

# Surgery on Intracranial Aneurysms Under Simultaneous Microscopic and Endoscopic Monitoring

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Endovascular treatment is appealing to both patients and practitioners alike for its less invasive nature and use of advanced equipment. However, follow-up angiography to confirm obliteration is necessary because reappearance of the aneurysm with coil compaction may sometimes occur even after successful coiling. Open clip surgery requiring no such follow-up procedures still has the advantage over the coiling if it is accomplished, and some aneurysms are more successfully treated with surgical clipping. In the treatment of intracranial aneurysms, those ideal for coiling are also amenable to clipping, and because coiling is more widely adopted, the more complex aneurysms tend to be treated with open surgery. Consequently, considering the adoption of various innovations, open surgery should be safer and should provide more lasting outcomes. To achieve optimal results in aneurysm surgery, we have adopted several types of monitoring, including physiological monitoring incorporating motor evoked potential, endoscope, and intraoperative indocyanine green or fluorescent angiography. Each type of monitoring has reportedly been effective at contributing to the safety and minimal invasiveness of aneurysm surgery.

The introduction of the endoscope for microsurgical treatment of cerebral aneurysms has been advocated because it enables the surgeon to “see around corners” and to observe areas hidden from the microscope,<sup>1–11</sup> Perneczky and Fries<sup>4,8</sup> elaborated on the general principles of endoscope-assisted microsurgery and described the 3 advantages of endoscopes as follows: increased light intensity while approaching an object, clarity of detail in close-up positions, and wider viewing angle. They initially presented the concept of endoscope-assisted microneurosurgery under simultaneous microscopic and endoscopic control.<sup>4,8</sup> The position and fixation of the endoscope are achieved by retractor arms fixed to the operating table or the headrest. Thus, the surgeon can perform microsurgical manipulations with both hands under simultaneous endoscopic and microscopic control at all times.<sup>4,8</sup> Therefore, the surgeon can inspect hidden structures, dissect

perforators at the back of the aneurysm, identify important vessel segments without retraction of the aneurysm or arteries, and check for completion of clipping.<sup>4,8</sup>

Here, we describe our techniques for the treatment of intracranial aneurysms under simultaneous monitoring with the operating microscope and endoscope held by the air-lock system.

## INSTRUMENTATION

Two types of rigid endoscopes with a viewing angle of 30° or 70°, an outer diameter of 2.7 mm, and a length of 225 mm (Olympus Optical Corp, Tokyo, Japan) are used. The endoscope is held with an endoscope-integrating holding device (EndoArm, Olympus), and joint motion is controlled with high-pressure gas and low force. It can be fixed with 1-touch operation, providing superior safety and handling (Figure 1). Illumination is provided with a xenon light source. The video units for endoscopy comprise an L-shaped camera adaptor (AR-TL12S, Olympus Optical Corp), a 3-tip camera (Olympus Optical Corp), a videocassette recorder (Sony Corp, Tokyo, Japan), and a 19-in video monitor (Sony Corp). The video monitor showing the endoscopic view is positioned in front of the surgeon.

## OPERATIVE PROCEDURE AND MANAGEMENT

The craniotomy, subarachnoid dissection, and cranial base osteotomy are performed in the usual manner. If the entire aneurysm wall cannot be visualized with the microscope after exposure of the aneurysm neck and sac, the rigid endoscope is introduced by hand under the microscope. If the endoscope reveals new information and surgical manipulation is necessary to clip the aneurysm, the endoscope is introduced into the operative field. After inspection of the entire wall of the aneurysm and confirmation of the rupture point in cases of subarachnoid hemorrhage, the perforators behind the aneurysm sac are dissected under simultaneous microscopic and endoscopic monitoring.

This procedure increases the safety and durability of the aneurysmal clipping; however, meticulous attention is required to prevent intraoperative morbidity. Mechanical injury



**FIGURE 1.** A, an endoscope-integrating holding device (EndoArm; Olympus). B, operative view of the microscope, endoscope, and monitor. C, joint motion is controlled with high-pressure gas and low force. It can be fixed with 1-touch operation, providing superior safety and handling.

of the nerves and blood vessels by endoscope hardware is possible because the endoscope provides a view only in front of, not behind, the endoscope tip. The operator should rather concentrate on the microscopic view, being careful not to touch the vulnerable structures with the endoscope while inserting. The operating room staff must pay attention and not touch the operating bed, bed controller, and endoscope holding system to avoid injury while the endoscope is inserted into the operative field. Because subarachnoid clot is an obstacle for endoscopic observation in ruptured cases, suction of the clot is inevitable. However, extensive clot removal should not be done in the dead angle of microscope. We should recognize that the point we can see with the endoscope is different from that which we can manipulate with instruments.

