Microscope Integrated Indocyanine Green Video-Angiography in Cerebrovascular Surgery

Reza Dashti, Aki Laakso, Mika Niemelä, Matti Porras, and Juha Hernesniemi

Abstract Microscope integrated indocyanine green video-angiography (ICG-VA) is a new technique for intraoperative assessment of blood flow that has been recently applied to the field of Neurosurgery. ICG-VA is known as a simple and practical method of blood flow assessment with acceptable reliability. Real time information obtained under magnification of operating microscope has many potential applications in the microneurosurgical management of vascular lesions. This review is based on institutional experience with use of ICG-VA during surgery of intracranial aneurysms, AVMs and other vascular lesions at the Department of Neurosurgery at Helsinki University Central Hospital.

Keywords Arteriovenous malformations · Indocyanine green · Intracranial aneurysm · Intraoperative angiography · Surgery

Introduction

Intra-operative monitoring of blood flow may play an important role during microneurosurgical management of vascular lesions. Various available methods of intraoperative blood flow measurement can provide real time information and improve the efficacy of treatment. Intraoperative angiography is known as the gold standard and its role during microneurosurgical management of intracranial aneurysms and arteriovenous malformations is well known [1–12]. Microvascular Doppler and ultrasonic perivascular flowmetry are among other methods widely used [13–16]. Indocyanine green video-angiography (ICG-VA) is a safe, and reliable method for assessment of blood flow which is recently introduced to the field of cerebrovascular surgery [17].

This review is based on institutional experience with use of ICG-VA during microneurosurgical management of cerebrovascular lesions. Microscope integrated ICG-VA (Opmi Pentero Carl Zeiss Ltd. Oberkochen, Germany) has been in routine use for the last four years in the Department of Neurosurgery at Helsinki University Central Hospital. During this period ICG-VA was used during microneurosurgical management of more than 1,200 intracranial aneurysms, 120 AVMs and some other vascular lesions.

Indocyanine Green Video-Angiography

The use of indocyanine green video-angiography in cerbrovascular surgery was introduced by Raabe et al. in 2003 [17]. The technique is based on obtaining high-resolution and high-contrast images detected by near infrared (NIR) camera integrated to operating microscope. After intravenous injection of the ICG dye its florescence is induced and detected by the NIR video camera. The result is a real time assessment of cerebral vasculature under magnification of operating microscope. ICG-VA has arterial, capillary and venous phases [17–19]. A dose of 0.2–0.5 mg/kg is recommended for ICG-VA, with a maximum daily dose limit of 5 mg/kg.

ICG-VA is now available and in routine use in many centers. The technique is believed to be a safe, practical and cost-effective method of real time assessment of blood flow. ICG-VA can be used during microneurosurgical management of intracranial aneurysms, AVMs, and other vascular lesions of brain and spinal cord. Similarly, together

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with microvascular Doppler and intraoperative angiography, ICG-VA can be a useful tool during surgery of vascular tumors and skull base lesions with close relation to major arteries. One of the unique advantages of the ICG-VA is its ability to assess the blood flow in perforating arteries [18–21]. The venous phase of the ICG-VA is another important feature which is particularly helpful in preserving the veins during various steps of dissection and/or retraction [17, 18]. This may play the key role during surgical resection of vascular malformations [22].

ICG-VA During Surgery of Intracranial Aneurysms

Microneurosurgical clipping is known as a durable method of treating for intracranial aneurysms (IAs). A perfect clip should occlude the aneurysm completely while the blood flow in the major and perforating branches is preserved. Detection of neck remnant or inadvertent vessel occlusion necessitates re-exploration if not already late. Intraoperative detection of improperly placed clip brings the advantage of immediate replacement to achieve complete occlusion of or to enhance the blood flow in a compromised vessel. Intraoperative angiography is suggested as the gold standard and the most reliable method to control the quality of clipping. However, limited routine availability, relatively high cost and [2, 4–6, 8, 9, 12, 23, 24] a complication rate of up to 3.5% are the major limitations [12, 25, 26]. Microvascular Doppler and ultrasonic perivascular flow probe are other methods of blood flow assessment [13–16]. Patency of perforating arteries, however, cannot be detected by above techniques.

