed to the feasibility to apply a temporary clip for pressure control, and securing the proximal neck of the aneurysms in IC-PC cases.

3.1. Illustrative cases

3.1.1. Case 1

A 77-year-old woman presented with an irregularly shaped 8-mm unruptured IC-Pcom aneurysm. The patient preferred definitive treatment for this aneurysm; thus, surgical clipping was performed. A preoperative examination revealed a large anterior clinoid process (Fig. 2A) that would have hindered the working space around the proximal neck of the aneurysm (Fig. 2B). After the aneurysm was visualized, the anterior clinoid process was removed extradurally, leaving the compact bone of the optic canal (Fig. 2C and D). With sufficient working space around the proximal neck, the aneurysm was appropriately obliterated (Fig. 2E and F; Supplementary Video 1). The patient's postoperative course was uneventful.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wnsx.2023.100154.

After right frontotemporal craniotomy, the sphenoid ridge was drilled to expose the compact bone of the orbit and create a larger working space. The dura propria was dissected from the superior orbital fissure and the temporal lobe was retracted posteriorly to expose the anterior clinoid process (ACP). The frontal dura was dissected to identify the posterior edge of the optic canal. Then, a small bony window was made

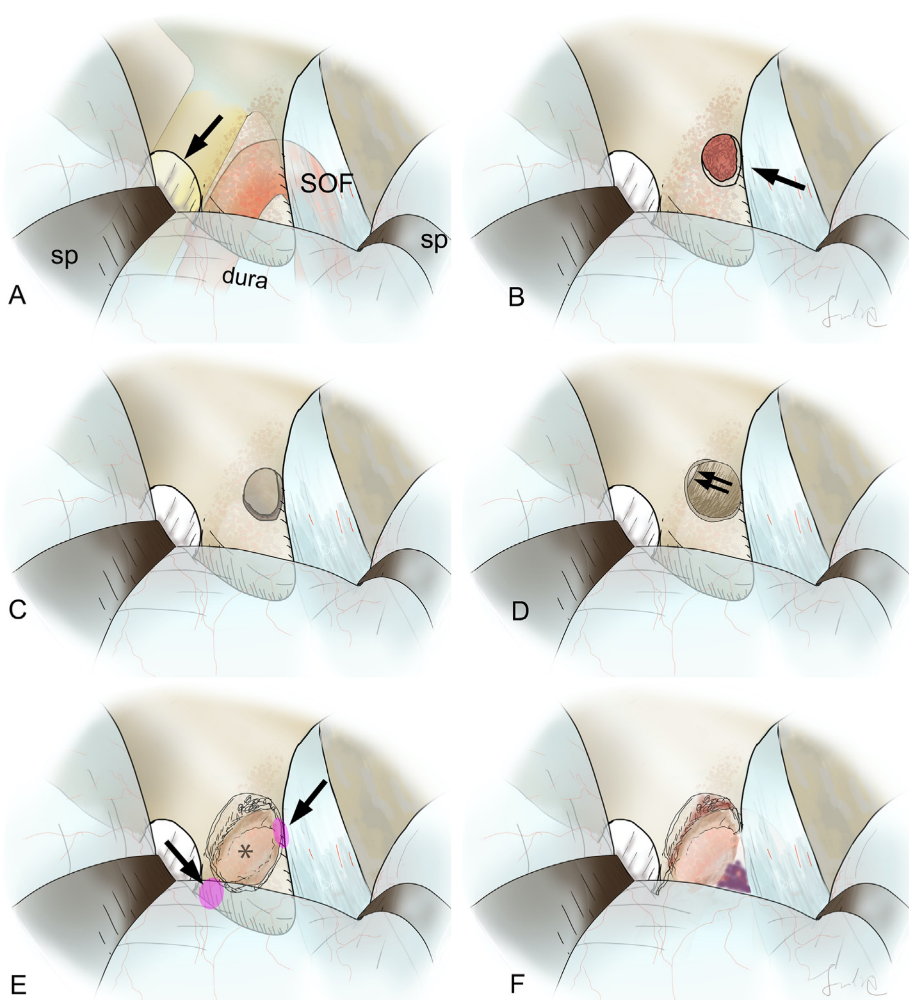

Fig. 1. Schematic drawing of our modified extradural anterior clinoidectomy technique. ACP, anterior clinoid process; ICA, internal carotid artery; sp, spatula A. The ACP is sufficiently exposed by retraction of the dura propria of the temporal lobe and dissection of the frontal dura from the anterior fossa to identify the posterior edge of the optic canal (arrow). B. A small window is made on the lateral edge of the ACP using a 3-mm cutting burr to reveal the cancellous bone inside (arrow). C. The ACP is hollowed by curettage with a robust blunt dissector. As the lateral wall of the optic canal consists of compact bone, this maneuver does not damage the optic nerve. D. By enlarging the window, the compact bone of the optic canal can be identified (double arrows). E. The ACP loses bony support when the lateral and posterior parts (arrows) are drilled and fractured, as the compact bone of the ACP on the ICA (asterisk) is absent or very thin. F. Final view. The optic canal is left unopened, with thin compact bone medially on the ICA.