## INTERNAL CAROTID ARTERY ANEURYSMS

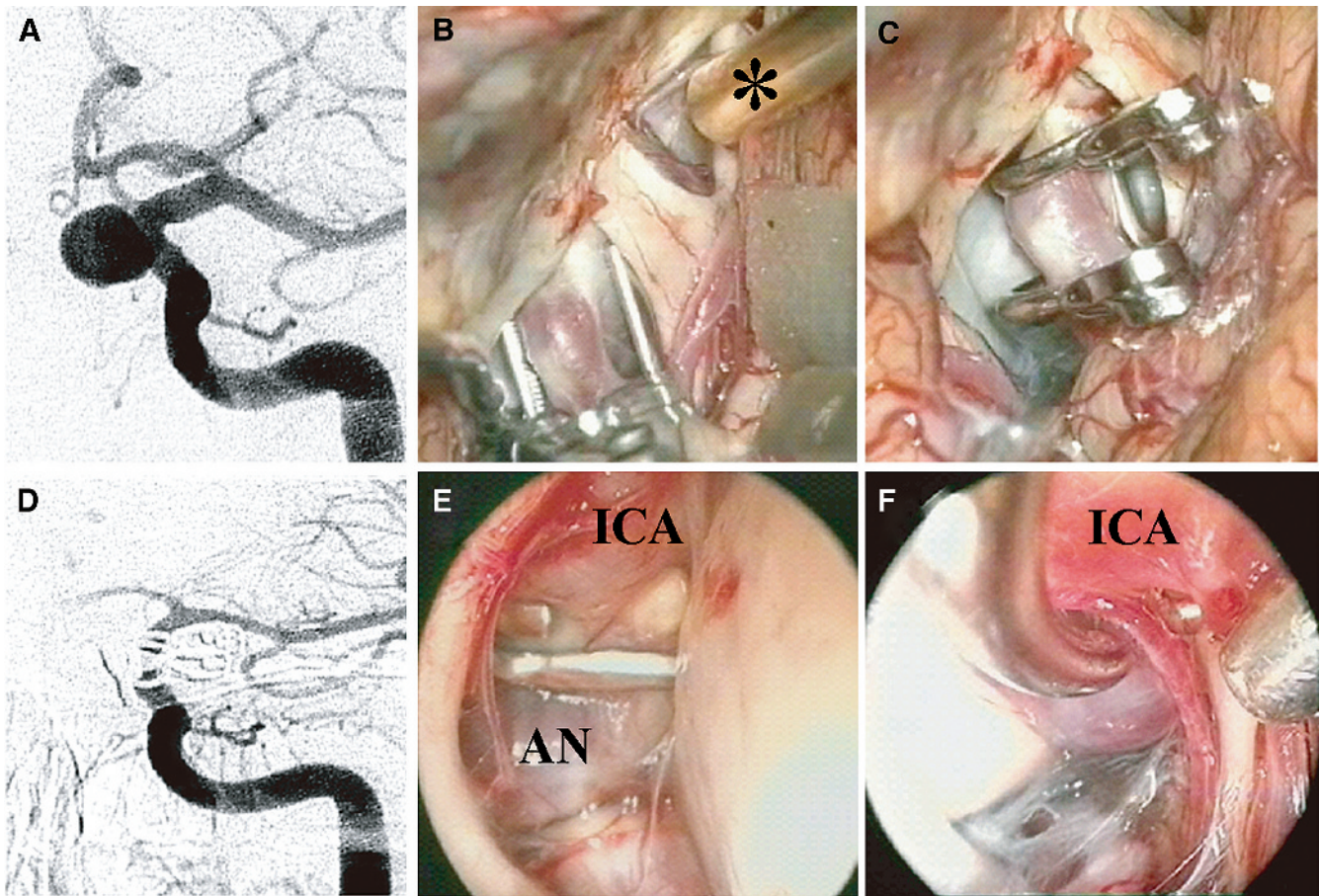
### Paraclinoid Aneurysms

Aneurysms encountered in the paraclinoid segment of the internal carotid artery (ICA) include ophthalmic artery aneurysms and superior hypophyseal artery aneurysms (located at branching sites), as well as ventral paraclinoid aneurysms and carotid cave aneurysms (located at non-branching sites). They usually arise from the medial/posterior aspect of the ICA.<sup>12,13</sup> The microscopic view of such aneurysms is obstructed by the ICA, optic nerve, and bony structures, including the anterior clinoid process. Because of

their location, such aneurysms are more difficult to visualize completely. Without a clinoidectomy, these aneurysms are generally unclippable or result in surgical treatment with disastrous outcomes.<sup>12,13</sup> Therefore, in an effort to achieve optimal results, various innovations have been adopted, including the contralateral approach<sup>14</sup> and skull base surgery techniques such as clinoidectomy. However, as we have shown, an aneurysm of this segment projecting to the medioposterior, completely invisible through the microscope, could be obliterated with a ring clip without removal of the bony structures under both endoscopic and microscopic monitoring.<sup>6,7</sup> To observe the medial aspect of the ICA, the endoscope is introduced from the medial and basal angle of the cranial window into the prechiasmatic cistern or the space between the optic nerve and the ICA. This position provides a view similar to that of the contralateral approach. Once the surgeon has confirmed the anatomical relationship among the dural ring of the ICA, proximal neck of the aneurysm, ophthalmic artery, and superior hypophyseal artery and has determined that sufficient space exists for the clip blade, neck clipping can be performed under both microscopic and endoscopic monitoring (Figure 2).