The first application of microscope integrated ICG-VA during aneurysm surgery was described by Raabe et al. [17]. ICG-VA was used during microneurosurgical clipping of 12 intracranial aneurysms and two patients with dural fistulas. They reported postoperative imaging studies to be comparable with ICG-VA findings in all patients (100%). The technique was reported as a simple and safe alternative to other intraoperative methods of blood flow assessment. In their next study Raabe and colleagues [19] compared the findings of ICG-VA with intra- or postoperative DSA during surgical treatment of 114 patients with 124 aneurysms in two neurosurgical centers. Their results revealed 90% correlation between ICG-VA and intraoperative DSA in 60 aneurysms. Intraoperative findings of the technique were reported to be comparable with 90% of postoperative DSA for another 45 aneurysms [19]. de Oliveira and colleagues [20] demonstrated the advantage of ICG-VA in intraoperative assessment of the patency of perforating arteries around the aneurysm.

Recently we published our experience with ICG-VA during microneurosurgical treatment of 239 intracranial aneurysms in 190 patients [18]. Intraoperative ICG-VA assessment of total occlusion of the aneurysms and patency of major or perforating arteries were retrospectively compared with postoperative CTA and/or digital subtraction angiography (DSA). A total of 457 ICG-VA applications were performed (1–5 for each aneurysm). Technical quality of ICG-VA was optimal for 218 aneurysms (91%) (Fig. 1). Deep location, giant size, and arachnoid scarring due to previous operations were responsible for inadequate quality in the rest of them.

In 14 aneurysms (6%), unexpected neck residuals were detected. This rate was significantly higher in deep seated aneurysms (anterior communicating or basilar artery locations). The effect of deep location of the aneurysm in the surgical field was statistically significant. However, this was not the case with the size or ruptured status of the aneurysm. Unexpected occlusion of major branching or perforating

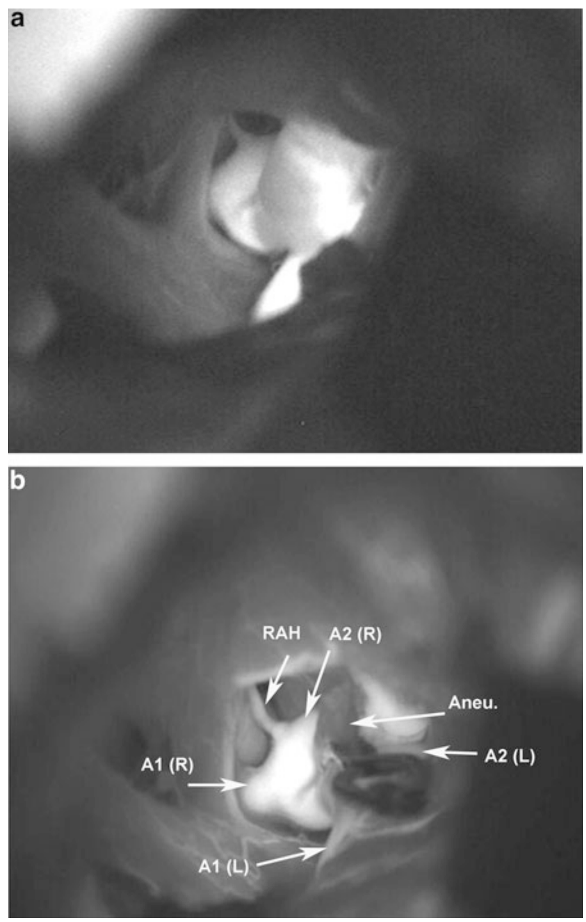

Fig. 1 ICG-VA images of an upward projecting anterior communicating artery aneurysm approached from left side. (**a**) Before clipping, (**b**) After successful clipping. *A1* Proximal segment of anterior cerebral artery; *A2* Post-communicating segment of anterior cerebral artery; *RAH* Recurrent artery of Heubner, *L* Left, *R* Right

arteries was found in 15 aneurysms (6%). Aneurysms located on middle cerebral artery surprisingly constituted the majority of them (n:10 = 67%). Other locations were anterior communicating, internal carotid-posterior communicating, and ICA posterior wall. Location, size and ruptured status of the aneurysm did not significantly affect the rate of unexpected branch occlusions [18]. Usefulness of ICG-VA was concluded in two other recent reports by Ma et al. [27] and Li et al. [28].

ICG-VA has limited ability to visualize the part of the base behind the aneurysm dome in deeply located aneurysms. Presence of blood clots in the field or arachnoid scarring are further restrictions. Based on our experience intraoperative DSA and or microvascular Doppler should be considered for verification of ICG-VA findings for deep sited, giant, thick walled and complex aneurysms.