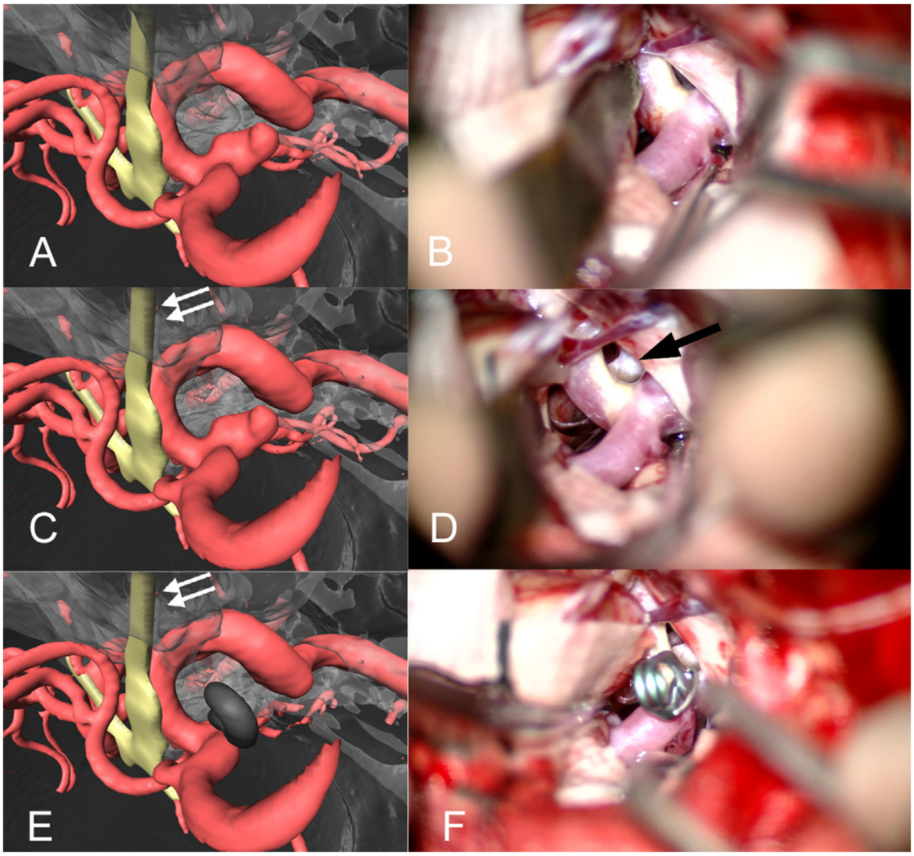

Fig. 2. Intraoperative view before and after ACP removal while leaving the optic canal unopened; 3-dimensional fusion images of preoperative CT and MRI are presented for the anatomical relationship. ACP, anterior clinoid process; CT, computed tomography; MRI, magnetic resonance imaging; Pcom, posterior communicating A. Three-dimensional fusion image from the preoperative CT and MRI shows a large ACP located near the aneurysm, suggesting a small working space near the proximal neck of the aneurysm. B. Real operative view of the case. The working space around the proximal neck is not large due to the tentorial edge and the ACP support. C. Three-dimensional fusion image in which the ACP is removed. After ACP removal, the retrocarotid space is increased. The optic canal is left unopened (double arrows). D. Real operative view after anterior clinoidectomy. The tentorial edge is moved laterally, losing the support of the ACP (arrow). Note that the retrocarotid space is larger and the posterior clinoid process can be seen (arrow). E. Three-dimensional fusion image of the postoperative CT. Double arrows show the intact optic canal. F. The aneurysm was clipped with sufficient working space and visualization of arteries such as perforators from the Pcom.

on the lateral side of the ACP to observe the cancellous bone inside. The cancellous bone near the bony window was curetted with a robust blunt dissector feeling the compact bone, and the lateral wall of the optic canal, which consists of compact bone, was identified. Subsequently, the superior wall of the ACP was removed with the optic canal under direct visualization. As the bone facing the internal carotid artery was absent, the ACP lost bony support after the posterior and lateral compact bones became thin and fractured. In this case, the aneurysm was exposed before the ACP fracture. By removing the ACP, we created a larger working space around the retrocarotid area, and the posterior clinoid process was observed around the proximal neck of the aneurysm.

