The Utility and Limitations of Intraoperative Near-Infrared Indocyanine Green Videoangiography in Aneurysm Surgery

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Key words
- Aneurysm
- Indocyanine green
- Near-infrared
- Surgery
- Videoangiography

Abbreviations and Acronyms
AComA: Anterior communicating artery
DSA: Digital subtraction angiography
ICA: Internal carotid artery
ICG: Indocyanine green

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OBJECTIVE: **To analyze the clip repositioning rate and the correlation between indocyanine green (ICG) videoangiography and conventional postoperative digital subtraction angiography for completeness of aneurysm occlusion and parent and branching vessel compromise.**

METHODS: **This retrospective study included 112 patients with 126 aneurysms who underwent microsurgical clipping and ICG videoangiography during aneurysm surgery at a single center from January 2008 to June 2013. Age, gender, aneurysm size, location, and rupture status were included in the model for analysis.**

RESULTS: **In 10 patients (8%), ICG videoangiography resulted in clip repositioning during surgery. Discordance between ICG videoangiography and postoperative angiography was observed in 5 patients (4%). There was no significant difference of ICG videoangiography—postoperative angiography discordance between ruptured and unruptured aneurysms ($P = 0.56$). On multivariate analysis, patient age, gender, aneurysm size, and rupture status did not reach significance. Ophthalmic internal carotid artery aneurysms were more likely to have discordance compared with all other aneurysms ($P = 0.04$; odds ratio, 10.8; confidence interval, 1.5—75.94).**

CONCLUSIONS: **ICG videoangiography is a very useful modality for intraoperative assessment of the adequacy of aneurysmal obliteration and patency of parent and perforating vessels. However, ICG videoangiography is not absolutely reliable as a stand-alone method during clipping of ophthalmic artery aneurysms and can be complemented with intraoperative digital subtraction angiography. ICG videoangiography can be used either as an alternative or as a complementary technique to intraoperative digital subtraction angiography during aneurysm surgery.**

INTRODUCTION

The goal of aneurysm surgery is to achieve complete exclusion of the aneurysm from the circulation while preserving parent and perforating or branching vessels. However, in the literature, the incidence of residual aneurysm and parent artery occlusion on postoperative angiography ranges from 1.8%—3.6% for residual aneurysm and 1.6%—21% for parent artery occlusion (1, 4, 6, 13, 14, 18, 20, 26, 29-31). Studies have documented that the use of intraoperative angiography during aneurysm surgery significantly alters the surgical procedure in 7%—34% of cases (1, 3, 6, 13, 17, 18, 24, 30). In 2003, Raabe et al. (22) introduced the technique of microscope integrated near-infrared indocyanine green (ICG) videoangiography for the intraoperative assessment of aneurysm obliteration and patency of parent and branch vessels during microsurgical clipping. In their study, they compared ICG videoangiography with intraoperative digital subtraction angiography (DSA) and postoperative DSA and concluded that ICG videoangiography provided significant information that led to readjustment of the aneurysm clipping in 9% of the cases and made it an excellent modality to assess clip position, although intraoperative DSA was more accurate than ICG videoangiography (22, 23). Since the work of Raabe et al., many studies have demonstrated the role of ICG videoangiography in assessing the adequacy of clipping (7, 19, 25, 31). In addition, studies have analyzed the clip repositioning rates for specific aneurysms, such as aneurysms of the anterior communicating artery (AComA) and ophthalmic artery, and provided a more specific assessment of the utility of ICG videoangiography and difficulties encountered in different types of aneurysms (8, 16). The limitations of ICG videoangiography include inability to detect residual neck in cases where vessels are occluded by blood clots, inability to visualize areas outside the field of the microscope, and difficulty visualizing residual neck in calcified and thrombosed aneurysms (15, 23). As a result of these limitations, studies have suggested either that intraoperative DSA and ICG videoangiography can be used complementary to each other or that intraoperative DSA continues to be the "gold standard" of intraoperative imaging during aneurysm surgery (9, 25, 31).

The aim of our study was to analyze the clip repositioning rate and the correlation between ICG videoangiography and postoperative angiography for completeness of aneurysm occlusion and parent vessel compromise. Our study should add to the broadening base of knowledge on the effectiveness of ICG videoangiography and focuses on the reliability of ICG videoangiography compared with postoperative DSA. Although the ideal situation would be to replace a variety of invasive intraoperative imaging methods with the relatively safe and quick ICG videoangiography, we hope to help specify the types of aneurysms and situations where ICG videoangiography would be superior to other intraoperative methods.