ICG-VA During Surgery of Brain Arteriovenous Malformations

During microneurosurgical treatment of brain AVMs, intradural strategy includes various steps of intraoperative orientation, localization of the lesion, identification of the arterial feeders, and preservation of the draining veins [29]. In our opinion ICG-VA can serve well during early stages of intraoperative orientation and localization of the vessels. The technique is able to demonstrate the superficial arterial feeders, early draining veins as well as normal ones (Fig. 2). Obtained images can be compared carefully with preoperative angiographic studies. This helps the orientation of surgeon under magnification of operating microscope. However, use of this technique during AVM surgery is limited to that part of lesion which is already exposed and illuminated in the field of microscope. We find ICG-VA very helpful in case of AVMs with cisternal component such as paracallosal or parasylvian ones where the major feeding arteries are in close relation to draining veins as well as the normal vessels. Here the early identification of large arterial feeder(s) and their temporary occlusion can facilitate the later steps of dissection. Comparison of the transit time of the ICG dye between the arterial and venous phases can also give an idea about the state of blood flow in the AVM during surgery. ICG-VA can be repeated safely within the limits of daily dose. We have not encountered any ICG related complications during surgery of AVMs.

Importantly, in AVM surgery, the technique can be only useful in early stages of superficial and sulcal dissection. We do not recommend using ICG-VA in detection of residual AVMs. Intraoperative or postoperative DSA remains the gold standard method in detecting residual AVMs.

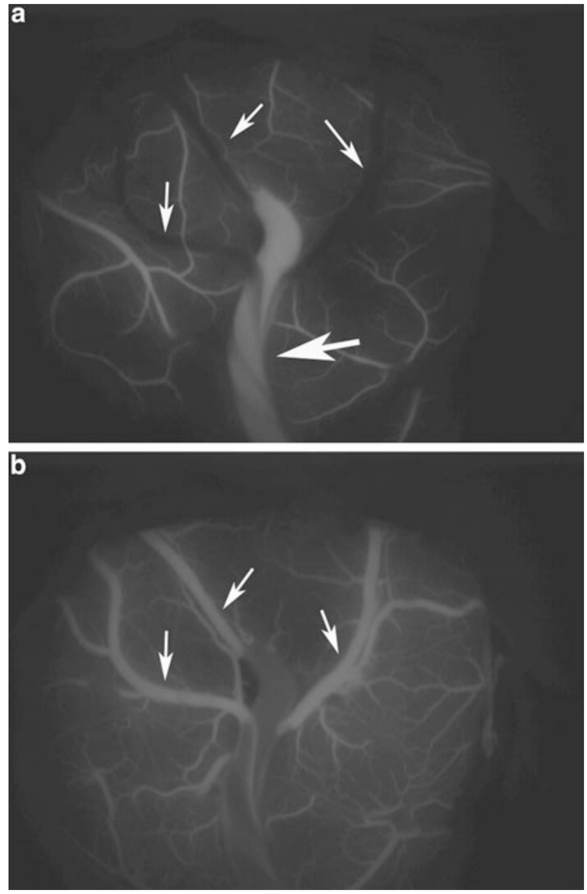

Fig. 2 ICG-VA images of an AVM located at right posterior temporal lobe. At the beginning of intradural part superficial veins are identified. (**a**) Early draining vein (*large arrow*), (**b**) Late filling of cortical veins (*small arrows*)

Recently, Killory et al., reported their experience with the use of ICG-VA during surgical resection of 10 brain AVMs [22]. The technique was found to be useful in early detection of feeding arteries and veins in nine out of ten cases (90%). The authors reported the ICG-VA to be not useful in detecting the nidus residuals or early draining veins.

We use ICG-VA during micro-neurosurgical management of various other vascular lesions and as well vascular tumors. During surgery of spinal AVMs the technique is helpful in identification of arterialized veins and fistula sites. Similar findings are indicated in the reports by Colby et al. [30] and Hettige et al. [31]. The usefulness of ICG-VA in assessment of the patency of EC-IC bypass procedures was studied by Woitzik et al. [32] and Penã-Tapia et al. [33].

In conclusion, ICG-VA can be used as a simple and practical method intraoperative blood flow assessment. A careful interpretation of the real time information obtained by ICG-VA can serve as a useful tool to improve the quality of microneurosurgical management of various cerebrovascular lesions.

Conflict of interest statement We declare that we have no conflict of interest.

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