One of the major causes of poor outcomes after surgical treatment of intracranial aneurysms is vascular injury. Despite careful attention to preserve patency of the parent arteries and perforating arteries around the aneurysm neck at the time of clip application, the complete preservation of blood flow cannot always be guaranteed. Rates of unexpected occlusion of major branches, demonstrated by postoperative angiography, has been reported as 4%–12%. One of the reasons for the morbidity is insufficient and indirect visual inspection to reveal arterial compromise or occlusion, especially during and after clipping. When there is strong ath-

Endoscopic indocyanine green video angiography in aneurysm surgery: an innovative method for intraoperative assessment of blood flow in vasculature hidden from microscopic view

Technical note

YOSHIHISA NISHIYAMA, M.D., PH.D., HIROYUKI KINOUCHI, M.D., PH.D., NOBUO SENGOKUYA, M.D., TATSUYA KATO, M.D., KAZUYA KANEMARU, M.D., HIDEYUKI YOSHIOKA, M.D., PH.D., AND TORU HIRONOSHI, M.D., PH.D.

Department of Neurosurgery, Interdisciplinary Graduate School of Medicine and Engineering, University of Yamanashi, Chuo, Yamanashi, Japan

Recently, intraoperative fluorescence video angiography using indocyanine green (ICG) has been widely used in aneurysm surgery. This is a simple and useful method to confirm complete occlusion of the aneurysm lumen and preservation of blood flow in the arteries around the aneurysm. However, the observation field of ICG video angiography is limited under a microscope, making it difficult to confirm the flow in the arteries behind the parent arteries or aneurysm. The authors developed a new technique of intraoperative endoscopic ICG video angiography to assess the blood flow in perforating arteries hidden by the parent arteries or aneurysm. The endoscope emits excitation light with a wavelength of approximately 800 nm, and video images were obtained through a cut filter. The authors used this ICG fluorescence endoscope in treating 3 patients with unruptured cerebral aneurysms. During clip placement, the endoscope was inserted to confirm aneurysm occlusion. Then, ICG was intravenously administered, and the fluorescence in the vessels was observed via the endoscope as well as under the microscope. The blood flow in the perforating arteries was clearly identified, and no procedural complication occurred. The authors conclude that the technique is very useful and facilitates intraoperative real-time assessment of the patency of perforating arteries behind parent arteries or aneurysms.

(http://thejns.org/doi/abs/10.3171/2012.5.JNS112300)

KEY WORDS • indocyanine green video angiography • endoscope • cerebral aneurysm • surgical complication • vascular disorders

Abbreviations used in this paper: AP = anteroposterior; CTA = CT angiography; DSA = digital subtraction angiography; ICA = internal carotid artery; ICG = indocyanine green; MCA = middle cerebral artery; PCoA = posterior communicating artery.
Endoscopic ICG video angiography

an endoscope can visualize structures hidden in the dead angle such as those behind the parent arteries, aneurysm, and/or skull base anatomicies.\textsuperscript{3,7,9,11,13,15,16,22-24,32} For example, posteromedially projecting internal carotid paral- 

noid aneurysm, which is completely invisible through the microscope, can be visualized by endoscope.\textsuperscript{15,16,22} However, ordinary endoscopy cannot provide fluorescence images of real-time blood flow of the vessels.

The authors applied intraoperative endoscopic ICG video angiography to aneurysm surgery to overcome these limitations. In this method, the blood flow and hemodynamics in the vessels behind the parent arteries observable by surgical microscope were clearly identified. The technical details of this procedure are demonstrated and its usefulness is discussed in this report.

Methods

Patient Population

This study included 3 patients (all female, ages 62, 68, and 73 years) with unruptured cerebral aneurysms. The patients were interviewed regarding a history of iodine allergy or previous anaphylactic reactions to contrast media or dye injection, and written informed consent, including agreement for the use of a new endoscope system, was obtained. The surgical procedures were performed as usual. Endoscopic ICG video angiography was performed before and after occlusion of the aneurysm.

Microscopic ICG Video Angiography

Intraoperative microscopic ICG video angiography was performed with an Olympus OME-9000 operating microscope. The system was designed to integrate near-infrared imaging into the surgical microscope and to obtain high-resolution and high-contrast near-infrared images.

