Original Research Article

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Endoscope-integrated indocyanine green video-angiography for cerebral aneurysm surgery: a more effective technique

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Abstract

Introduction: Microscope-integrated indocyanine green video-angiography (mICG-VA) is used as an adjunct to aneurysm surgery in checking for small compromised perforating arteries and the remnant of an aneurysmal neck. A limitation of mICG-VA is the inability to access the deep area where small vessels are located behind the aneurysm sac or the parent artery. The endoscope-integrated ICG-VA (eICG-VA) is not only a tool in obtaining a wide angle of surgical view, but also is a technique to detect real-time blood flow during aneurysm clipping.
Methods: Patients with an unruptured cerebral aneurysm who had conventional endoscope-assisted microsurgery and eICG-VA were enrolled. We compared the efficacy and additional details of imaging from both types of procedures.
Results: The data of seven patients were reviewed. In two cases of small perforating arteries that were hidden by the aneurysm sacs, more details were detected by eICG-VA. While the performance of the conventional technique was limited, the eICG-VA revealed a wide view in the deep area during aneurysm clipping.
Conclusion: The eICG-VA provides more details of the aneurysm, especially in small perforating vessels that were hidden by the aneurysm. It can resolve the limitations of the conventional endoscope and mICG-VA.

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Introduction

The most important concept of aneurysm surgery is to completely obliterate the neck of the aneurysm. At the same time, the perforating or parent artery should be preserved during aneurysm clipping. Preservation of the small perforating arteries located at the posterior side of the parent vessel or aneurysm sac is a challenge. These arteries might be injured by clipping, which leads to a morbidity from cerebral infarction. A number of devices were developed to solve these problems that include intraoperative digital subtraction angiography (DSA), Doppler ultrasound microprobe, endoscope-assisted microsurgery and microscope-integrated indocyanine video-angiography (mICG-VA). Unfortunately, there were some limitations from each of these devices. For example, intraoperative DSA takes a long time to perform and can only detect blood flow from a large parent artery or aneurysmal sac. Hence, it cannot detect the small perforating arteries and the frequency of complications related to the procedure is slightly high [4]. The Doppler ultrasound microprobe is a non-invasive device to depict the blood flow pattern of a vessel or aneurysm remnant but it cannot access the deep area and the area located behind the aneurysmal sac. During the recent decade, indocyanine green (ICG) angiography was developed as a useful tool in intraoperative real-time to assess the blood flows of the parent, branching or perforating vessels [7]. It is an uncomplicated and safe way to apply ICG because it has a short half-life and is rapidly eliminated by the liver without metabolic breakdown. We can inject the ICG via a peripheral line many times in an operation. We can see the image by the device which is integrated with fluorescence in approximately 5–10 s (a peak time at 9.0 s and a washout time at 31.3 s) [10]. The

ICG allergy is scarcely reported. It can also substitute as an adjunct device for the Doppler ultrasound microprobe or intraoperative DSA.

Indocyanine green can be integrated with a microscope as ICG video-angiography (ICG-VA). The microscope-integrated ICG-VA (mICG-VA) is used to detect the remnant of an aneurysmal neck and the patency of small perforating arteries and the parent vessels. It has the advantage for a real-time check of the patency of small perforating arteries, parent artery and the completion of occlusion. The success rate for preservation of the perforating artery and complete neck obliteration has increased with a significant intraoperative clip modification rate of 15% [9]. However, it has some limitations in the assessment of the small arteries, especially in the areas which are hidden by the corner of the aneurysm or parent vessel and in the deep area. White light endoscope-assisted microsurgery has been established. It provides at least 50% wider surgical anatomical view of the case and can lead to a readjustment of the aneurysm clip. However, the endoscope is unable to detect the real-time dynamic blood flows during surgery [1, 3]. The new endoscope-integrated indocyanine video-angiography (eICG-VA) device was introduced to address the limitations of the endoscope and mICG-VA because it provides a close enlarged view and can access the deep or posterior area that is hidden by the aneurysm or parent artery for evaluation before and post clipping of the aneurysm. Furthermore, the surgeons can also evaluate the real-time dynamics of the blood flows. The outcomes of treatments have improved [6].

