# Dual-Channel Endoscopic Indocyanine Green Fluorescence Angiography for Clipping of Cerebral Aneurysms

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■ OBJECTIVE: **Neuroendoscopy is useful for assessing status of perforators, parent arteries, and aneurysms beyond the straight line of microscopic view during aneurysm clipping. We aimed to evaluate the clinical usefulness of our endoscopic indocyanine green angiography (ICGA) system, which can simultaneously display visible light and indocyanine green fluorescent images.**

■ METHODS: **Surgical clipping of 16 unruptured aneurysms in 10 patients was performed via the keyhole approach. Using our endoscopic ICGA and commercial microscopic ICGA systems, we prospectively compared 10 targeted cerebral aneurysms at the posterior communicating ($n = 4$) and anterior choroidal ($n = 6$) arteries.**

■ RESULTS: **Microscopic ICGA and endoscopic ICGA were feasible during surgery. Microscopic ICGA displayed 50% of branch orifices, 100% of branch trunks, and 20% of exact clip positions, whereas endoscopic ICGA showed 100% of these. Based on endoscopic ICGA findings such as incomplete clipping and compromise of parent arteries or branches, clips were repositioned in 2 cases, and additional clips were applied in 2 cases. Complete occlusion and residual neck states were achieved in 6 and 4 aneurysms after surgery. There were no neurologic deficits within 3 months after surgery except for frontalis palsy and anosmia in each patient.**

■ CONCLUSIONS: **The endoscopic ICGA system with dual imaging of visible light and indocyanine green fluorescence was very useful for assessing geometry of aneurysms and surrounding vessels before clipping and for evaluating completeness of clip position after clipping.**

## INTRODUCTION

In the treatment of cerebral aneurysms, novel surgical skills and devices such as keyhole approaches, fluorescence imaging, neuroendoscopy, intraoperative neurophysiologic monitoring, and cerebral angiography are rapidly being introduced because they help to reduce surgical morbidity and mortality.[1-8] One such technique, using indocyanine green (ICG) fluorescence, is microscopic indocyanine green angiography (ICGA), which since its introduction by Raabe et al.[7] has been widely used to detect and readjust the compromise of perforators and parent arteries and incomplete clipping of cerebral aneurysms. However, the microscopic ICGA system has some limitations in visualizing vascular structures beyond the line of microscopic view and deeply seated structures with weak illumination. Neuroendoscopy is helpful to overcome such microscopic drawbacks, magnify the areas of interest, and obtain longer ICG fluorescence.[2,3] When a keyhole approach is used, the limitations of the microscope and the need for a neuroendoscope become more profound. We have already reported a prototype of a dual-channel endoscopic ICGA system to combine the advantages of microscopic ICGA and neuroendoscopy.[9] Thereafter, the system was improved with a smaller camera size, higher display resolution, and fine modifications. Although there are 3 clinical

**Key words**
- Cerebral aneurysms
- Clipping
- Indocyanine green fluorescence
- Indocyanine green fluorescence angiography
- Neuroendoscope

**Abbreviations and Acronyms**
ACha: Anterior choroidal artery
CT: Computed tomography
DSA: Digital subtraction angiography
ICA: Internal carotid artery
ICG: Indocyanine green
ICGA: Indocyanine green angiography
PCoA: Posterior communicating artery

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**Table 1.** Basal Characteristics and Surgical Outcomes

| Case | Age (years)/Sex | Location of Target Aneurysm | Maximal Diameter (mm) | Approach | Locations of Other Aneurysms | Operation Time (minutes) | Surgical Results | Postoperative Complications | Modified Rankin Score | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Preoperative | At Discharge | After 3 Months |
| 1 | 72/F | AChA, left | 4 | LSO | None | 120 | Complete occlusion | None | 0 | 1 | 0 |
| 2 | 52/M | AChA, left | 5.8 | LSO | PCoA, MCA (M1, M2) | 250 | Residual neck | Transient third nerve palsy | 0 | 1 | 0 |
| 3 | 56/M | AChA, right | 2.4 | SSO | None | 140 | Complete occlusion | Frontalis palsy | 0 | 1 | 1 |
| 4 | 59/F | AChA, right | 4.1 | FL | None | 145 | Complete occlusion | Transient third nerve palsy | 0 | 2 | 0 |
| 5 | 58/F | PCoA, right | 2.4 | LSO | MCA | 100 | Complete occlusion | None | 0 | 0 | 0 |
| 6 | 73/F | PCoA, left | 8.6 | LSO | None | 130 | Residual neck | None | 0 | 0 | 0 |
| 7 | 73/F | AChA, left | 4.7 | FL | ACoA | 280 | Complete occlusion | Transient frontalis palsy, anosmia | 0 | 1 | 1 |
| 8 | 59/M | AChA, left | 6.5 | LSO | None | 140 | Residual neck | Delayed asymptomatic left post IC infarction | 0 | 1 | 0 |
| 9 | 61/F | PCoA, left | 3 | FL | MCA | 120 | Complete occlusion | None | 0 | 1 | 0 |
| 10 | 75/F | PCoA, left | 4.6 | FL | None | 120 | Residual neck | None | 0 | 0 | 0 |