The operative field was illuminated through the microscope by a light source with a wavelength covering part of the ICG absorption band (range 700–850 nm, peak 805 nm). The ICG dye was injected into a peripheral vein as a bolus (the standard 25-mg dose dissolved in 5 ml of water).\textsuperscript{25,26} After the dye solution arrived in the vessels of interest illuminated by the near-infrared light, ICG fluorescence was induced. The fluorescence (range 780–950 nm, peak 835 nm) was recorded by a non- 

tensified video camera. An optical filter blocked both ambient and excitation light so that only ICG-induced fluorescence was collected.\textsuperscript{25,26} Thus, arterial, capillary, and venous angiographic images could be observed on the video screen in real time. The images were recorded on compact disks and reviewed later for analysis. The setup allows high-resolution near-infrared images based on ICG fluorescence to be visualized without eliminating visible light during the investigation (that is, without darkening the operating room).

Endoscopic ICG Video Angiography

The endoscope system consisted of a xenon light source device (Visera CLV-S40Pro, Olympus), rigid endoscopes (A70940A, A70941, Olympus), and a video pro- 

cessor system (Visera OTV-S7Pro, Olympus), which are all commercially available. The endoscope system also included a newly designed camera head with an image sensor highly sensitive to infrared light and a cut filter to collect fluorescence from ICG. The viewing angle of the endoscopes was 30° or 70°, and the outer diameter was 4.0 mm. The tip of the endoscope was positioned to observe the hidden field behind the aneurysm.

Surgical Procedure

The craniotomy and subarachnoid dissection were performed in the usual manner. After exposure of the aneurysm, the endoscope was manually introduced near the aneurysm under the microscope to visualize the area behind the aneurysm. Before and after clip placement, ICG dye was injected into a peripheral vein and the fluorescence was observed simultaneously under the surgical microscope and via the endoscope.

Results

Endoscopic ICG video angiography allowed enhanced visualisation of blood flow in the parent arteries and the perforating arteries behind the aneurysm before and after clip placement. Further, the intended and appropriate position of the clip blade was confirmed by means of endoscopic ICG video angiography with respect to parent artery blood flow. In all 3 cases, complete occlusion of the aneurysm sac and preservation of blood flow in the arteries around the aneurysm neck were confirmed by means of a combination of microscopic and endoscopic video angiography. No patient showed any ischemic lesions on postoperative CT. There were no side effects such as allergic reactions related to ICG administration or morbidity related to the endoscope.