This article compares the resolution of imaging between the conventional endoscope and the eICG-VA. Illustrative cases demonstrate the results of the procedures.

Methods

After this study has been approved by the ethical committee of the Fujita Health University, the informed consent was signed by the patients before surgery. We initially studied patients who underwent aneurysm surgery. The conventional endoscopic and eICG-VA were used to detect the aneurysm anatomy including the small perforating arteries before, during and after clipping. Additional data compared the conventional endoscope to eICG-VA.

The conventional endoscope was an angled rigid endoscope (Machida Endoscope Co., Ltd., Chiba, Japan) with a white light source. The telescope viewing was 0 and 30 degrees.

For eICG-VA, a KARL STORZ endoscope (KARL STORZ GmbH & Co. KG, Tuttlingen, Germany) was used. It consisted of the light source (D-light P system) that was controlled with a single-pedal foot switch and one-stage, camera control unit, camera head and a straight forward telescope 0 degree with a diameter of 5.8 mm and a length of 19 cm (Figure 1). The device was integrated with near-infrared imaging that absorbs the ICG fluorescence band light wavelength in the range of 780–820 nm. The other excited wavelength light was blocked by a camera filter. The high-definition image of the endoscope was recorded. This device was used to inspect the aneurysm and small arteries after the ICG injection and there was a period of 5–10 s to evaluate the details of the emphasised area. The final images were analysed to compare between the techniques.

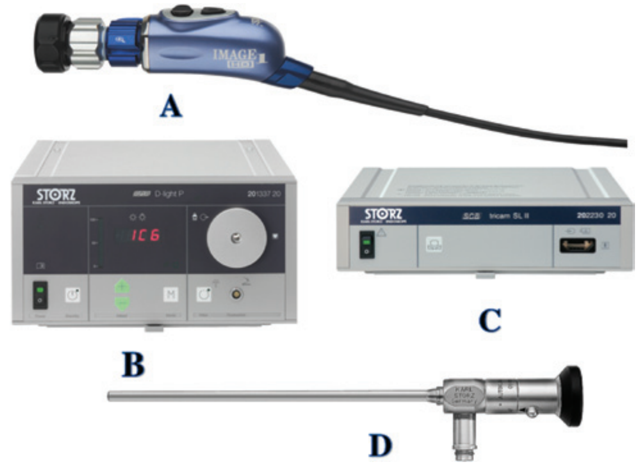

Figure 1: The eICG-VA device from KARL STORZ. (A) Camera head and hand switch to the ICG mode. (B) Light source (D-light P system). (C) Camera control unit. (D) Straight telescope.

Results

Aneurysm surgery was performed using the conventional endoscope-assisted microsurgery and eICG-VA in a total of seven cases (Table 1). Additional details were obtained from the eICG-VA before and after clipping in two patients as shown below. In the first case, additional data from eICG-VA helped avoid a complication during placement of the aneurysmal clip by detecting a small perforating artery. In the second case, a small perforating artery was detected after clipping and it was preserved from the clip.

Table 1: Summary of patient data.

No.	Age/sex	Diagnosis	Yield of eICG-VA
1.	71/female	MCA aneurysm	Small perforating arteries
2.	60/male	MCA aneurysm	–
3.	57/male	MCA aneurysm	–
4.	62/female	Oph aneurysm	Small perforating arteries
5.	66/female	MCA aneurysm	–
6.	68/female	MCA aneurysm	–
7.	67/male	SCA aneurysm	–

MCA=Middle cerebral artery, Oph=ophthalmic artery, SCA=superior cerebellar artery.

None of the patients developed complications related to the application of endoscopic ICG-VA.