3.1.2. Case 2

A 45-year-old woman with chronic kidney disease presented with severe headache and vomiting. Brain computed tomography (CT) revealed a Fisher group 2 subarachnoid hemorrhage (SAH) (Fig. 3A). Subsequent magnetic resonance angiography (MRA) showed a right IC-Pcom aneurysm (Fig. 3B). To avoid the use of contrast media, surgical clipping was performed. As the original MRA and CT images showed a large anterior clinoid process (Fig. 3C and D), an extradural anterior clinoidectomy was performed to ensure a sufficient working space around the proximal neck of the aneurysm (Fig. 3E and F). After the anterior clinoidectomy, the dura was opened and the intracranial ICA and aneurysm exposed. The aneurysm was optimally obliterated under temporary occlusion of the intradural portion of the ICA. The patient's postoperative course was uneventful. After a period of vasospasm, the patient was discharged without neurological deficits (Supplementary Video 2).

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After the right frontotemporal craniotomy, the temporal dura was dissected from the sphenoid ridge. By cutting the dura propria, the temporal lobe was retracted posteriorly to expose the anterior clinoid process (ACP). The frontal dura was dissected to observe the bone notch in the optic canal. A small window was then created in the compact bone of the lateral sphenoid ridge with a high-speed drill, and the cancellous bone inside the ACP was curetted out. Through the bony window, we could see the lateral wall of the optic canal, which consists of compact bone. The superior wall of the ACP was drilled away, while the optic canal was visualized. As the compact bone on the inferior surface of the ACP was absent or very thin, the remaining part was anchored to the surrounding structure by the lateral and posterior walls. Removal of these two compact bone structures enabled removal of the ACP from the dura. After the clinoidectomy, the Sylvian fissure was opened and the internal carotid artery (ICA) identified. After dissection of the distal neck of the aneurysm, a temporary clip was applied to the ICA and the aneurysm clip occluded.

4. Discussion

Here, we presented a modified extradural anterior clinoidectomy method in which the optic canal is left unopened. Anterior clinoidectomy is a well-established surgical procedure[1,2] for which many modifications have been suggested.[3–11] By performing the traditional anterior clinoidectomy and opening the distal dural ring, the surgeon can decompress the optic nerve, mobilize the ICA, and create a larger working space around the ICA. However, not all lesions require the benefits provided by traditional anterior clinoidectomy. In some cases, a small increase in the retrocarotid or proximal pericarotid space renders the surgery safer or more feasible, for example, by securing the intradural ICA or obtaining direct sight and a larger working space near the proximal neck of the aneurysm. Such a technique of intradural anterior clinoidectomy that does not require opening of the optic canal, was previously reported.[12] When the surgeon removes the ACP from inside the dura, the planned