Illustrative Cases

Case 1

This 73-year-old woman was admitted to our institution for treatment of an unruptured left ICA-PCoA aneurysm that was incidentally diagnosed by MRI. Preoperative angiograms showed a laterally projecting left ICA-PCoA aneurysm (Fig. 1A). Clipping of the aneurysm was performed via a pterional approach under magnification by means of a combination of microscopic and endoscopic ICG video angiography. No patient showed any ischemic lesions on postoperative CT. There were no side effects such as allergic reactions related to ICG administration or morbidity related to the endoscope.
Fig. 1. Case 1. A: Preoperative angiogram showing the laterally projecting left ICA-PCoA aneurysm (AP view). B: Microscopic view before clip placement showing the neck of the laterally projecting aneurysm. C: Microscopic view before intravenous injection of ICG, showing no fluorescence. D: Microscopic ICG video angiographic image obtained after injection of ICG, showing the aneurysm and the parent and branching arteries. E: Postoperative CT angiogram showing disappearance of the aneurysm. F: View through the endoscope, which was introduced medial to the ICA, revealing the origin of the PCoA and perforating arteries behind the ICA. G: Endoscopic view before intravenous injection of ICG, showing no fluorescence. H: Endoscopic view after injection of ICG clearly showing the blood flow in the PCoA and the anterior choroidal artery behind the ICA. I: Microscopic view obtained after tentative clip placement. Because of minor bleeding, tentative clipping was done using a straight clip. J: Microscopic ICG video angiogram obtained after the tentative clipping. K: View via endoscope introduced distal to the aneurysm, revealing the neck of the aneurysm, with yellowish discoloration due to arteriosclerotic changes that could not be identified by microscope. L: Image from endoscopic ICG video angiography, which confirmed the location of aneurysm neck and the blood flow of perforating arteries behind ICA, which were not visible under microscopic ICG video angiography. M: View through the surgical microscope after placement of additional clips. N: Microscopic ICG video angiographic image obtained after clip placement showing no fluorescence in the aneurysm and preservation of the blood flow in the parent and branching arteries. O: Endoscopic view showing aneurysm neck (with strong arteriosclerotic changes) after additional clip placement. P: Endoscopic ICG video angiographic view obtained after clipping revealing no fluorescence in the aneurysm neck and preservation of blood flow in the PCoA and perforating artery, which were not visible under microscopic ICG video angiography. AN = aneurysm; ON = optic nerve. The asterisks indicate the endoscope; open arrowheads, the PCoA; and solid arrowheads, the anterior choroidal artery.
ing tissue, minor bleeding from the aneurysm occurred. Therefore, tentative occlusion was performed with a straight clip (Fig. 1I). The endoscope introduced into the distal side to the aneurysm revealed that the neck of the aneurysm was discolored (yellowish) by arteriosclerotic changes that could not be identified via microscope (Fig. 1K). Microscopic and endoscopic ICG video angiography (Fig. 1J and L, respectively) were performed after tentative clipping. Endoscopic ICG video angiography confirmed the blood flow of perforating arteries behind the ICA, which were not visible under only microscopic ICG video angiography (Fig. 1L). Two more clips were applied to the residual aneurysm neck (Fig. 1M: microscope; Fig. 1O: endoscope). Finally, microscopic (Fig. 1N) and endoscopic (Fig. 1P) ICG video angiography was performed again. Endoscopic ICG video angiography revealed preservation of the blood flow in the PCoA and perforating artery and no fluorescence of the aneurysm dome (Fig. 1P). Postoperative CTA showed disappearance of the aneurysm (Fig. 1E). The patient’s postoperative course was uneventful, and she was discharged from our hospital 2 weeks after the operation.

Case 2

This 68-year-old woman was admitted to our institute for treatment of an asymptomatic unruptured left MCA aneurysm, which was diagnosed by medical check-up of the brain that included MRI and MR angiography. Preoperative angiography showed the left MCA aneurysm (Fig. 2A). A left pterional craniotomy and clip placement was performed under the same monitoring as used in Case 1. The aneurysm was occluded using a curved clip, with careful attention not to obliterate the blood flow in the perforating arteries and trunk of the MCA (Fig. 2B). The endoscope was introduced distal to the aneurysm and revealed no aneurysm neck remnant and no kinking of the MCA (Fig. 2E). Microscopic (Fig. 2C) and endoscopic (Fig. 2F) ICG video angiography revealed no fluorescence in the aneurysm neck and preservation of the blood flow in the trunk of the MCA and the perforating arteries behind M1. Endoscopic video angiography clearly demonstrated patent origins of the perforating arteries. Postoperative angiograms showed disappearance of the aneurysm (Fig. 2D). The patient’s postoperative course was uneventful, and she returned to her previous employment 2 weeks after the operation.

Case 3

This 62-year-old woman had a history of an atherothrombotic cerebral infarction of the right posterior cerebral artery. At the time of the infarction, an unruptured right MCA aneurysm was incidentally diagnosed by MR angiography. Surgical treatment of the aneurysm was undertaken at her request. Preoperative angiography showed the right MCA aneurysm (Fig. 3A). The aneurysm was occluded using a curved clip (Fig. 3B). The endoscope introduced proximal to the aneurysm revealed no neck remnant of the aneurysm and no stenosis of the MCA (Fig. 3E). Microscopic ICG video angiography showed successful occlusion of the aneurysm (Fig. 3C). The en-
doscope provided images behind the aneurysm, and complete occlusion of the aneurysm with preservation of the blood flow in the MCA trunk as well as the perforating arteries arising from the M2 segment was clearly visualized (Fig. 3F). Postoperative CTA showed disappearance of the aneurysm (Fig. 3D). The patient’s postoperative course was uneventful, and she left our hospital 2 weeks after the operation.

