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Usefulness of 4K-resolution Indocyanine Green Endoscope for the Removal of Spontaneous Intracerebral Hematomas

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Abstract

Indocyanine green (ICG) is a cyanine dye useful for visualizing blood vessels; it has been developed for endoscopy and is used in skull base surgery. Endoscopy is widely used for hematoma removal after an intracerebral hemorrhage since it is minimally invasive and has a shorter operation time than craniotomy. However, with this technique the surgical field is limited and it is difficult to obtain an adequate orientation; thus, it is challenging to locate the bleeding point, and postoperative rebleeding has been reported. We performed intraoperative ICG near-infrared fluorescence imaging to locate the bleeding point. This purpose of this study was to evaluate the usefulness of ICG angiography during endoscopic hematoma removal in two patients, using two endoscope types and comparing their visualization of perforating branches during the procedure. ICG angiography was performed in two different cases of putaminal hemorrhage, using the SPIES NIR/ICG-System and IMAGE1 S Rubina (both KARL STORZ, Tuttlingen, Germany) at the intraoperative bleeding site. The intraoperative use of ICG allowed the clear visualization of the perforating branches and real-time confirmation of active bleeding. We could also distinguish an old hematoma from the active bleeding point. The IMAGE1 S Rubina has adequate brightness for contrast enhancement, allowing surgical manipulation simultaneously to the enhancement phase. ICG fluorescence angiography is useful to identify the damaged vessel and perform hemostasis. We expect other similar devices to be developed in the future, accompanied by flexible and thin rigid endoscopes.

Keywords: endoscopy, fluorescence angiography, hematoma removal, indocyanine green, intracerebral hemorrhage

Introduction

Indocyanine green (ICG) is a fluorescence-emitting cyanine dye, used to visualize blood vessels and confirm blood flow in vascular operations, such as clipping surgery.[1)] Since the development of ICG endoscopes in 2013, ICG contrast has been used for endonasal skull base surgery, allowing the visualization of the internal carotid artery, through the dura mater and bone, and the perforating branches to the optic nerve and pituitary stalk after tumor removal.[2)]

On the other hand, an endoscopic method for hematoma removal was introduced in 2000, using a transparent sheath to guide the endoscope, and endoscopic hematoma removal after intracerebral hemorrhage has become a common procedure.[3)] Xu et al. reported that endoscopic surgery is less invasive and can be performed in a shorter time than traditional craniotomy.[4)] However, this technique is limited by the narrow surgical field provided by the sheath, and understanding the exact anatomy is more difficult than with craniotomy. The bleeding points are challenging to identify, and postoperative bleeding has been reported as a serious complication after endoscopic hematoma removal.[5)] Therefore, we performed intraoperative ICG near-infrared fluorescence (ICG-NIRF) imaging to locate the bleeding point and identify the damaged vessel causing the hemorrhage. The purpose of the study was to evaluate the usefulness of ICG angiography during endo-

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Fig. 1 IMAGE1 S Rubina (KARL STORZ, Tuttlingen, Germany). The circle shows the endoscope pedal.

scopic hematoma removal. We used two types of ICG endoscopes and examined the following characteristics for hematoma removal procedures: bleeding vessel visibility, contrast between hematoma and vessel, and ease of hemostasis.

Case Report

We performed ICG angiography at the surgical site in proximity to the supposed bleeding point in two patients. We injected 3 mL of a solution with 25 mg ICG (Daiichi Sankyo, Tokyo, Japan) diluted in 10 mL of saline, followed by a boost of 10 mL of saline. ICG is photo-engineered and stabilized by rapid binding to the blood proteins; the maximum absorption wavelength shifts immediately from 785 nm in an aqueous solution to 805 nm in blood.

In the two cases reported here, the ICG endoscopes used were IMAGE1 SPIES NIR/ICG-System and IMAGE1 S Rubina (both KARL STORZ, Tuttlingen, Germany). The camera for both endoscopes is a straight 0° telescope, 4 mm in diameter. The light can be changed to ICG mode using a pedal (Fig. 1).