Case illustrations

Case No. 1

A 71-year-old female was diagnosed with unruptured MCA aneurysm on the left side. The frontotemporal approach technique was performed. The aneurysm was identified under the microscope and mICG-VA. The neck and small perforating arteries surrounding the aneurysm were revealed (Figure 2A,B). After clipping, the conventional white light endoscope was used to check the completion of aneurysm obliteration and preservation of a small perforating artery. Furthermore, with eICG-VA, additional details of the small artery that surrounded the aneurysm sac after clipping were seen while white light endoscopy could not show this result (Figure 2C,D).

Case No. 4

A 62-year-old female was diagnosed as unruptured right ophthalmic artery aneurysm. The frontotemporal approach was performed and the anterior clinoid process was completely removed. We checked the aneurysm sac and surrounding arteries with mICG-VA, white light endoscope and eICG-VA before clipping (Figure 3). We obtained additional data of a small perforating artery behind the aneurysm sac from the eICG-VA. The direction of placing the clip was considered which preserved the small perforating artery.

Discussion

Intraoperative ICG-VA has been used for a decade as an adjunct to aneurysm clipping. Some authors suggested substituting ICG-VA for intraoperative DSA to detect the

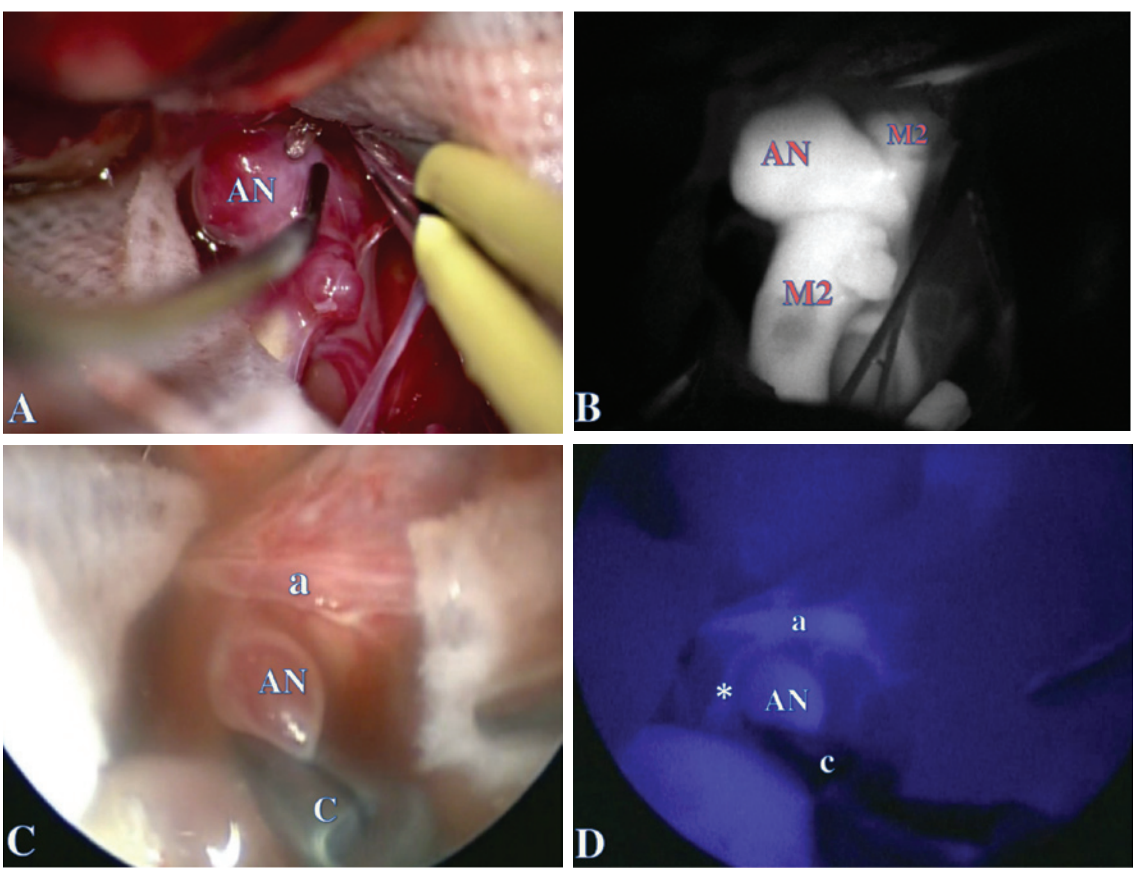

Figure 2: A 71-year-old presented with an unruptured right middle cerebral artery aneurysm. (A) Intraoperative microscopic view of the aneurysm sac and parent artery including small perforating arteries. (B) mICG-VA showed the M2 artery and aneurysm sac. (C) Conventional endoscopic view after the aneurysm was clipped and the clip was obliterated at the neck of aneurysm. A small artery surrounding the dome of aneurysm was also detected. (D) eICG-VA shows the additional information of the small artery (*) around the neck of the aneurysm. AN=Aneurysm, a=artery, c=clip.

