Intraoperative Imaging for Vascular Lesions

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KEYWORDS

• Neurovascular surgery • Intraoperative imaging • Digital subtraction angiography
• Indocyanine green angiography • Doppler ultrasonography • Laser speckle contrast imaging
• Neuronavigation • Neuroendoscopy

KEY POINTS

- Intraoperative digital subtraction angiography is typically selected to assess for complete resection of arteriovenous malformations and obliteration of dural arteriovenous fistulas.
- Intraoperative indocyanine green dye video angiography frequently provides the greatest benefit in assessing vessel patency after aneurysm clipping, assessing bypass graft patency, and identifying/obliterating dural arteriovenous fistulas.
- The selection of adjunctive imaging modalities is performed on a case-by-case basis because no one modality is superior in every regard.
- New technologies are in development and the neurovascular surgeon needs to stay abreast of these technologies to provide optimal patient care.

INTRODUCTION

Ischemic events during neurovascular surgery are a frequent cause of new postoperative neurologic deficits. Therefore, maintenance of central nervous system tissue perfusion is of utmost importance. Intraoperative imaging techniques can reduce the risk of ischemic events, as well as the need for additional surgery or intervention in the setting of incompletely treated pathology. Several intraoperative imaging modalities exist; however, no one approach is superior in every aspect.[1,2] The careful selection and use of intraoperative imaging techniques is associated with improved outcomes.[2] Therefore, the neurovascular surgeon must be familiar with, and understand the strengths and weaknesses of each of the imaging modalities. Although the operative microscope helps to visually inspect vessels from the outside, vessel patency and residual aneurysm filling cannot be discerned from visual inspection alone. Herein we review several modalities for adjunctive intraoperative imaging in open neurovascular surgery.

DIGITAL SUBTRACTION ANGIOGRAPHY

Intraoperative digital subtraction angiography (DSA) was first introduced in 1974.[3] It was further developed for routine use in the 1990s. DSA has become the gold standard for assessing intracranial vasculature. It allows for the visualization of vessels when there are calcifications, atherosclerotic plaques with thick walls, partially or completely thrombosed aneurysms, or giant aneurysms. Intraoperative DSA has proven useful in the assessment of aneurysm, extracranial–intracranial (EC–IC) and intracranial–intracranial (IC–IC) bypass, arteriovenous malformation (AVM), and dural arteriovenous fistula (DAVF).

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Aneurysm Surgery

The objective in aneurysm clip ligation is to occlude the aneurysm neck while maintaining patency of parent, branching, and perforating vessels. Postoperative DSA has shown approximately a 2% to 8% incidence of residual aneurysm filling, along with a 4% to 12% incidence of occlusion of parent or branching vessel, depending on the difficulty of the aneurysm.[4,5] A residual aneurysm neck, if left untreated, may result in subsequent aneurysm growth and rupture. Thus, this often necessitates an additional surgery or procedure to prevent deleterious consequences. Occlusion of a parent or branching vessel typically results in stroke by the time the postoperative DSA is completed.[6]

Intraoperative DSA first gained popularity for use in correcting imperfectly positioned aneurysm clips with improvement in surgical outcomes.[4] The rate of aneurysm clip readjustment after intraoperative DSA ranges from 8% to 34%.[7] Intraoperative DSA is typically reserved for the treatment of complex aneurysms; however, the preoperative angiogram may not be a good predictor of need for intraoperative DSA.[8] DSA along with 3-dimensional rotational angiography allows for even a small aneurysm neck remnant to be visualized. Intraoperative DSA may also assist in locating the correct vessel for sacrifice when an aneurysm is located on a distal segment of a small-caliber vessel (**Fig. 1**). Intraoperative DSA may demonstrate vasospasm occurring from vessel manipulation, which can be treated immediately.[9] Intraoperative DSA has limitations in aneurysm surgery in that it does not provide information about the integrity of perforating vessels.[2] In addition, even with an experienced team, intraoperative DSA still typically requires a minimum of 20 minutes to perform.[10] Many neurosurgeons use a time limit of 8 to 10 minutes before considering an ischemic event to be irreversible. The delay between clip placement and clip readjustment is often too great to avoid ischemic complications. Batjer and colleagues[11] reported that clip readjustment for occluded vessels after intraoperative DSA was associated with a 33% stroke rate.

Extracranial–Intracranial and Intracranial–Intracranial Bypass

EC–IC and IC–IC bypass have proven useful in treating complex intracranial aneurysms, moyamoya, and atherosclerosis.[12–18] EC–IC bypass is well-suited for augmenting blood flow, whereas IC–IC bypass is often used in the treatment of complex and/or giant aneurysms not amenable to straightforward clipping or endovascular management. In patients suffering hemodynamic insufficiency secondary to internal carotid stenosis or occlusion, or middle cerebral artery stenosis, the goal is to augment cerebral blood flow (CBF) and cerebrovascular reserve capacity to prevent future ischemic events.[17,18] In aneurysm treatment, bypass allows for flow reduction through the diseased segment or trapping of the diseased vessel segment and removing it from the circulation.[12–14] The postoperative bypass patency rate is reported to be between 90% and 96%.[10] Hence, a primary goal in cerebral bypass is to avoid graft occlusion or stenosis at the anastomosis site(s), which can lead to downstream ischemia. Intraoperative and postoperative DSA remains the gold

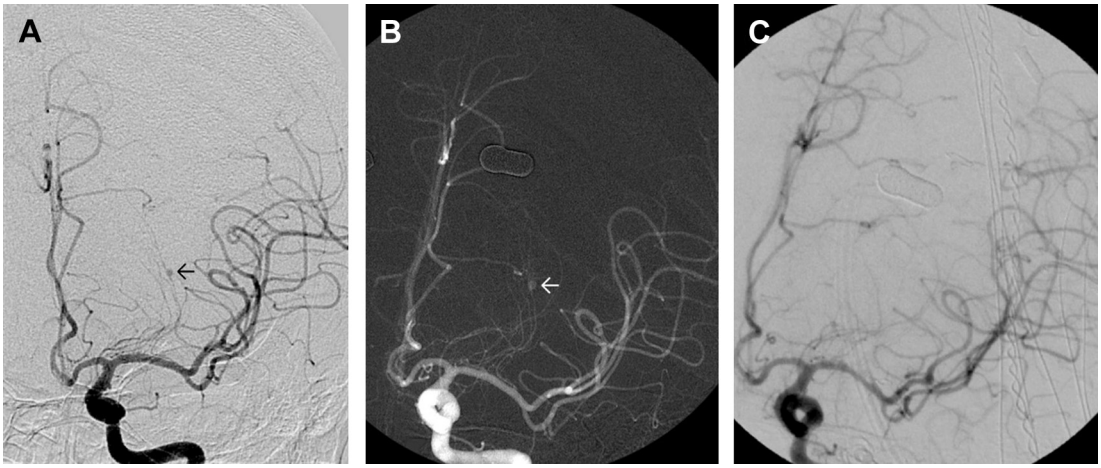

Fig. 1. (*A*) Preoperative digital subtraction angiography (DSA) showing lenticulostriate aneurysm (*black arrow*). (*B*) Intraoperative DSA showing the lenticulostriate aneurysm (*white arrow*). (*C*) Intraoperative DSA after clip ligation of the proximal parent vessel of the lenticulostriate aneurysm.