The IMAGE1 SPIES NIR/ICG-System, the traditional model, can be used to observe ICG contrast by darkening the surrounding area. Therefore, with this system, only observation is possible during the ICG contrast phase due to the lack of ambient light, and surgical procedures cannot be performed while contrasting. The more recent model, IMAGE1 S Rubina, solved this problem, allowing the contrast to be visible under white light. In addition, various acquisition modes are available with the Rubina systems: the overlay mode generates a superimposed image by projecting the ICG-NIRF data onto a white light image; the ICG-NIRF data can be displayed in green or blue depending on the imaging purpose. In monochromatic mode, only the ICG-NIRF image is displayed in white for maximum visibility; however, this modality requires to darken the surroundings. Finally, the intensity-map mode displays the ICG-NIRF signal intensity by changing the color according to the image type.[5] We used the overlay mode in this hematoma removal study. We performed ICG angiography using one ICG endoscope per case and compared the intraoperative findings.

The present study was approved by the Institutional Review Board of the Nippon Medical School (Approval No. R 1-11-1212). The medical records and brain imaging scans of the patients were reviewed according to the ethical principles of the Declaration of Helsinki. The patients consented to the publication of the images.

Case 1

A 67-year-old male was brought to our hospital with disorientation; on examination, he had a Japan coma scale (JCS) score of 20 and right hemiplegia, with Manual Muscle Test (MMT) score of 1. He had no relevant medical or pharmacological history and was previously independent in activities of daily livings (ADLs). Computerized tomography (CT) showed a left putaminal hemorrhage equivalent to 50 mL (Fig. 2a), and he underwent endoscopic hematoma removal on the third day from onset. The patient was placed in the supine position with a 3-point pin fixation. A transparent endoscopic sheath (regular type, outer cylinder diameter 10 mm, total length 120 mm; Neuroport, Olympus, Tokyo, Japan) was inserted from the most superficial part of the hematoma, located using neuronavigation. The hematoma was confirmed and removed with irrigation, and a suspected perforating branch was identified (Fig. 2b). The operating room was darkened to perform ICG angiography with the IMAGE1 SPIES NIR/ICG-System, revealing a bleeding perforating branch (Fig. 2c). Due to the dark visual field during ICG imaging, the surgery was stopped, and only observation was performed. Postoperatively, the hematoma was confirmed to be adequately removed, and there was no obvious new infarction (Fig. 2d). However, on the 18th postoperative day, the patient's level of consciousness was still JCS 20, and the paralysis was unchanged. He was transferred to the hospital for rehabilitation with a modified ranking scale (mRS) score of 5.

Case 2

A 50-year-old male with left hemiplegia for the previous two days was brought to our hospital. He had no relevant medical or pharmacological history and was previously independent in ADLs. At admission, he had disorientation with JCS 10, left hemiplegia with MMT 2 in the left upper

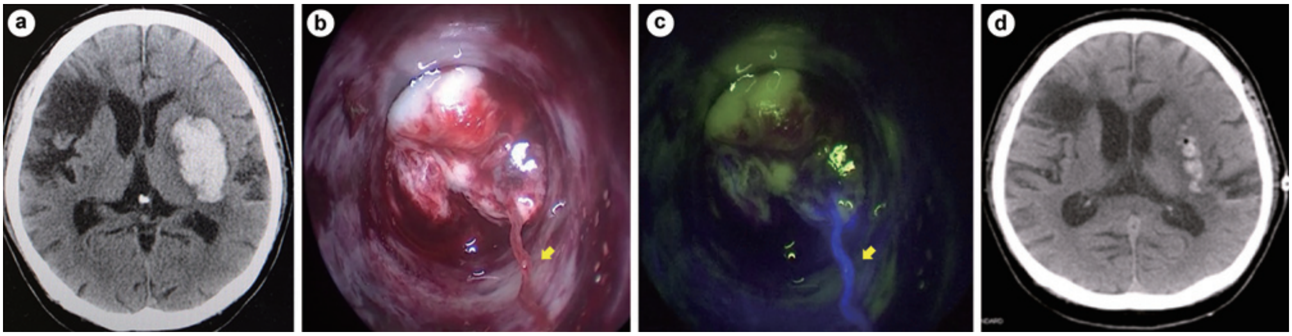

Fig. 2 Case 1. a) CT image of the left putaminal hemorrhage, equivalent to 50 mL. b) Surgical view under the white light. c) Surgical view under the ICG mode. The arrowhead shows the disrupted perforating branch. d) Postoperative CT confirms the hemorrhage removal.