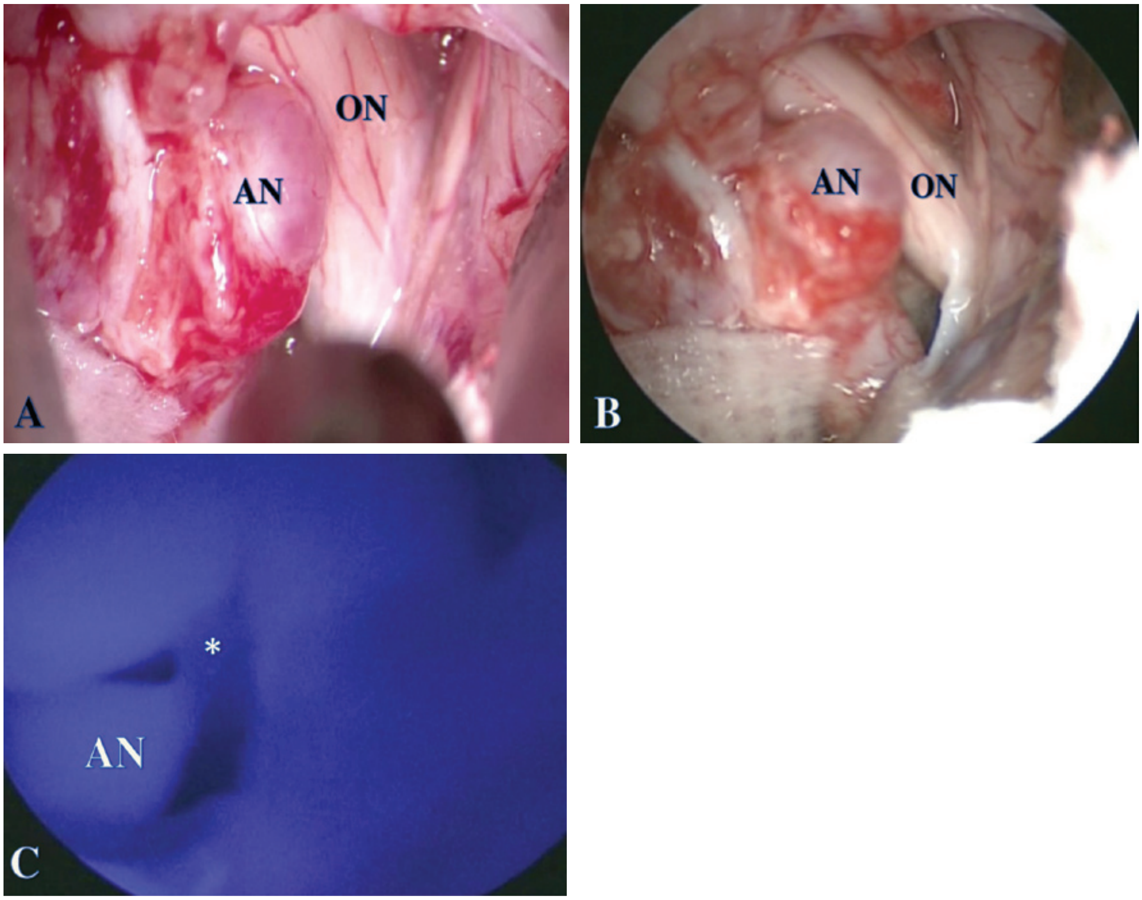

Figure 3: A 62-year-old female had clipping performed at an unruptured ophthalmic artery aneurysm. (A) Microscopic view of the aneurysmal sac and optic nerve. (B) Endoscopic view of the aneurysm and the relationship with the parent artery before clipping. (C) eICG-VA was performed and more information of the perforator arteries (*) behind the aneurysm was obtained. AN=Aneurysm; ON=optic nerve.

remnant of an aneurysm neck or to preserve the small perforating arteries during aneurysm clipping [8]. The mICG-VA especially is a most useful device because it provides an uncomplicated and safe procedure. Several reports reviewed and established the yield of ICG-VA to detect an artery remnant and preserve a perforating artery while clipping an aneurysm [2]. However, mICG-VA still had the inability to access the deep area, especially in a hidden corner or behind the aneurysm before clipping. This might cause an injury during clipping and compromise the small perforating arteries [5]. Endoscope-assisted microsurgery resolves this potential morbidity [11]. The endoscope cannot evaluate the real-time blood flows during clipping. However, the eICG-VA provides the advantage of dynamic study and can move as widely as required by the surgeon. The duration of fluorescence under the eICG-VA is longer than the mICG-VA. This function of the endoscope is superior to the microscope. The endoscope offers the ability to change the rearrangement of the applied clipping or apply additional clipping to 20% [5, 9].

In this study, the imaging was compared between eICG-VA and conventional endoscopy for the neck remnant and preservation of small perforating arteries or parent artery before, during and after clipping. We recruited only patients with an unruptured aneurysm with the number of cases limited to the limitations of the devices. For all cases, we clearly visualised the parent artery, aneurysm sac and small perforating arteries before and after clipping. The conventional endoscope was applied first and then the ICG for mICG-VA was injected. After checking with the microscope, a change to the endoscope was done immediately to see the illumination of the fluorescence and moved to different angles of view until the fluorescent colour could not be seen (total elimination from the intraluminal blood vessel). The surgeon could recognise the perforating arteries in two of the seven patients and additional information was obtained for preservation of the

