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Tools and techniques

# Fluorescein-guided resection of brain arteriovenous malformations: A short series

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ABSTRACT

Brain arteriovenous malformations (AVM) are complex and highly challenging lesions, for which intraoperative indocyanin green fluorescence video angiography is widely used. Fluorescein video angiography (FVA) recently appeared as an alternative technique but the feasibility and usefulness of this technique is yet uncertain. This short series reports our preliminary experience of FVA in intracranial AVM surgery. We retrospectively studied the cases of seven patients who had FVA for an AVM surgery. The primary objective of this study was to assess the utility of FVA as judged by the surgeon. Secondary objectives were the evaluation of the tolerance of bolus injection of fluorescein in the context of cranial surgery, the comparison with ICG and the rate of complete removal. For each of the seven patients, FVA was performed after exposure of the AVM and before the resection; it was visualized directly through the eyepieces of the microscope and helped in the identification of arterial feeders and draining veins. In one case, post-resection FVA allowed the visualization of a residual shunt and the resection was completed. In two cases, ICG and FVA brought comparable information. The resection was complete in all cases, confirmed by post-operative imaging. There was no anaphylactic complication. This preliminary work suggests that FVA is a simple and well tolerated technique, comparable to ICG angiography. Prospective and larger studies are needed to confirm the clinical benefit of this tool.



## 1. Introduction

Brain arteriovenous malformations (AVMs) are complex and highly challenging lesions. While several therapeutic strategies may be proposed, surgery remains the most effective technique on haemorrhagic risk when feasible [1]. However, the proximity of eloquent areas and the presence of *en passage* feeders might increase the functional risks of surgical removal. In that context, a fine intra-operative knowledge of AVM anatomy and haemodynamics appears highly relevant.

Indocyanin Green (ICG) fluorescence video angiography was developed as an intraoperative complement to more conventional anatomical imaging modalities. It allows fine visualization of blood flow through the vessels by the injection of a dye, and thus helps in the understanding of the angioarchitecture of the AVM. This technique has proven to be safe and effective, even when compared to intraoperative digital subtraction angiography (DSA) [2,3]. However, the emission of ICG is only visible in the near infra-red, meaning that the environment cannot be correctly seen and white light microscopic images have to be studied apart [4].

The constant development of intraoperative microscopy now makes it possible to use fluorescein to use fluorescein, a very old and well-known fluorophore, as an alternative to ICG. Fluorescein is already widely used for retinal angiography, and shows a fluorescence spectrum within the visible light wavelength. Its possible applications are wide in neurosurgery, including tumoral and vascular pathologies [5–8]. To our knowledge, there are only a few studies assessing the use of sodium fluorescein in vascular neurosurgery, one in aneurysmal surgery and one in the context of AVMs [9,10]. The aim of this work was to evaluate the feasibility and usefulness of sodium fluorescein video angiography for AVM surgery and to report our preliminary experience.

## 2. Materials and methods

We included retrospectively 7 patients who had sodium fluorescein video angiography for an AVM surgery from June 2015 to July 2016 in our institution. The clinical characteristics of the patients and the morphological characteristics of the AVMs are shown in Table 1. All patients had pre-resection fluorescein video

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**Table 1**
Patient population and characteristics. MCA: Middle Cerebral Artery; PCA: Posterior Cerebral Artery; ACA: Anterior Cerebral Artery; SSS: Superior Sagittal Sinus; LS: Lateral Sinus; MCV: Middle Cerebral Vein.

| Patient, age/sex | Diagnostic circumstance | Localization | Arterial feeders | Draining veins | Nidus (mm) | Spetzler grade | Operating time (mn) | Resection | Post operative imaging | Post operative complications |
|---|---|---|---|---|---|---|---|---|---|---|
| 1, 62/M | Rupture | Right parietal | MCA | SSS | 10 | I | 68 | Complete | AngioTDM | None |
| 2, 24/M | Generalized seizure | Right temporal | 2 (MCA, PCA) | SL | 20 | I | 202 | Complete | Arteriography | None |
| 3, 70/M | Rupture | Right parietal | 2 (MCA) | SSS, LS | 15 | II | 130 | Complete | AngioTDM | Complex partial seizure |
| 4, 53/M | Fortuitous | Left frontal | 2 (ACA, MCA) | SSS | 30 | II | 120 | Complete | AngioMR | None |
| 5, 35/M | Generalized seizure | Right parietal | 3 (ACA, MCA, PCA) | SSS | 13 | II | 110 | Complete | Arteriography | None |
| 6, 50/M | Headache | Right parietal | 2 (PCA, MCA) | SSS | 20 | II | 91 | Complete | AngioMR | None |
| 7, 46/M | Partial seizure | Right parietal | 3 (ACA, MCA, PCA) | SSS, LS, torcular, MCV | 30 | III | 100 | Complete | Arteriography | Left proprioceptive deficit |

angiography (FVA), and three patients had complementary post-resection injection. Two patients had concomitant pre-resection ICG video angiography.

