Intraoperative biplanar rotational angiography during neurovascular surgery

Technical note

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Object. The purpose of this study was to evaluate the authors’ initial experience with the integration of high-resolution rotational and biplanar angiography during neurovascular operative procedures.

Methods. Eight patients with intracerebral arteriovenous malformations (AVMs) and aneurysms underwent surgical treatment of their lesions in a combined endovascular surgical suite. After initial head positioning, preoperative biplane and rotational angiography was performed. Resection of the AVM or clipping of the aneurysm was then performed. Further biplane and rotational 3D angiograms were obtained intraoperatively to confirm satisfactory treatment.

Results. One small residual AVM identified intraoperatively necessitated further resection. One aneurysm was clipped during endovascular inflation of an intracarotid balloon for temporary proximal control. The completeness of treatment was confirmed on intraoperative 3D rotational angiography in all cases, and there were no procedure-related complications.

Conclusions. Intraoperative rotational angiography performed in an integrated biplane angiography/surgery suite is a safe and useful adjunct to surgery and may enable combining endovascular and surgical procedures for the treatment of complex vascular lesions. (DOI: 10.3171/2008.12.JNS081018)

Key Words • intraoperative angiography • rotational angiography • 3D angiography • endovascular surgical suite • aneurysm • arteriovenous malformation

OVER the past few decades, angiography has evolved with the introduction of rotational angiography, 3D morphometry, and 3D rotational angiography.6,7,12,16 Rotational angiography permits assessment and improve identification of anatomical details of neurovascular lesions including aneurysm shape, size, relationship to neighboring vessels, and AVM characteristics along with their 3D angioanatomy.6,7 This novel angiographic procedure has been used in neuroradiology to visualize complex vascular lesions and provide optimal treatment using high-resolution, high-quality imaging. To date, such high-quality imaging has been restricted to angiography suites, whereas conventional intraoperative angiography is most commonly performed using portable fluoroscopic equipment. The latter provides lower resolution, single-plane images.

There are advocates for routine intraoperative angiography performed immediately after treatment with portable equipment, or postoperatively in angiography suites.14,9,14,15 A recent meta-analysis has shown that routine intraoperative angiography remains the most cost-effective way to confirm satisfactory surgical aneurysm clipping.14 However, the conventional equipment has limitations associated with suboptimal image quality, uniplanar image guidance, and lack of 3D acquisition. The integration of high resolution 3D biplane angiography in the setting of an endovascular/surgical suite is a promising step toward improved intraoperative diagnostics and endovascular support during neurovascular surgery.3,11

In the present study we describe our initial experience with intraoperative rotational angiography in aneurysm and AVM surgery done in our combined endovascular/surgical suite. The feasibility of intraoperative rotational angiography in the management of aneurysms and AVMs is evaluated.
Intraoperative rotational angiography

Methods

Because intraoperative 3D rotational angiography has not been performed previously, we applied this technique to cases of progressively increasing complexity to confirm both its feasibility, practicality, and utility.

During 4 consecutive months, 8 patients with intracranial vascular lesions (6 AVMs and 2 large aneurysms) underwent surgical treatment in our combined endovascular/surgical suite. This suite consists of a fully equipped operating theater combined with full biplane and rotational DS equipment (GE Advantx LCN Plus biplanar DSA Unit, GE medical system) a DS angiography control room and a computer room (GE workstation Advantage 4.2, GE medical system), and ample operative space (12 × 10 m), which is required for endovascular and microsurgical procedures (Fig. 1).

The DS angiographic system consists of a standard biplane C-arm unit comprising a floor-mounted frontal plane and a ceiling mounted lateral plane, allowing for both biplanar fluoroscopy with digital acquisition and rotational 3D angiography. The angiography table is equipped with a radiolucent head fixation system. The table is mounted on a pivot, which is capable of laterally rotating the long axis of the table 180° to switch the patients’ orientation from a position that enables angiography (Fig. 2), to a position (usually a 90° turn) that brings the patient into a surgical field (Fig. 3). Seven flat-panel display monitors enable the surgical and endovascular operators to view biplane angiographic images and 3D images. A neuronavigation system (Stealth, Medtronic) and microscope (OPMI Neuro, Zeiss NC4) are also installed.