Table 2: Advantages and disadvantages of eICG-VA.

Advantages	Disadvantages
Close wide view and adjustable angle to access the small perforating arteries in the hidden areas especially the posterior aspect of parent artery or aneurysm sac	Limitation of a rigid telescope: no flexible angle of the device
Real-time assessment of blood flow in the blood vessels or aneurysm sac	ICG allergy
Longer duration of ICG-VA image while checking the secure structure in the area of interest than mICG-VA	Accessible only with dissected arteries
Short time to perform and low cost	Cannot see or poor quality in the atherosclerotic plaque area
Can repeat to perform many times during one operation	Cannot perform three-dimensional imaging

small perforating arteries. In other cases, the details from eICG-VA did not change the management when compared with conventional endoscopy. We concluded that the efficacy of eICG-VA is superior to the conventional endoscope especially for the real-time dynamics of the blood flows. Hence, the advantages and disadvantages of eICG-VA are summarized in Table 2.

There were some limitations of the device. The large size of the telescope made it difficult to access a small area. A smaller flexible telescope may be helpful. Furthermore, if it can be made compatible with colour mapping software, it may be used to study blood flow patterns, especially at the completion of clip obliteration. For diseases other than aneurysm, we may apply this device in microvascular decompression because it can reveal the vascular structure in the decompression site.

Conclusion

Endoscopic-assisted microsurgery can provide only static vascular imaging but the eICG-VA reveals the characteristics of blood flows while performing surgery. A neurosurgeon can get reliable data before, during and after aneurysm clipping. It is easy to perform and the outcome of treatment can improve.

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