Intraoperative angiography in the resection of arteriovenous malformations

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Surgical resection of 13 operatively obscure arteriovenous malformations (AVM’s) was accomplished with the assistance of intraoperative angiography, which was performed stereographically to provide three-dimensional orientation and was repeated until total resection of the AVM was confirmed. All films obtained were subtracted to improve clarity. The method presented here may be useful for the resection of all types of AVM. Only two patients had residual AVM after the initial operation. No complications attributable to angiography were noted.

KEY WORDS • arteriovenous malformation • intraoperative angiography • head holder • cassette holder

The spatial orientation of an arteriovenous malformation (AVM) is often a major problem during surgery because the abnormal vessels are buried within the brain parenchyma and are invisible to the surgeon. The methods attempted to overcome this problem include intraoperative angiography and stereotactic localization of the lesion. Although both of these methods are useful in identifying the precise location of an AVM, sufficient information about the spatial orientation of the lesion is difficult to obtain intraoperatively. In 1978, the Study Group on Microsurgical Treatment of Neurovascular Disease advocated the use of intraoperative angiography, but cautioned that the intensifiers usually available in the operating room were inadequate to produce high-quality images.

This article describes the technique we use for intraoperative angiography, which provides the surgeon with valuable information and can be performed in any operating suite because it requires a minimum of special equipment. Stereographic observation permits the spatial orientation of a lesion, and our method provides nearly the same image quality as conventional angiography. We would like to stress the usefulness of this method for intraoperative orientation and for confirmation of total resection during surgery on AVM’s.

Clinical Material and Methods

Fifteen operations were performed under the guidance of intraoperative cerebral angiography on 13 patients with AVM’s. Angiography was performed using one of two methods, depending on the location of the lesion and the age of the patient.

Patient Population

The clinical features of the 13 patients in this series are summarized in Table 1. There were four males and nine females, ranging in age from 1 to 61 years (mean age 27.9 years). Twelve patients presented with a symptomatic intracerebral hemorrhage, from which eight made a complete neurological recovery prior to surgery. Seizures and headache were prominent in the one patient without hemorrhage (Case 10). The time interval from hemorrhage to surgery ranged from 9 hours to 2 years. One patient with neurological deficits at the time of surgery, whose clinical condition had stabilized, had typical hemiparesis secondary to the mass effect of the hemorrhage (Case 4). One patient with an intracerebellar AVM also had stable cerebellar signs (Case 7). Another patient with an AVM in the cerebellar pontine angle (Case 2) was in a vegetative state at the time of operation.

Angiographic Equipment

The equipment required includes an x-ray system, tubing, a syringe, and contrast medium. In addition, to attach the film cassette to the Sugita head frame, a pair of simple devices are needed for observation of the middle cerebral artery or a single device for films of the posterior circulation or anterior cerebral artery (Fig. 1).
TABLE 1
Clinical summary of 13 patients with completely resected arteriovenous malformation (AVM)*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Location</th>
<th>Preoperative Symptoms</th>
<th>Device Used</th>
<th>Outcome</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1, F</td>
<td>vein of Galen</td>
<td>seizure, vomiting</td>
<td>lateral</td>
<td>no deficit</td>
<td>preop embolization</td>
</tr>
<tr>
<td>2</td>
<td>11, F</td>
<td>lt cerebellar hemisphere</td>
<td>vegetative state</td>
<td>supine</td>
<td>slight psychomotor deficit</td>
<td>IOA failed to reveal lesion at 1st op</td>
</tr>
<tr>
<td>3</td>
<td>12, F</td>
<td>rt occipital</td>
<td>headache, vomiting</td>
<td>supine</td>
<td>no deficit</td>
<td>metal skin clips interfered with visualization of AVM</td>
</tr>
<tr>
<td>4</td>
<td>16, M</td>
<td>lt frontotemporal</td>
<td>hemiparesis, aphasia</td>
<td>lateral</td>
<td>hemiparesis, aphasia</td>
<td>no deterioration after surgery</td>
</tr>
<tr>
<td>5</td>
<td>20, F</td>
<td>lt cerebellar hemisphere</td>
<td>headache, vomiting</td>
<td>supine</td>
<td>no deficit</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>22, F</td>
<td>rt frontal</td>
<td>semicoma</td>
<td>supine</td>
<td>no deficit</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>24, F</td>
<td>intercerebellar</td>
<td>seminoma</td>
<td>supine</td>
<td>minimal cerebellar signs</td>
<td>evacuation of hematoma on admission</td>
</tr>
<tr>
<td>8</td>
<td>33, F</td>
<td>rt temporal</td>
<td>headache, vomiting</td>
<td>lateral</td>
<td>no deficit</td>
<td>multiple associated aneurysms</td>
</tr>
<tr>
<td>9</td>
<td>33, F</td>
<td>rt temporal</td>
<td>headache, hemiparesis</td>
<td>lateral</td>
<td>hemiparesis</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>41, F</td>
<td>lt temporal</td>
<td>seizure</td>
<td>lateral</td>
<td>no deficit</td>
<td>preop embolization</td>
</tr>
<tr>
<td>11</td>
<td>43, M</td>
<td>rt parietal</td>
<td>headache, vomiting</td>
<td>supine</td>
<td>no deficit</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>46, M</td>
<td>lt parietal</td>
<td>speech disorder, disorientation, hemianopsia</td>
<td>supine</td>
<td>hemianopsia</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>61, M</td>
<td>lt temporal</td>
<td>semicoma</td>
<td>lateral</td>
<td>no deficit</td>
<td>ventricular drainage on admission</td>
</tr>
</tbody>
</table>