Endovascular and Surgical Setup

Patients are transferred to the endovascular/surgical suite and general anesthesia is induced. The patient’s head is fixed in the head fixation apparatus and positioned according to the location of the vascular abnormality. The radiolucent frame enables the positioning of the head about 20° above the heart axis. The angiographic catheter is introduced at the beginning of the procedure. Thereafter, diagnostic biplane angiography and rotational 3D angiography are performed with the head fixed in the desired position (Fig. 2) to obtain baseline imaging studies, optimize quality, and ensure that the head position does not preclude complete movement of the 3D rotational gantry around the surgical field. Rotational images are obtained by 200° rotation of the C-arm in 5 seconds. After this, the table is laterally rotated to the surgical area (Fig. 3) and the surgery is performed using routine methods. Whenever an angiogram is required, the bone flap is returned to the head and fixated with a single miniplate, thus decreasing air artifact. The patient is then covered with a sterile plastic covering (Fig. 4) and rotated back to the angiographic position. These maneuvers take ~ 5 minutes. Intraoperative biplane and rotational imaging are then performed (Video 1), providing image quality identical to that of routine diagnostic 3D angiography. The patient is then rotated back to the surgical field.

Video 1. Performance of intraoperative biplane and rotational angiography. Click here to view with Windows Media Player.

In the first 3 cases we performed with this technique, the angiogram was repeated at the end of the procedure to reconfirm satisfactory resection or clipping. However,
due to the high quality of the images obtained intraoperatively, we are reevaluating the need to repeat angiography at the end of the procedure.

Special Considerations in Aneurysm Surgery

Intraoperative angiography may be used to assess the adequacy of aneurysm obliteration but also as an endovascular adjunct for obtaining proximal flow control instead of exposing proximal vessels in the neck or paraclinoid region. After initial surgical exposure of the aneurysm, the patient is rotated to the angiographic position and a balloon catheter is introduced via the femoral route and the tip is positioned in the parent artery, ready to perform the balloon occlusion. The patient is then rotated back to the surgical field and the procedure continued. When proximal vascular control is desired, the patient is rotated back to the angiographic position for balloon inflation under direct fluoroscopy, and then rotated back for continuation of surgery. Anticoagulation therapy with heparin is introduced as a single bolus of 100 IU/kg during balloon occlusion, which lasts a few minutes. Clipping of the aneurysm neck is then performed with the aneurysm softened, and the balloon is then deflated. No further anticoagulation therapy is needed. With the patient back in the angiographic position, biplane and 3D angiography is performed to assess the clipping.

Results

Our technique was applied successfully in all 8 cases, including 6 AVMs and 2 aneurysms. In 1 of the AVM cases consisting of a small residual lesion from a previous surgery, the preoperative angiogram after head positioning showed spontaneous obliteration of the AVM. Further surgical exploration was deemed unnecessary, and the patient was scheduled for follow-up angiography in 6 months.

The other 5 patients with AVMs underwent surgical removal, and in 1 case a small residual lesion was identified during intraoperative angiography, necessitating continuation of the surgery for total resection. There were no new neurological complications after the combined endovascular and surgical treatment in the patients with AVMs.

Both aneurysms included in this series were large and unruptured. Surgical exclusion of the aneurysm was confirmed after intraoperative standard and rotational angiography. In 1 case, a balloon catheter was inflated for 3 minutes in the high cervical internal carotid artery to provide proximal vascular control and aneurysm softening. There were no procedure-related complications. One patient’s preoperative visual deficit improved moderately after decompression of the aneurysm.

Rotational angiography provided excellent image quality in all cases with reliable interpretation allowing a definite diagnosis of the exclusion of AVMs or total obliteration of the 2 aneurysms with patency of parent vessels.