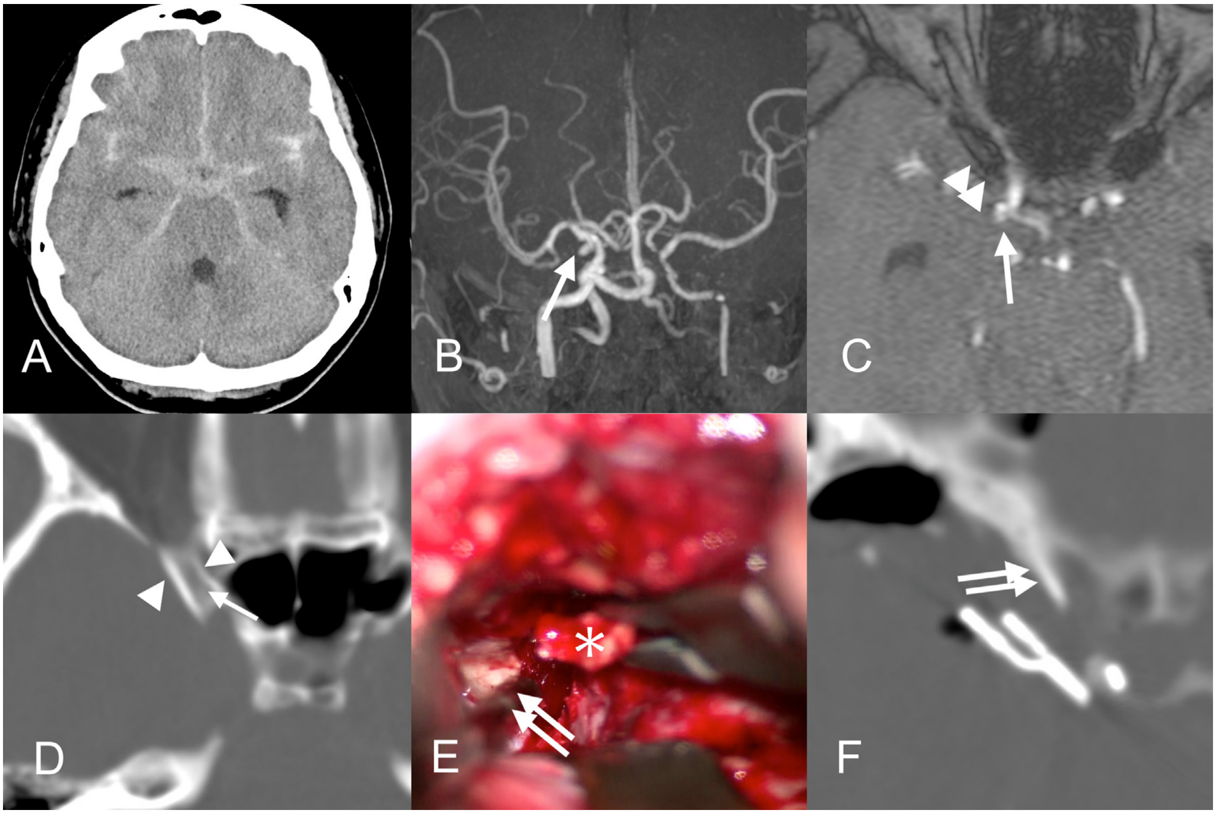

Fig. 3. A 45-year-old woman with subarachnoid hemorrhage. ACP, anterior clinoid process; CT, computed tomography; IC-Pcom, internal carotid posterior communicating; MRA, magnetic resonance angiography A. Initial CT showing a Fisher group 2 subarachnoid hemorrhage. B. MRA shows right IC-Pcom aneurysm (arrow). C. The ACP is relatively large and its tip positioned near the proximal neck of the aneurysm. D. Bone-window image of the initial CT scan. The ACP is surrounded by a high-density compact bone shell (arrowheads) and low-density cancellous bone (arrow). E. The ACP (asterisk) is removed in an extradural fashion, leaving the optic canal unopened (double arrow). E. Postoperative CT shows the remaining lateral wall of the optic canal (double arrows).

amount of bone removed is determined by observing the relationship between the ICA, optic nerve, and related pathological lesions. However, in extradural clinoidectomy, other landmarks are needed, including the optic canal.

In traditional anterior clinoidectomy, the optic canal is opened before the ACP tip removal.[12] However, drilling of the optic canal is associated with a risk of heat or mechanical injury to the optic nerve.[10] Opening the optic canal with a micro-rongeur can eliminate the risk of heat injury to the optic nerve, but it cannot eliminate the risk of mechanical injury. When optic nerve decompression is not required, the surgeon need not open the optic canal as described above.

As we previously reported,[4] the content of the ACP is well demarcated by compact bone in most cases, and the compact bone is absent or very thin on the surface of the ICA in most cases, presumably due to lifetime pulsation. Inside the hard compact bone shell, cancellous bone and/or pneumatization exists in 97% of patients (Fig. 3D).[4] Hence, it is safe to open a small window at the lateral edge of the ACP using a high-speed drill in these cases, which can be judged by preoperative thin-slice bone CT images, as there is sufficient room inside the compact bone. The internal content can be curetted away using a robust blunt dissector such that the compact bone of the optic canal is identified through this window. When pneumatization occurs, the mucosa is pushed away from the connecting sinus; even in such cases, the medial bony surface after dissection of the mucosa is the compact bone of the optic canal. After the superior and lateral walls are drilled out with the optic canal under direct visualization, the ACP is anchored only to the hard posterior part, as there is no or minimal connection facing the ICA. Removal of this anchor causes the ACP to lose its hard bony support, which can be extracted from the surrounding dura. Hence, the optic canal remains unopened. In our method, the optic strut remains with the lateral wall of the optic canal (Fig. 4).