* Lateral = device for lateral position; supine = device for supine or prone position; IOA = intraoperative angiogram.

**Fig. 1.** Photographs of the device for fixing the film and intraoperative layout of the equipment. The setup is shown with the patient in the lateral position (left) and in the supine or prone position (right).

Surgical Technique

The lateral view is favored for observing anatomical relationships because there is less overlapping of the arteries. Landmarks such as hemostatic or aneurysm clips are placed in the operating field and stereographic angiograms are taken as necessary to reveal the three-dimensional relationship between these landmarks and the AVM.

Internal Carotid Artery AVM's. When intraoperative angiography is indicated for an AVM in the internal carotid artery system, the superficial temporal artery, which has been exposed at the scalp incision, is punctured and a guide wire is introduced (with or without the assistance of an operating microscope). The guide wire is then advanced into the common carotid artery, and a catheter is passed over the guide wire into the artery for a predetermined length. Three angiographic exposures are usually taken initially to decide the best timing in relation to the contrast medium injection. Because of the presence of the catheter within the external carotid artery, the injected contrast medium fills only the internal carotid artery, thus providing better pictures. Before every injection of contrast medium, a plain radiogram is taken for subtraction, and two angiograms are obtained for stereographic observation of the cerebral arteries. The catheter is left in place throughout the operation and is connected to a pressure monitor filled with physiological saline plus 2000 U/liter of heparin to prevent catheter thrombosis (Figs. 2, 3, and 4).

Verteobasilar AVM's or Young AVM Patients. Posterior circulation lesions are visualized using a retro-
Fig. 2. Case 6. A: Preoperative angiogram showing an arteriovenous malformation (AVM) fed from the anterior cerebral artery and having mass effect due to a huge intracerebral hematoma. B–E: Intraoperative angiograms indicating the precise location of the AVM using stereographic observation. The intraoperative angiogram taken at the end of the operation (E) clearly reveals a small residual piece of the AVM (arrow). F: Postoperative angiogram demonstrating complete disappearance of the AVM.

Fig. 3. Artist’s drawings of stereographic angiograms showing the location of the lesion in Case 6 (left) and Case 13 (right).
grade brachial artery approach. This technique is also used in children under 10 years of age. Through a cannula inserted for continuous measurement of blood pressure, a 50-cm guide wire is inserted into the proximal subclavian artery. A catheter is passed along the guide wire and is positioned at a site measured from the point of insertion. The pressure cuff of a sphygmomanometer is then placed in the axilla and inflated to 200 mm Hg. Visualization of the posterior circulation is achieved by injection of 8 to 12 ml of contrast medium. The films are subtracted and examined stereographically. Intraoperative maintenance of the catheter and the method of exposure are the same as used for an internal carotid artery AVM (Fig. 5).