FVA was performed after craniotomy, durotomy and exposure of the AVM. We administered a bolus of 2 mg/kg of sodium fluorescein through a peripheral intravenous line. ICG angiographies were performed as reported by other authors [11–13].

We used an OPMI Pentero 900 (Carl Zeiss Meditech, Jenna, Germany), equipped with the Yellow560 fluorescence module (emission 560 nm). The microscope was also equipped with the INFRARED800 module to perform ICG video angiography (emission spectrum of 700–780 nm).

The primary objective of this study was to assess the utility of FVA as judged by the surgeon. Secondary objectives were the evaluation of the tolerance of bolus injection in the context of cranial surgery, the comparison of FVA with ICG and the rate of complete removal.

## 3. Results

Sodium fluorescein video angiography performed before the resection was useful in all cases to understand the haemodynamics of the AVM, through either direct visualization of shunts or differentiation of arterialized veins from arteries. Intravascular fluorescence was observed approximately 20 s after the intravenous bolus, and was directly observed through the eyepieces of the microscope, along with a fine visualization of the structures surrounding the AVM. Secure manipulation of the brain and vessels could be performed during FVA, even if the visualization was slightly darker than in white light microscopy. Post-resection FVA showed a residual shunt in one case, leading to additional removal. However, residual fluorescence from the first injection was diffuse across the surgical field and made interpretation of the images more difficult. For concomitant ICG/FVA cases, the input given by the two techniques was identical. No anaphylactic complication was observed after the administration of sodium fluorescein. Post-operative imaging confirmed complete removal in all cases.

## 4. Illustrative case

We treated a 35-year-old man (Table 1, case 5) who showed a chronic history of uncontrolled generalized nocturnal seizures. He was found to harbour a right parietal cerebral Grade II AVM, with three arterial feeders from the anterior, middle and posterior cerebral arteries. The venous drainage was superficial and unique towards the superior sagittal sinus (Fig. 1). The nidus measured

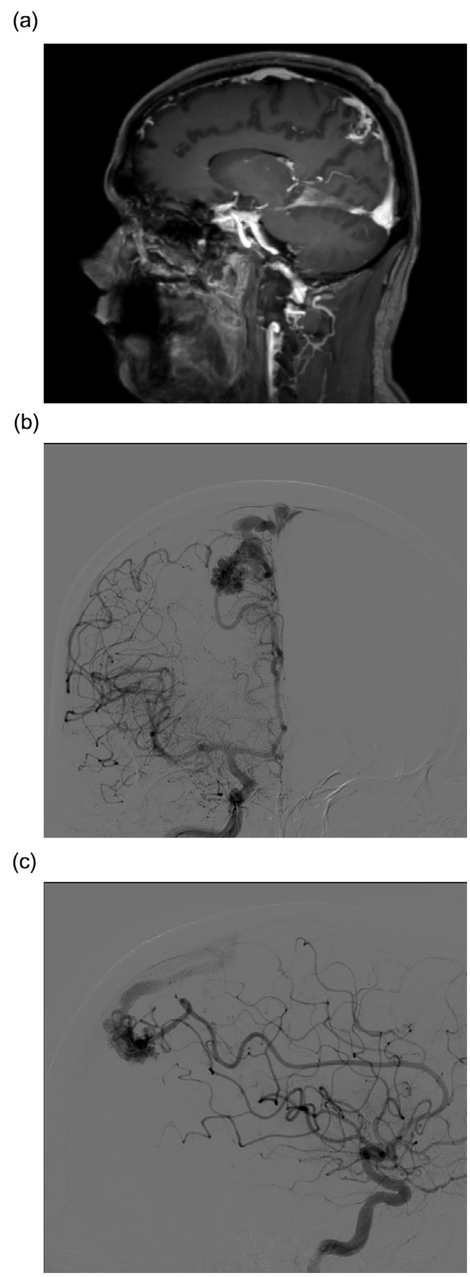


**Fig. 1.** (a) Contrast-enhanced sagittal T1-weighted MRI showing a right parietal nidus (b) and (c) Digital subtraction angiography showing a main afference from the anterior cerebral artery, and a unique venous drainage towards the superior sagittal sinus.

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