### Supraclinoid Aneurysms

Posterior communicating artery (PCoM<sub>A</sub>) aneurysms and anterior choroidal artery (AChor<sub>A</sub>) aneurysms are the 2 types of major trunk aneurysms located in the supraclinoid segment of the intracranial ICA. Treatment of these aneurysms

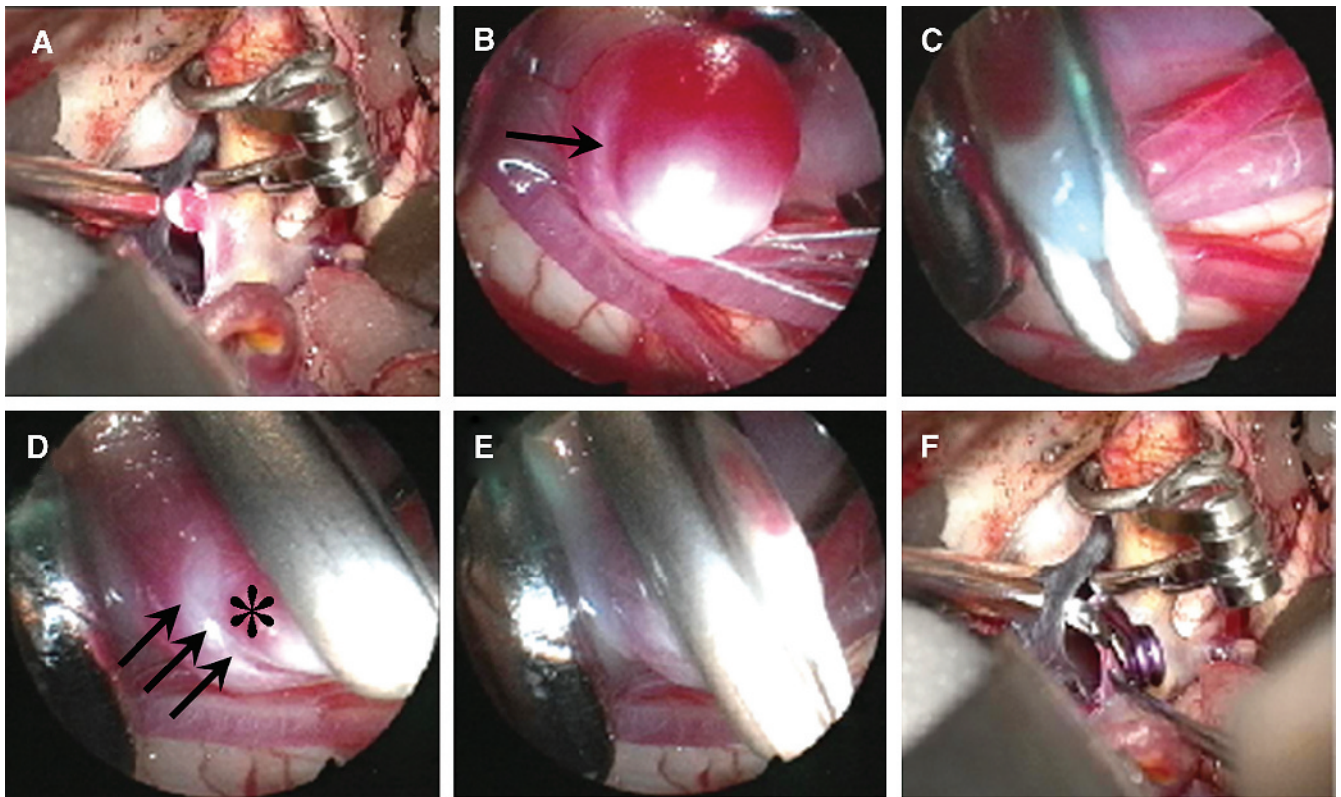


**FIGURE 2.** Illustrative case of a left internal carotid artery (ICA) paraclinoid aneurysm (AN). A, preoperative angiogram showing the left paraclinoid aneurysm projecting from the medial wall of the ICA. B, to observe the medial aspect of the ICA, the endoscope (asterisk) was introduced from the medial and basal angle of the cranial window into the prechiasmatic cistern. The first angled ring clip was applied under both microscopic and endoscopic monitoring. C, the second angled ring clip was applied posterior to the first clip. D, postoperative angiogram showing complete obliteration of the aneurysm. E, the endoscope after clipping showing the adequate position of the clip. F, the endoscope introduced lateral to the ICA showing preservation of the perforators.

requires preservation of the PComA, AChorA, and perforators to avoid morbidity. For these cases, the major benefit of endoscopic and microscopic monitoring is visualization of the perforators behind the aneurysm. With relatively small aneurysms, surgical manipulation under a microscope enables visualization of the proximal portion but not the origin of the perforators. Figure 3 shows that 2 perforators of the AChorA under the microscope were divided from the single trunk by the endoscope. In this case, therefore, stenosis of the neck caused total branch ischemia. The important point is that the stenosis caused by the neck clipping usually occurs in the dividing origin of the perforators, which is almost impossible to determine with the microscope, as mentioned previously. Figure 4 shows that the late occurrence of perforator occlusion caused by tight clipping or distortion of the clip was discovered with continuous direct visualization of the perforators behind the aneurysm.

In this segment, in which large aneurysms with a posterior projection adhere to the perforators, the necks of all aneurysms on the PComA should be dissected from the perforators. For this purpose, the endoscope not only reveals the anatomy of the medial aspect of the aneurysm but also makes it possible to create ample space for insertion of the clip blade along the proximal portion of the PComA for reconstruction by gentle dissection (Figure 5). In addition, for clipping of broad-necked aneurysms, fenestrated straight or angled clips are sometimes applied. Usually, the medial blade of the fenestrated clip is applied beyond the ICA and is not visualized by the microscope. The endoscope can clearly visualize the medial blade.