METHODS

Clinical Data

This retrospective study from January 2008 to June 2013 was approved by the institutional review board at the Louisiana State University and carried out in accordance with the Health Insurance Portability and Accountability Act. The study population comprised 112 consecutive patients with 126 aneurysms who underwent microsurgical clipping and ICG videoangiography during surgery. Only the patients operated on by a single surgeon (B.G.) were included in our study because the ICG videoangiography technique is observer dependent, and its utility may differ between 2 observers. All patients were evaluated with computed tomography angiography preoperatively. Of these, 93 (83%) patients were evaluated further with catheter angiography preoperatively. All 112 patients underwent postoperative DSA.

We retrospectively reviewed the inpatient case records, preoperative and postoperative angiography details, outpatient data, and operative notes of all selected patients. All charts were studied for patient demographics, aneurysm characteristics (size, location, and rupture status), Fisher grade in ruptured aneurysms, and intraoperative details with the clipping techniques and the number of clips used to achieve occlusion. Data on ICG videoangiography findings after clip placement and rate of clip repositioning were collected from the database. Postoperative angiography details were evaluated for the presence of aneurysmal remnant, inadvertent parent artery occlusion requiring clip repositioning, and branch vessel compromise. Intraoperative and ICG videoangiography videos were also reviewed in all cases by 2 neurosurgeons separately (M.S. and S.A.). Computed tomography angiography was performed to determine the relationship of the aneurysms to the surrounding bony structures. The discordance between ICG videoangiography and postoperative angiography was defined as ICG videoangiography demonstrating aneurysm obliteration and normal vessel flow but postoperative DSA showing either an aneurysm remnant or parent or branch vessel occlusion requiring clip repositioning.

Patients in whom all clinical, radiologic, operative, and follow-up data were unavailable were not included in this study. Patients who were excluded were 2 patients with AComA aneurysms, 1 patient with posterior communicating artery aneurysm, and 1 patient with an internal carotid artery (ICA) bifurcation aneurysm.

ICG Videoangiography

ICG videoangiography was performed using the technical principles described by Rabbe et al. (22-24). In brief, a 25-mg bolus of ICG dye was injected into a peripheral vein, and the operative field was illuminated by a light source (near-infrared) that covers a part of the ICG absorption band (range, 700–850 nm). When the dye reaches the vessels within the near-infrared light illuminated region, the ICG fluorescence was induced, and the blood flow pattern was recorded by a nonintensified video camera attached to the surgical microscope. The OPMI PENTERO (Carl Zeiss Meditec, Inc., Dublin, California, USA) has an integrated ICG videoangiography technology with the operating microscope to obtain high-resolution and high-contrast images. An optical filter blocks the ambient and excitation light so that only ICG-induced fluorescence can be seen and recorded. ICG videoangiography was performed after placement of the aneurysm clip based on the visual inspection. However, if there was any evidence of stenosis or flow compromise on ICG videoangiography, the clip was repositioned, and follow-up ICG videoangiography was performed after an interval of 3–10 minutes (1–2 ICG half-lives) to avoid residual intravascular fluorescent activity (9).

Postoperative DSA

All patients underwent postoperative angiography between day 1 and day 5. The digital subtraction angiograms were obtained in at least 3 projections (anteroposterior, lateral, and oblique). The neuroradiologist interpreted the postoperative angiograms in consultation with the operating neurosurgeon and was unaware of the intraoperative ICG videoangiography findings. In cases of residual aneurysms or parent artery occlusion or stenosis on postoperative DSA, clip repositioning with repeat angiography was carried out based on the clinical status of the patient and the extent of parent artery stenosis or the size of residual aneurysm.

Statistical Analysis

Statistical analysis was carried out using SPSS v20 (SPSS, Inc, Chicago, Illinois, USA), Microsoft Excel (Microsoft, Redmond, Washington, USA), and OpenEpi online epidemiologic calculators (provided by the U.S. Centers for Disease Control, Atlanta, Georgia, USA). χ^2 and Pearson correlation tests were used to evaluate the association between the variables. The independent t test was used to compare the means. Comparisons were considered significant only if P value was < 0.05. Univariate analysis was used to identify the covariates that might affect the outcome. Binary logistic regression analysis was used to identify the independent predictors of the discordance.

RESULTS

During the study period, 112 patients with 126 intracranial aneurysms underwent surgical clipping; 74.2% of the patients were women. Mean age of the patients was 52 years. Of the 126 aneurysms, 120 were located in the anterior circulation, and 6 were in the posterior circulation. Rupture had occurred in 66% of the aneurysms. Table 1 includes the demographic profile of patients.

In 10 patients (8%), ICG videoangiography resulted in clip repositioning during surgery. Causes of clip repositioning included residual aneurysmal remnant in 7 patients, parent artery compromise in 2 patients, and branch vessel compromise