and lower limbs, and left hemispatial neglect. A CT scan showed a right putaminal hemorrhage equivalent to 50 mL, and magnetic resonance imaging (MRI) showed no obvious vascular malformations or aneurysms. Endoscopic hematoma removal was performed the day after admission (Fig. 3a). The patient was placed in the supine position with a 3-point pin fixation. A transparent endoscopic sheath (regular type, outer cylinder diameter 10 mm, total length 120 mm; Neuroport) was inserted into the superficial upper layer of the hematoma, located using neuronavigation. After the soft hematoma was removed while maintaining the layer between the brain surface and the blood, a hard hematoma was noted, surrounded by several vessels. We considered the possibility of a bleeding point in the observed area and performed ICG angiography with IMAGE1 S Rubina, which revealed a perforating branch, though without evident active bleeding from the vessel. Contrast leakage was noted from the deep part of the vessel (Fig. 3b). The anterior perforating branch was identified as a passing artery; after removing the hematoma from the point of contrast leakage, active bleeding and further contrast leakage from the disrupted perforating branch were located posteriorly (Fig. 3c). In addition, the old hematoma was not enhanced by the contrast, thus it was possible to distinguish between the new and old bleeding (Fig. 3d). ICG was used to guide the hematoma removal and hemostasis while observing the contrast-enhanced area as necessary; then, the hematoma cavity was filled with oxidized cellulose (Surgicel, Johnson & Johnson, New Brunswick, NJ, USA) and closed (Video 1).

Postoperative CT showed that the hematoma was entirely removed, and MRI showed no obvious infarction (Fig. 3e). Rehabilitation was performed after the surgery, and ADL abilities improved until the patient could walk with a cane. Both left limbs had an MMT score of 4, and the patient was transferred to the hospital for rehabilitation on postoperative day 38 with an mRS score of 2.

Discussion

ICG angiography during surgery at the site of a hard hematoma or collection of perforating branches, suspected to be in proximity to the bleeding point, can help detect the site of contrast leakage. Unnecessary vascular damage can be avoided with accurate localization of the bleeding point. Active bleeding can be confirmed in real-time when the leaking site is located, and hemostasis can be easily achieved. This imaging modality is useful to overcome the difficulty in finding the bleeding point(s) in the narrow surgical field provided by the endoscope. It is also useful to identify and repair vascular injuries caused by suction tubes or endoscopes during hematoma removal. However, it should be noted that when the dye leaks from the blood vessels, it mixes with the spinal fluid and becomes slightly less visible. ICG angiography is also useful to distinguish new bleeding points from old hematomas since the latter are not enhanced by the contrast. Miki et al. reported that the spot sign on CT angiography is associated with active bleeding from the ruptured vessel and with postoperative rebleeding, which leads to poor outcomes.[6] Achieving complete hemostasis of an intraoperative active bleeding by electrocoagulation is critical to prevent postoperative recurrent hemorrhage; therefore, it is useful to perform ICG contrast imaging to locate accurately the bleeding point(s).[6] With the IMAGE1 SPIES NIR/ICG-System, only observation was possible intraoperatively due to the darkened surrounding area. On the other hand, the IMAGE1 S Rubina allows ICG contrast with white light; thus, surgical operations can be performed while the contrast is visible.

Rigid endoscopes with outer diameters of 4 and 5.8 mm have been designed for ICG angiography, and the future development of thinner rigid endoscopes may allow a greater ease for these surgeries since interference in the endoscopic sheath can be reduced. In this study, we used a 0° telescope; however, 30° and 45° telescopes have also been produced and can be useful for ventricle observation and endonasal skull base surgery. Currently, only rigid telescopes are in use; the future development of flexible ICG