F, female; AChA, anterior choroidal artery; LSO, lateral supraorbital; M, male; PCoA, posterior communicating artery; MCA, middle cerebral artery; SSO, superciliary supraorbital; FL, frontolateral; ACoA, anterior communicating artery; IC, internal capsule.

reports about the usefulness of the endoscopic ICGA system,[1-3] our system has the distinguishing features of simultaneous imaging and real-time merging of ICG fluorescence and visible light. The aim of this study was to evaluate the safety and usefulness of our endoscopic ICGA system in clinical circumstances.

## MATERIALS AND METHODS

### Patient Selection

This study was prospectively performed in patients undergoing surgical clipping of unruptured cerebral aneurysms arising at the internal carotid artery (ICA)—posterior communicating artery (PCoA) and the anterior choroidal artery (AChA) between August 2015 and July 2016. Institutional review board approval was received. Inclusion criteria were as follows: 1) adult patients 20—80 years old; 2) medical conditions tolerating general anesthesia and surgical clipping; 3) unruptured cerebral aneurysms arising at the ICA-PCoA and AChA, the orifices of which were expected to be difficult to identify with the microscope; 4) aneurysms >3 mm in maximal diameter, aneurysms <3 mm with which other multiple aneurysms were scheduled to be simultaneously clipped via the same corridor, or aneurysms that patients were eager to have treated regardless of the size or shape; 5) no previous history of porphyria or hypersensitivity to ICG; 6) no use of drugs that influence the effect of ICG, such as photosensitizers; and 7) patient provision of informed consent. Surgical clipping of 16 cerebral aneurysms in 10 patients was performed; among the patients, 6 had single aneurysms, 3 had 2 aneurysms each, and 1 had 4 aneurysms. Patients consisted of 3 men and 7 women with a median age of 60 years (range, 52—75 years). Targeted cerebral aneurysms arose from the ICA-PCoA in 4 patients and the ICA-AChA in 6 patients. Of the lesions, 4 were left-sided, and 6 were right-sided, with a median maximal diameter of 4.4 mm (range, 2.4—8.6 mm) (Table 1).

### Microscopic ICGA and Endoscopic ICGA Systems

Using a microscopic ICGA system (Leica M720 OH5 and FL800; Leica Microsystems, Wetzlar, Germany) and the endoscopic ICGA system (LAP-2C; Korea Electrotechnology Research Institute, Seoul, Korea) that our team previously developed,[9] the safety and usefulness of endoscopic ICGA were compared with microscopic ICGA. Our endoscopic ICGA system was upgraded with a smaller camera, similar in size to commercial cameras for neuroendoscopes, and the resolution of the display was much improved (Figure 1). The merits of our endoscopic ICGA system are simultaneous display and real-time merging of visible light and fluorescent imaging through the dual-channel camera and software. Commercial 2.7-mm neuroendoscopes were used (HOPKINS Straight Forward Telescope 0° and Forward-Oblique Telescope 30°; KARL STORZ GmbH & Co., Tuttlingen, Germany). ICG was intravenously injected as a bolus of 0.3—0.4 mg/kg (25 mg dissolved in 5 mL of sterile normal saline).

First, identification of the ICA as a parent artery, the orifice and trunk proper of the PCoA and AChA as branches, other perforators, the aneurysm, and the clip blade was attempted with the microscope and endoscope in a visible light mode before and immediately after clipping. Second, ICG was injected when clipping was considered satisfactory. The structures were