In this report, we presented two cases of IC-Pcom aneurysm that required a retrocarotid space enlargement. As shown in Fig. 2, enlargement of the retrocarotid space provided better visualization around the Pcom perforators. In other SAH cases, when removing prepontine hematomas, a brightly lit workspace can increase the surgeon's confidence. For this purpose, we did not need to remove the optic strut, which can injure the ICA. Anatomically, this technique can be applied when the purpose is to cut the distal dural ring to mobilize the ICA; however, in such cases, ICA mobilization should be limited by determination of ophthalmic artery origin and length.

5. Limitations

This technique has several limitations. First, it remains difficult to remove the hard compact bone owing to the limited working space. However, with appropriate dural retraction, it can be removed using a small drill or rongeur under direct visualization. Second, approximately seven percent of patients have insufficient cancellous bone or pneumatization,[4] which can be judged by preoperative thin-slice CT; in such cases, our method cannot be applied, and cautious drilling with more attention to the optic canal is needed.

6. Conclusions

Our cases demonstrated that the anterior clinoid process can be removed without requiring optic canal opening when optic nerve decompression is not required.

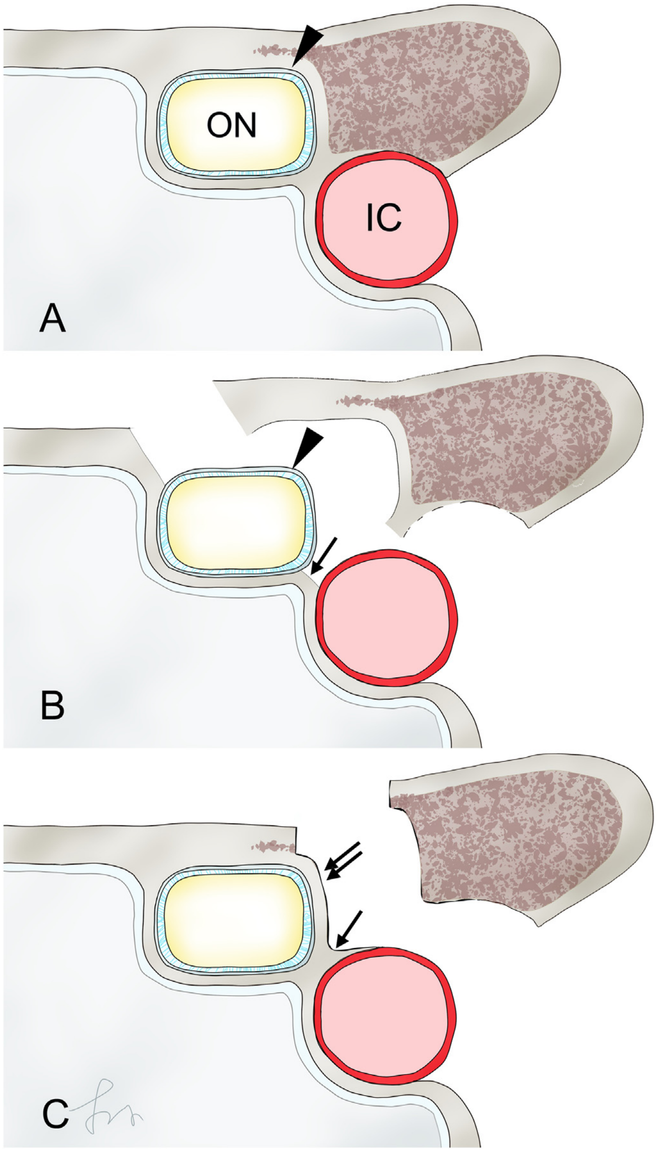

Fig. 4. Schematic illustration of our modification of anterior clinoidectomy. IC, internal carotid artery; ON, optic nerve A. Coronal section of anterior clinoid process. Arrowhead: dura around the ON. B. *In* traditional clinoidectomy, the optic canal is opened and the dura around the ON is exposed (arrowhead). The optic strut is carefully removed. C. Modifications described in this report. The optic canal and strut are left with thin bony remnants around the ICA.

Ethical approval

All procedures performed in this study involving human participants were done so in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Credit author statement

Toshikazu Kimura: Conceptualization, Methodology, Manuscript-writing, figure preparation, Yasuhiro Takeda:figure preparation Shunsuke Ichi: Supervision, Manuscript-editing.

Informed consent

Informed consent was obtained from all study participants. Each patient provided written consent allowing the publication of his/her radiological images and information on his/her clinical course, which could allow the revealing of his/her identity by recognition of the patient images or information printed or written herein.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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