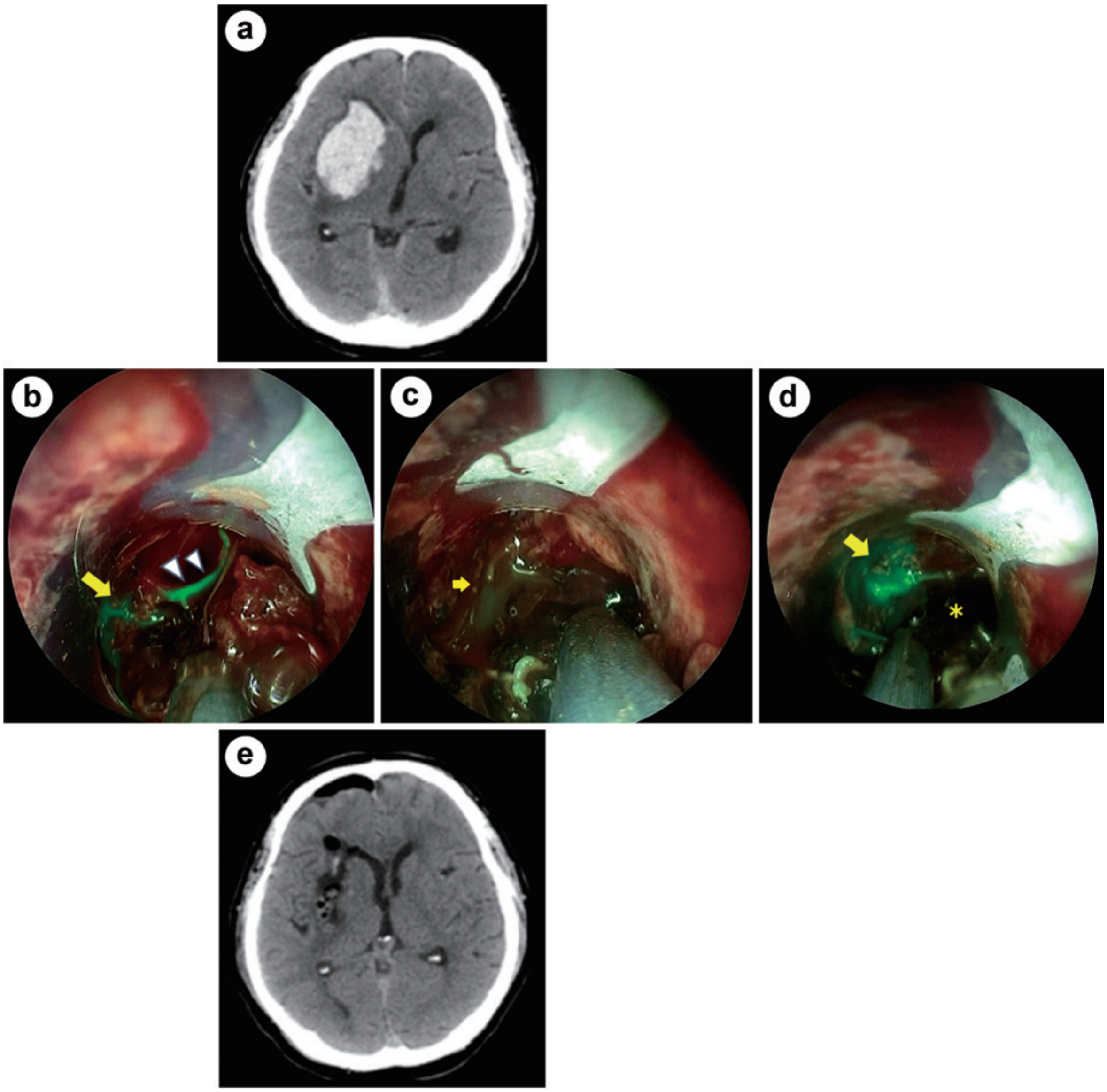

Fig. 3 Case 2. a) CT images of the right putaminal hemorrhage, equivalent to 50 mL. b) A passing artery is highlighted with indocyanine green (white arrowhead), and contrast medium leakage is confirmed from the deeper area (yellow arrow). c) The arrow shows the active bleeding from a disrupted artery. d) The * shows the old hematoma; the new bleeding posteriorly is identified in green (yellow arrow). e) Postoperative CT confirms the hemorrhage removal.

endoscopes may further expand the surgical range. Large-scale clinical trials of endoscopic removal of intracerebral hematomas, including postoperative rebleeding rate using ICG endoscopy, are warranted.

In conclusion, ICG fluorescence angiography is useful in endoscopic hematoma removal to locate the bleeding point and responsible vessel and then perform hemostasis. Further development of endoscopic devices is expected.

Supplementary Material

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Conflicts of Interest Disclosure

None

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