This segment of the ICA has a peculiar category of aneurysms known as “blood blister” aneurysms of the anterior wall of the ICA. It is generally accepted that simple neck clipping is risky and that trapping the ICA with or



**FIGURE 3.** Intraoperative photographs of the left internal carotid artery–anterior choroidal artery (ICA-AChorA) aneurysm. A, the aneurysm was located on the lateral surface of the ICA. Before and after clipping of the aneurysm, the endoscope was introduced lateral to the ICA. B, endoscopic view showing the relation of the origin of the AChorA and the aneurysm neck. The proximal aneurysm neck was adhered tightly around the origin of the AChorA (arrows). C, even though the clip was placed adequately under the microscopic view, the endoscopic view could show the occlusion of the perforators of the AChorA. D, after the clip replacement, endoscopic inspection revealed that there was a neck remnant (asterisk). E and F, final endoscopic and microscopic views showing complete obliteration of the aneurysm, sparing the AChorA.

without bypass surgery or clip-on wrapping is recommended. Trapping or clipping the aneurysm to catch the intact wall of the ICA is critical for preventing postoperative rupture. In this regard, the endoscope, which provides higher magnification than the microscope, can provide an accurate margin of the pathological aneurysmal wall and contribute to the durability and safety of the surgical treatment (Figure 6).

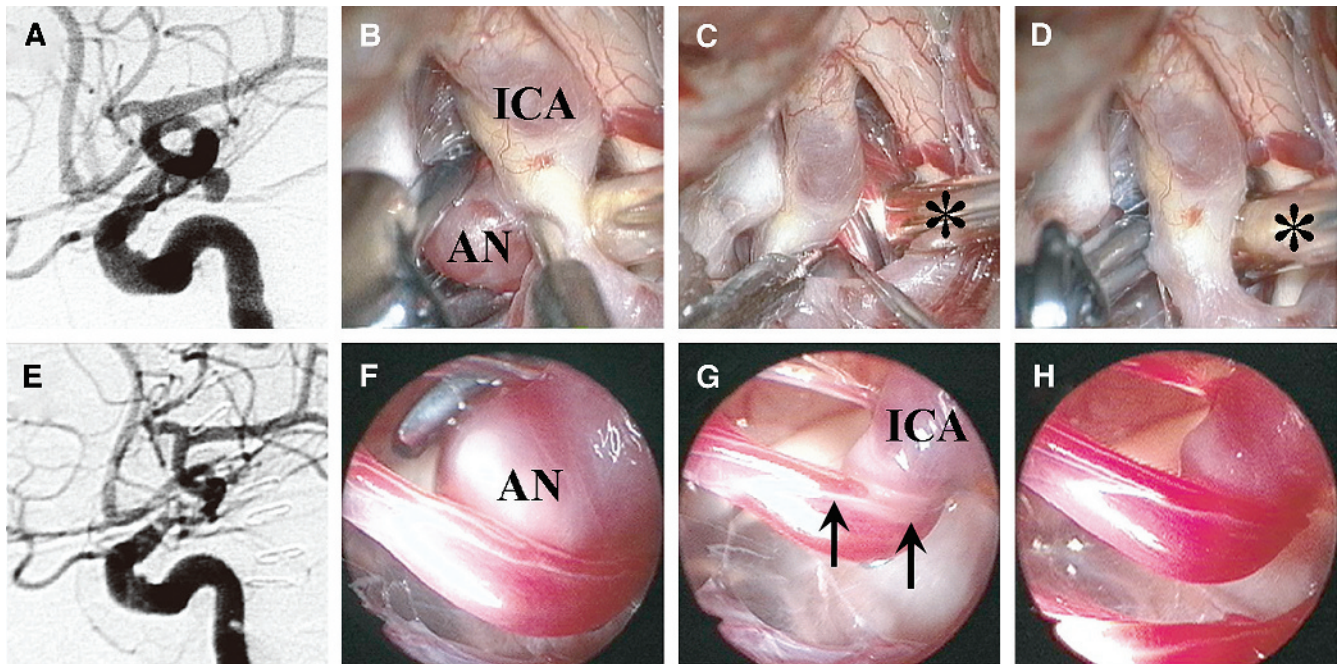
### ANTERIOR COMMUNICATING ANEURYSMS

We adopt the interhemispheric approach to the complex types of anterior communicating artery (AComA) aneurysms, including the large, high-position, and upward- or posterior-projecting types. This approach with bifrontal craniotomy can provide ample working space while the microscopic view can confirm the entire aspect of the AComA complex. However, in the pterional approach, the posterior wall of the AComA, where the hypothalamic artery usually divides, would not be visible. In contrast to AChorA, no monitoring is yet available for the memory. We basically confirm the patency of the hypothalamic artery by indocyanine green or fluorescein video

angiography and the endoscope for clipping AComA aneurysms.

### BASILAR TIP ANEURYSMS

The basilar apex aneurysm is one of the most difficult to treat because it is deeply seated and accompanied by thalamoperforating arteries. We use the subtemporal approach for this aneurysm, in which the opposite side of the aneurysm is likely to not be visible. Because thalamoperforating arteries usually divide from the P1 segment of the posterior cerebral artery, the perforators sometimes adhere to the lateral wall of the aneurysm. Therefore, the dissection and preservation of the thalamoperforating arteries on the contralateral side are key to clipping this aneurysm without morbidity. We introduce the endoscope through the space either above or below the oculomotor nerve and fix it in front of the basilar tip. This setting of the endoscope provides the view obtained by the pterional approach, and the wide viewing angle of the endoscope clearly reveals both perforators (Figure 7). In addition, the high magnification and direct lighting more



**FIGURE 4.** An illustrative case of a left internal carotid artery–anterior choroidal artery (ICA-AChorA) aneurysm. A, preoperative angiogram showing the aneurysm. B, a left pterional craniotomy was performed. The aneurysm (AN) was projecting from the posterior-lateral wall of the ICA. C, the endoscope (asterisk) was introduced medial to the ICA. D, a straight clip was applied to the aneurysm neck. E, postoperative angiogram showing complete obliteration of the aneurysm and preservation of the AChorA. F, endoscopic view showing the relation of the origin of the AChorA and the aneurysm neck. A straight clip was applied to the aneurysm neck under both microscopic and endoscopic monitoring. G, the late occurrence of perforator occlusion caused by tight clipping or distortion of the clip was discovered with continuous direct visualization of the perforators behind the aneurysm. H, repositioning of the clip was successful.

accurately reveal the deep surgical field, contributing to successful clipping of this aneurysm.