**Discussion**

Recently, intraoperative fluorescence angiography using ICG and fluorescein has been playing a pivotal role in confirmation of real-time blood flow in the vasculature during surgery. The use of ICG video angiography was first reported by Raabe et al. The technique can visually confirm the blood flow of all the vasculature exposed to microscope and is therefore useful for vascular surgery including aneurysm clipping, vascular anastomosis, and arteriovenous shunt obliteration. Although ICG video angiography provides clear fluorescence images, it cannot visualize vessels if the excitation light does not illuminate ICG dye in them. Therefore, the blood flow of vessels that are not visible under the surgical microscope cannot be evaluated by this method.

On the other hand, 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. It is possible to observe vasculature behind aneurysms, parent arteries, and/or skull base anatomy, and use of an endoscope can make clipping surgery safer. However, existence of blood in the vessels does not always mean existence of blood flow in those vessels; thus direct and quantitative evaluation of blood flow is desirable.

Video angiography using fluorescence is suitable for these purposes, and we applied a new system involving the combined use of endoscopy and fluorescence video angiography. The ICG fluorescence endoscope adopted in the present study was originally developed as a supporting tool for detection of the sentinel lymph nodes that contain metastases in patients with gastric cancer. With the flexible scope instead of the rigid scope, the bronchial fluorescence endoscope subsequently became established as a device for the diagnosis and treatment of lung cancer. Furthermore, a fluorescence flexible endoscope has been used for in vivo visualization of placental blood vessels in fetoscopic laser photocoagulation of placental vascular anastomosis in twin-twin transfusion syndrome. In the above studies, a laparoscope, bronchoscope, or uteroscope was used. However, the working space available in intracranial surgery is narrower. The need for illumination must be balanced against the relative safety of smaller-diameter endoscopes. We used a 4-mm-diameter endoscope in the present study, and this provided sufficient near-infrared illumination, but a smaller diameter might make it easier to attain optimal placement without compressing surrounding structures.

In this short report, we demonstrated the efficacy and safety of this endoscopic ICG video angiography system. This system may reduce the postoperative morbidity re-

---

**Fig. 3.** Case 3. **A:** Preoperative angiogram showing the right MCA aneurysm. **B:** Intraoperative microscopic view showing occlusion of the aneurysm by means of a curved clip. **C:** Microscopic ICG video angiographic view showing successful aneurysm occlusion and preservation of the blood flow in the parent arteries. **D:** Postoperative CT angiogram showing occlusion of the aneurysm. **E:** View via the endoscope introduced proximal to the aneurysm revealing no neck remnant of the aneurysm and no kinking of the MCA. **F:** Image from endoscopic ICG video angiography, which allowed visualization of the area behind the aneurysm. Complete occlusion of the aneurysm and preservation of the blood flow in MCA trunk as well as the perforating arteries arising from the M2 segment were clearly visualized. The asterisks indicate the endoscope.
lated to vascular compromise and may be especially effective in cases involve complicated or large aneurysms. To establish the effectiveness of this method, further study with a larger number of patients is necessary.

Conclusions

We present a new technique of endoscopic ICG video angiography. This technique provides real-time observation of blood flow in small arteries hidden from microscopic view and may lessen operative morbidity related to vascular occlusion.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article. Author contributions to the study and manuscript preparation include the following. Conception and design: Kinouchi, Nishiyama. Acquisition of data: Nishiyama, Senbokuya, Kato. Analysis and interpretation of data: Nishiyama, Senbokuya. Drafting the article: Nishiyama. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Kinouchi. Study supervision: Kinouchi.

References


Manuscript submitted December 26, 2011. Accepted May 5, 2012. Please include this information when citing this paper: published online June 8, 2012; DOI: 10.3171/2012.5.JNS112300. Address correspondence to: Hiroyuki Kinouchi, M.D., Ph.D., Department of Neurosurgery, Interdisciplinary Graduate School of Medicine and Engineering, University of Yamanashi, 1110 Shimokato, Chuo, Yamanashi 409-3898, Japan. email: hkinouchi@yamanashi.ac.jp.