Illustrative Case

This 19-year-old man presented with a right posterior frontal hemorrhage causing moderate left hemiparesis. Cerebral angiography demonstrated a small, diffuse parasagittal precentral gyrus AVM. He subsequently underwent surgery at another institution. A residual AVM was identified postoperatively, and radiosurgery was suggested. Follow-up angiography at 3 years showed no change in the size of the residual AVM, and the patient was transferred to our institution for further treatment. After discussion in our multidisciplinary AVM clinic, resection of the residual lesion was considered the most effective treatment. Figure 5B shows the immediate preoperative angiogram obtained with the patient’s head in the radiolucent head frame. After craniotomy and resection of the AVM, intraoperative rotational angiography was performed and a persistent shunt with a residual microneuridus was revealed (Fig. 5C and D). Further exploration and resection of the suspicious area was performed and the final angiogram confirmed total excision of the AVM (Fig. 5E). Identification of this tiny residual AVM would have been more difficult without high quality intraoperative imaging and 3D reconstruction. The patient’s postoperative course was uneventful without any new neurological deficits.

Discussion

Endovascular interventions have been performed in the operating room with a portable C-arm system, especially in general vascular surgery and abdominal aortic aneurysm repair, and many neurosurgical units still use this technique in routine intracranial vascular surgery. Although the results are acceptable, the imaging quality is insufficient for neurovascular interventions. Furthermore, the limitations of this technique preclude sophisticated imaging techniques such as rotational angiography and 3D acquisition. On the other hand, combined endovascular and microsurgical approaches for intracranial vascular lesions have gained further attention and it has been suggested that evolving endovascular technologies need to be integrated into the microsurgical management of these
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lesions. Conventional therapy with a single modality has been a failure in some complex vascular cases. Lawton et al.\(^\text{10}\) reported on a series of 77 patients who underwent multimodality treatment and concluded that this strategy should be used for complex and complicated vascular cases. Ricci and colleagues\(^\text{13}\) reported on a small series of giant paraclinoid and vertebrobasilar aneurysms treated with the combined endoscopy/microsurgery approach. They concluded that the endovascular procedure allowed for safe and reliable proximal control during microsurgical treatment of the aneurysm. A combined technique of flow alteration has been described by Hoh et al.\(^\text{8}\) for treatment of aneurysms unsuitable for clipping or coil ing. Although these different applications of combined treatments were not performed in the angiographic suite, they emphasize the importance of close collaboration in the management of these formidable lesions.

Neurovascular surgery performed in the endovascular/surgical unit has several advantages.\(^\text{11}\) First, coil embolization and aneurysm clip ligation can be performed in the same setting and under a single session of general anesthe sia. If the coiling attempt is unsuccessful, surgical repair can be performed immediately. Second, postoperative angiography can immediately confirm the position of the clip after aneurysm clipping or exclusion of the AVM. Third, combined surgical exposure can be performed via an endovascular procedure when this approach is considered optimal, or when a transarterial–venous approach proves unsuccessful, such as in dural arteriovenous fistulas with isolated sinus. Fourth, excellent quality images along with rotational angiography and 3D acquisition can be obtained intraoperatively. Finally, superficial landmarks on the surface of the brain or at the resection site can help with the exact localization of a possible residual AVM. Murayama et al.\(^\text{11}\) described their initial experience with an endovascular operating suite and confirmed its effectiveness and practicality in intracranial vascular procedures. However, they did not report the use of intraoperative rotational 3D angiography. In our view, the addition of intraoperative rotational 3D angiography offers the surgeon the same advantages with respect to improved assessment of the angioarchitecture, as those afforded by 3D angiography in the routine diagnostic setting.\(^\text{7}\) Our preliminary experience with this concept and intraoperative rotational angiography has encouraged us to perform more neurovascular procedures in the endovascular/surgical suite.

Current Limitations of the Combined Endovascular and Surgical Suite

Currently, movements of the operating/angiography table are restricted to orthogonal (x, y, and z plane) movements. Most conventional angiography tables do not provide for tilt and yaw the way that conventional surgical tables do. This limits patient selection to those in whom significant adjustments of table position are not required.
This limitation also exists in the endovascular operating suite we used in the present study, and will hopefully be addressed with new table designs in the future.

**Conclusions**

Our initial experience with intraoperative 3D rotational angiography suggests that this technique is safe, efficacious, and practical. We believe that this technique will improve the accuracy and quality of intraoperative imaging, and increase safety and completeness in the management of neurovascular lesions.

**Disclaimer**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Please include this information when citing this paper: published online March 20, 2009; DOI: 10.3171/2008.12.JNS081018. Supplemental online information:


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