### BASILAR TRUNK ANEURYSMS

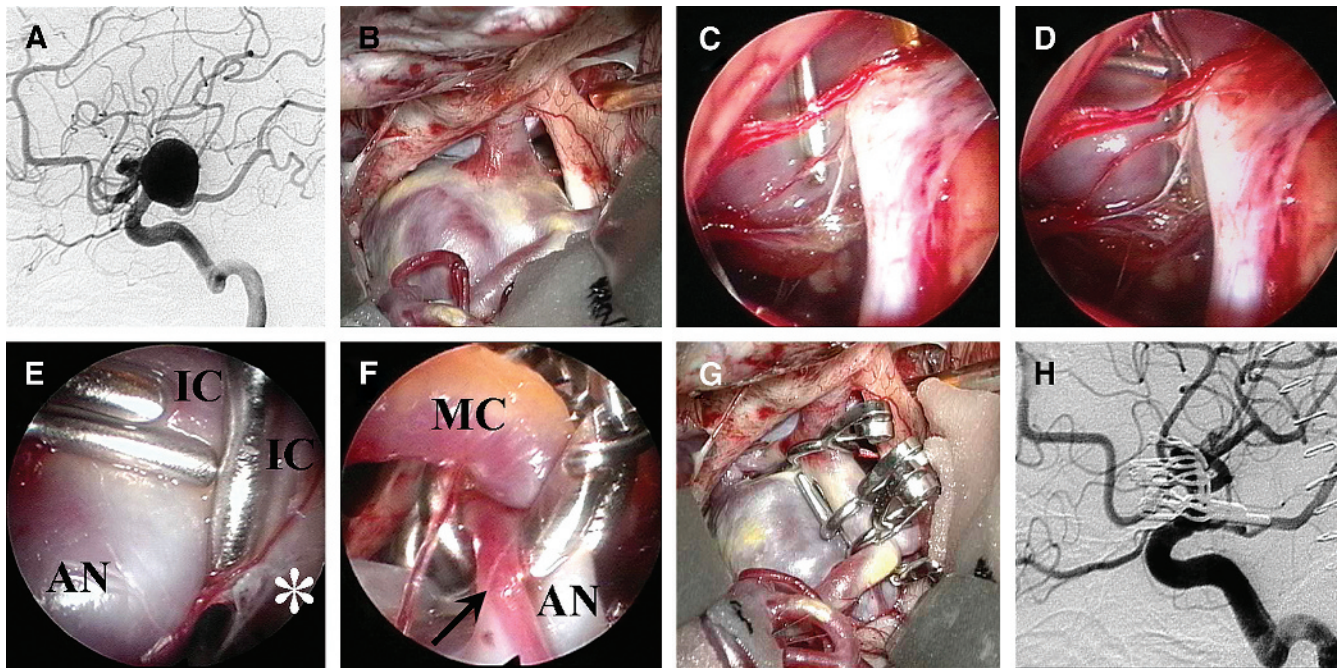
Basilar trunk aneurysms are treated with a variety of approaches, including the subtemporal, anterior transpetrosal, retrolabyrinthine-transsigmoidal, and combined supratentorial/infratentorial-posterior transpetrosal, depending on the level of the aneurysm. These approaches access the aneurysm by different routes; however, the direction is all lateral in nature, and then the opposite side of the aneurysmal neck and basilar trunk would not be visible under the microscope. As Figure 8 shows, the severely sclerotic artery and fragile wall of the aneurysm cannot be manipulated aggressively. The endoscope can be a powerful tool for providing a view behind the parent artery and the clip blade. Endoscope observation with indocyanine green or fluorescein videoangiography also contributes to the preservation of the basilar artery perforators.

### VERTEBRAL ARTERY ANEURYSMS

Vertebral artery–posterior inferior cerebellar artery (VA-PICA) aneurysms and VA-dissecting aneurysms are

major lesions of this portion. If the aneurysms are seated in the midline or deep portion of the posterior fossa, the same precautions used with basilar trunk aneurysms should be taken. Furthermore, the critical issue when clipping this aneurysm is to confirm the distal portion of the VA to control bleeding in case of rupture. Proximal occlusion is the usual method for controlling bleeding caused by aneurysmal rupture during clipping. However, in this segment of the VA, bleeding sometimes cannot be controlled by proximal occlusion because sufficient blood flow comes from the contralateral VA. Clearly, control of the distal portion of the VA is essential. The side view of the endoscope can help to reveal the entire VA from the intracranial entrance to the VA junction.

Even dissecting aneurysms have been cured with endovascular treatment, and the opportunity to treat them by clipping has been declined. However, VA dissection involving the PICA often needs direct surgery involving proximal occlusion or trapping of the VA with revascularization of the PICA. For occlusion of the VA, confirmation of the pathological dissecting wall and the preservation of VA perforators are necessary. As shown in Figure 9, the endoscope can reveal the hidden portion of the VA under the microscope.