Results

Radiographic Features

In all but one patient (Case 2), the nidus of the AVM was well defined by intraoperative angiography. In Case 2, a patient with an AVM in the left cerebellopontine angle, angiography failed to demonstrate the lesion because the vertebral artery branched directly from the aorta. In another patient, with a right occipital AVM (Case 3), angiography failed to completely visualize the AVM during the initial operation because it was hidden by metal skin clips. At the second operation, performed without the use of metal skin clips, intraoperative angiography clearly revealed the rest of the AVM and it was completely removed. In two patients, the nidus of a small (< 0.5 cm) AVM in the left paraventricular (Case 13) or right occipital region (Case 3, second operation) was well defined by intraoperative angiography. In all cases, a fine network of vessels was revealed with clarity similar to that achieved with conventional angiography. Technical failure or complications such as catheter occlusion or embolism were not noted.

Operative Results

For all patients in whom intraoperative angiography was successful, total removal of the AVM was confirmed intraoperatively. In one patient (Case 2), intraoperative angiography failed to reveal the lesion because of an anomaly of the vertebral artery. At a second
Intraoperative angiography during AVM resection

Fig. 5. Case 5. A: Preoperative angiogram showing an arteriovenous malformation (AVM) in the left cerebellar hemisphere. B: Initial intraoperative angiogram revealing a hemostatic clip as a landmark (arrow) and AVM. C and D: Subsequent angiograms demonstrating a small residual AVM in front of the landmark clip (C, arrow) followed by complete resection (D). E: Postoperative angiogram showing successful resection of the AVM.

operation, angiography via the contralateral brachial artery revealed the lesion and complete removal was achieved. This patient was in a vegetative state at the time of operation but subsequently made an excellent recovery. The patient in whom metal skin clips initially interfered with visualization of the AVM (Case 3) underwent successful complete removal at the second operation with the guidance of intraoperative angiography.

Discussion

The more sophisticated operations being performed as a result of the availability of the surgical microscope have intensified interest in methods for the intraoperative evaluation of ongoing procedures. The vascular anatomy of an AVM is best understood by cerebral angiography, which shows the nidus, arterial feeders, and draining veins. Planning a surgical trajectory to the malformation requires a detailed knowledge of the anatomy of these components, which are spread threedimensionally within the brain parenchyma. However, it is sometimes quite difficult to demonstrate the three-dimensional anatomy of an AVM intraoperatively, and postoperative angiography often reveals a residual lesion in such cases. To avoid such failures, the surgeons tend to remove more brain than is absolutely necessary. Intraoperative angiography with stereographic viewing provides a solution to this problem.

In recent years, several techniques for intraoperative angiography have been proposed, but they are
generally only feasible in specially equipped hospitals. Parkinson, et al., developed a neurosurgical head holder combined with a cassette film changer. Even though it provides excellent angiograms, their method requires specialized complex equipment for fixation of the head and reveals only one direction of projection. Foley, et al., reported on the usefulness of a portable digital subtraction unit, but such a device is prohibitively expensive ($180,000 to $200,000). In contrast, our method requires very simple devices: a pair of film cassette holders for projection at right angles to the floor and/or a single holder for projection parallel to it, both of which cost less than $70. The films obtained are 13 × 18 cm in size and are adequate to observe the operating field. The clarity of the image is nearly equal to that of a conventional angiogram and is far sharper than that obtained by digital subtraction angiography alone. Moreover, this method has the advantage of being performed without the need for repositioning or redraping the patient. The technique described here may be of great value in patients with an AVM, especially if the lesion is deep-seated or consists of loose and fine vessels, both for defining the anatomy of the lesion and for verifying complete removal intraoperatively.

Conclusions

This method of intraoperative angiography for AVM surgery can be performed in any operating suite and provides image quality similar to that of conventional angiography. Resection of an AVM under the guidance of repeated intraoperative angiograms makes complete removal more likely. The digital subtraction technique and stereographic observation are also valuable for this purpose.

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