**FIGURE 5.** An illustrative case of a large left internal carotid artery–posterior communicating artery (ICA-PCoMA) aneurysm. A, preoperative angiogram showing the large aneurysm pointing posteriorly. B, a left pterional craniotomy was performed. The proximal portion of the PComA shared the common neck with the aneurysm. C, the endoscope introduced into the prechiasmatic cistern revealing that several perforators of PComA adhered to the medial wall of the aneurysm. The perforators were dissected from the aneurysm sac, and oxycellulose was inserted between them under endoscopic monitoring. D, a straight ring clip and 2 right-angled ring clips were applied to reconstruct the PComA and ICA without repositioning of the multiple clips. E, high-magnification view of the endoscope revealing correct positioning of the clips. The PComA (asterisk) and ICA (IC) were reconstructed by the straight and angled ring clips. The perforators adhering to the aneurysm (AN) were not obliterated by clips. F, finally, an angled clip was applied to the aneurysm in the distal-to-proximal direction under the middle cerebral artery (MC), avoiding occlusion of the anterior choroidal artery (AChorA; arrows). G, the final microscopic view showing completion of clipping of the aneurysm. H, postoperative angiogram showing complete obliteration of the aneurysm and preservation of the PComA and AChorA.

## CONCLUSION

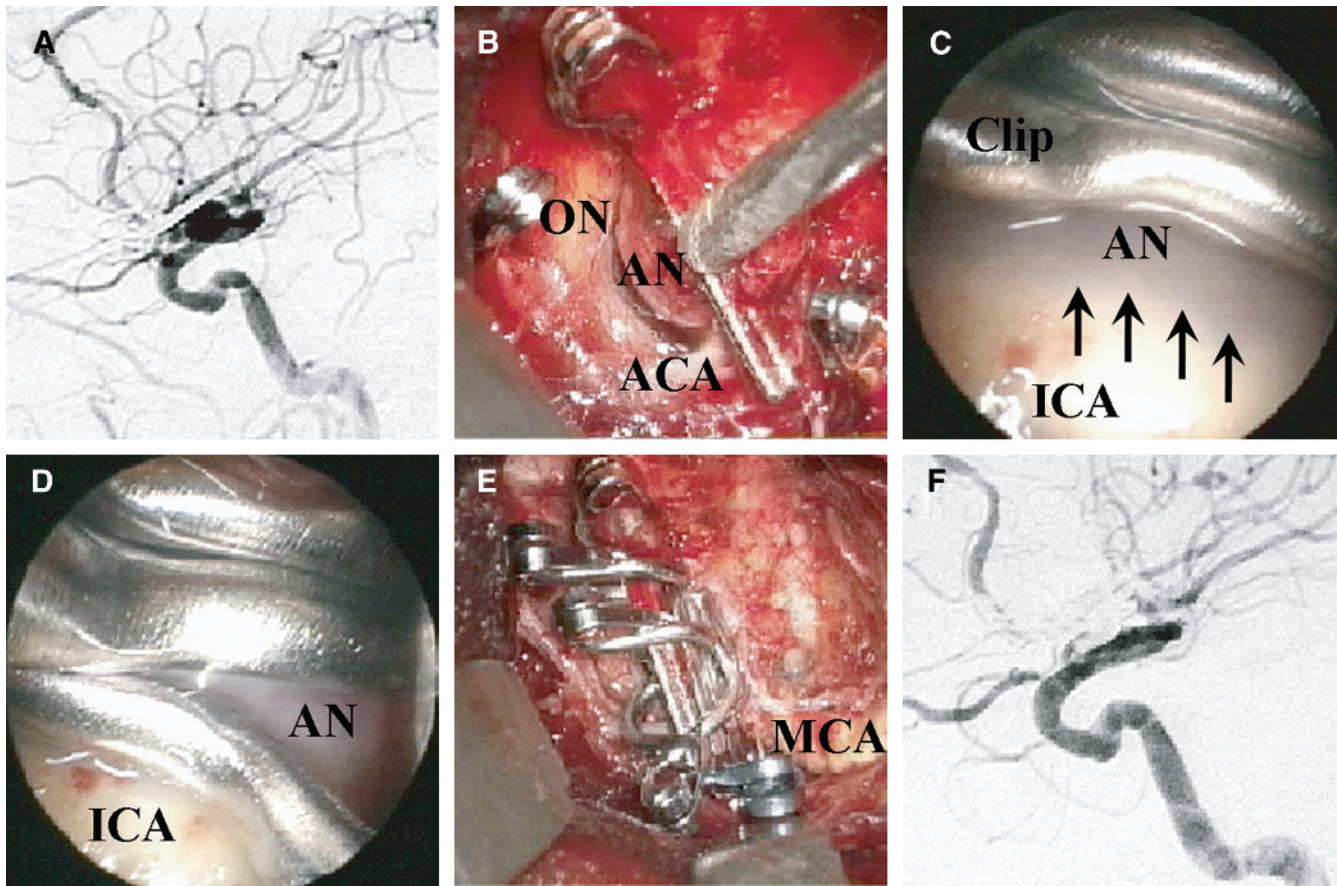
Simultaneous endoscopic and microscopic guidance was successfully used to clip intracranial aneurysms. This method can reveal important information hidden from the microscope and can be used to monitor the working environment under direct continuous visualization. This method increases the safety and durability of the aneurysmal clipping; however, meticulous attention is required to prevent the endoscope from causing morbidity during surgery.

## Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

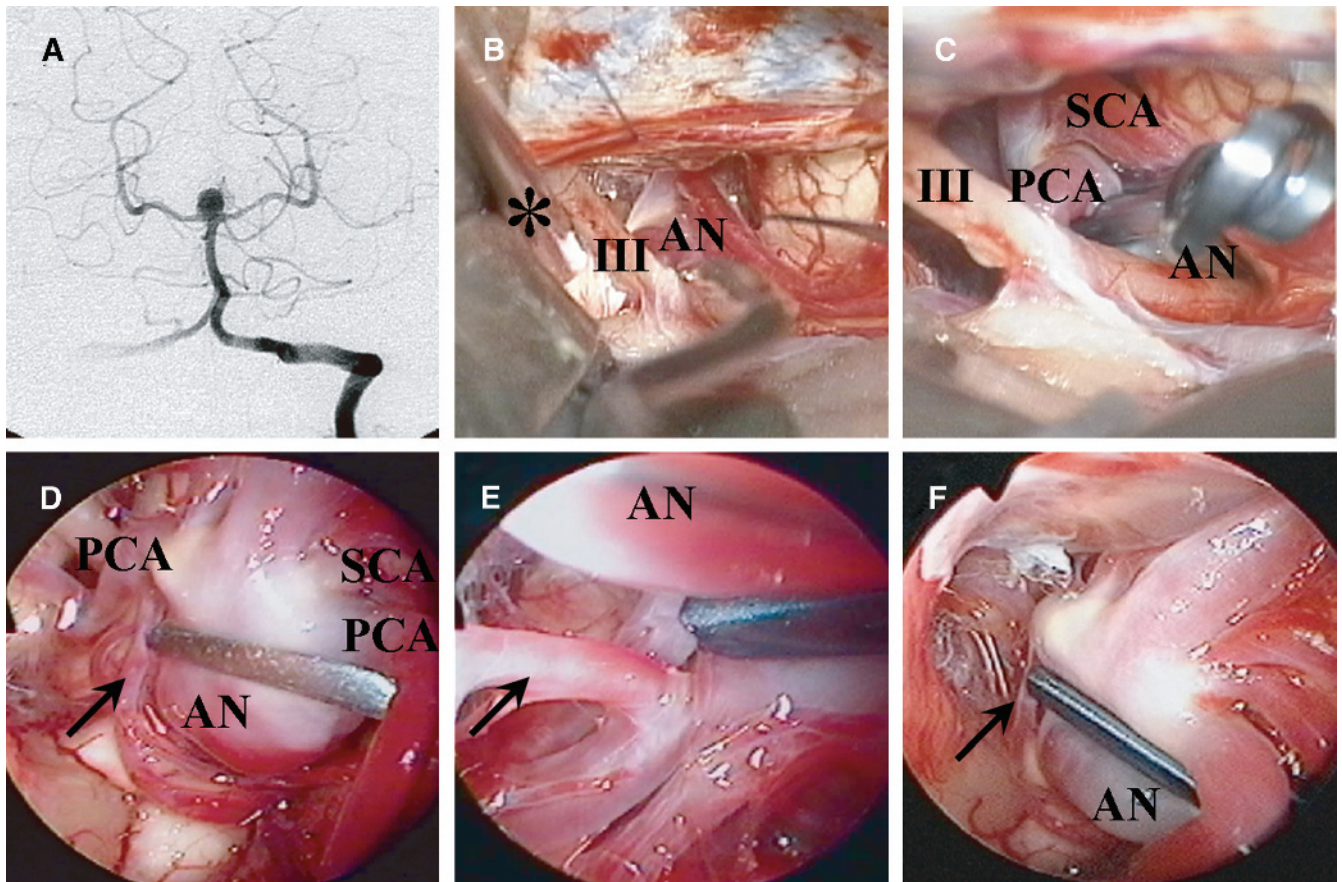
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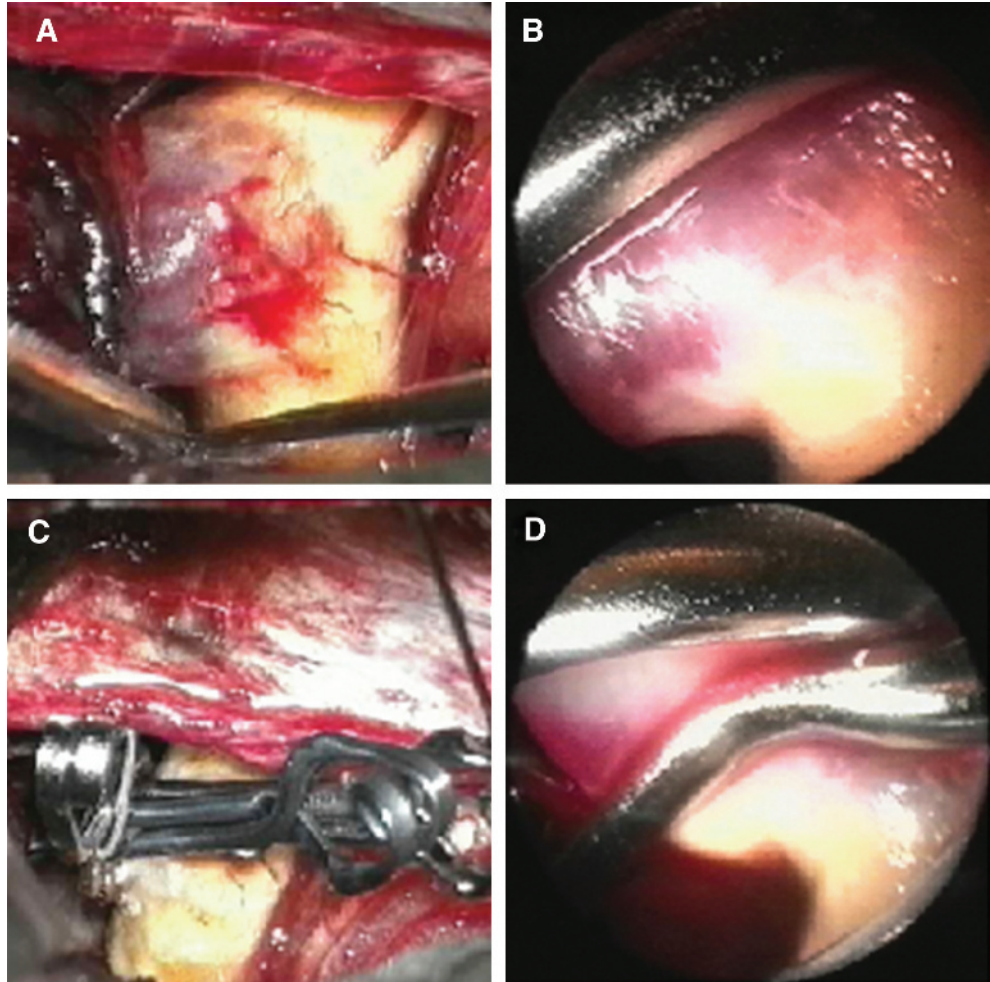
**FIGURE 6.** A case with a regrown aneurysm on the right anterior wall of the internal carotid artery (ICA). The ruptured aneurysm was initially clipped 3 years ago. A, the follow-up angiography showing that the neck remnant became prominent. B, microscopic view showing the anterior wall aneurysm (AN) of the ICA initially clipped 3 years before the present surgery. C, the endoscope was quite effective for investigating the border (arrow) between the aneurysm (pathological) wall and intact (sclerotic) ICA wall. D, the regrown aneurysm was clipped directly. The clips were applied to catch the intact ICA wall under the monitor of endoscope. E, multiple clips were applied to occlude the pathological wall. F, postoperative angiogram 3 years after surgery showing complete obliteration of the aneurysm. ACA, anterior cerebral artery; MCA, middle cerebral artery; ON, optic nerve.

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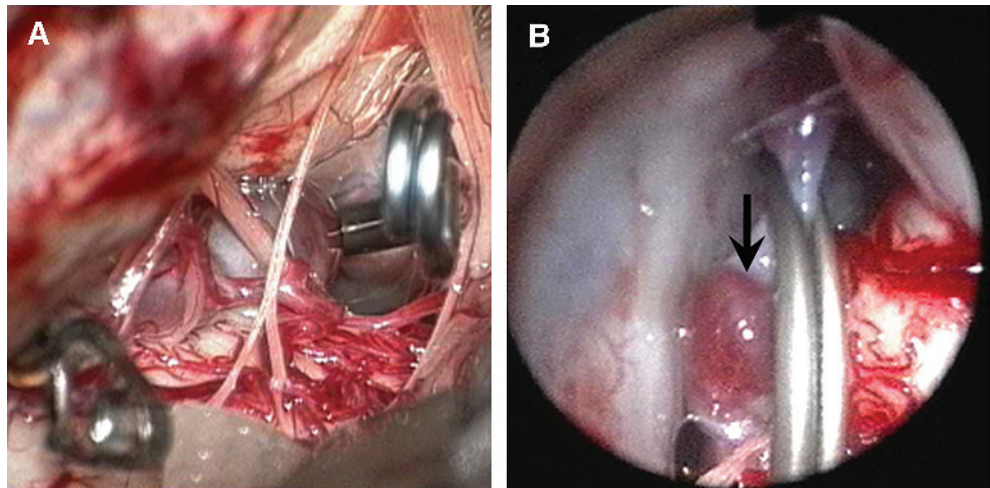


**FIGURE 7.** An illustrative case of an unruptured basilar tip aneurysm. A, preoperative angiogram showing the basilar tip aneurysm projecting upward. B, a right subtemporal craniotomy was performed. Microscopic view showing the right side of the arteries and aneurysm under the oculomotor nerve (III). The endoscope (asterisk) was introduced above the oculomotor nerve (III) and fixed in front of the basilar tip. C, a straight clip was applied to the aneurysm neck. D through F, endoscopic view also clearly showing the complete obliteration of the aneurysm and the preservation of the perforators of the opposite posterior cerebral artery (PCA; arrow). SCA, superior cerebellar artery.





**FIGURE 8.** An illustrative case of a ruptured large basilar trunk aneurysm treated by a right subtemporal approach. A, a large aneurysm located on the anterior wall of the sclerotic basilar artery. B, endoscopic view after the first clip showing a dog ear-shaped neck remnant. C, the straight ring clip was then applied to occlude the neck remnant. D, final endoscopic view showing complete occlusion of the aneurysm.



**FIGURE 9.** An illustrative case of an unruptured left vertebral artery (VA) dissection. A, microscopic view after trapping the VA dissection showing the enlargement of the vertebral artery. B, the thin-walled segment of VA dissection was clearly shown by the endoscope introduced anterior to the vertebral artery.