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Use of Intraoperative Angiography in Neurosurgery

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Neurosurgeons have long recognized that intraoperative angiography could be of significant help to guide surgery for aneurysms, vascular malformations and intracranial anastomoses. In recent years, the advent of portable digital subtraction angiography equipment has allowed neurosurgeons to obtain high quality, rapid sequence cerebral angiograms in the operating room. We have used this equipment to verify clip placement on aneurysms, assess the excision of vascular malformations, and to guide injection of liquid adhesive into arteriovenous malformations in the operating room. The expanded use of stereotaxic surgery for functional and tumor work has also been facilitated in recent years by CT and MR scanning. Stereotaxic neurosurgery can be modified to include angiography so that risk of injury to intracerebral vessels will be lessened. Angiographic landmarks can also be used to define intracerebral structures. In this paper, we will outline the use of intraoperative angiography in open neurosurgical procedures as well as its application to stereotaxic procedures.

Over 20 years ago, Loop and Foltz (1966) reported using portable x-ray equipment and spot films to obtain limited intraoperative cerebral angiography. In the past, intraoperative angiography was performed by the surgeon either by direct puncture of the cervical carotid artery or by retrograde catheterization of the superficial temporal artery or other external carotid artery branches. Portable conventional x-ray units were used and one or two films were obtained using manual film changers. These early systems were hampered by several limitations: (1) portable x-ray equipment gave poor quality images; (2) the lack of a rapid way to change cassettes limited the study to one or two exposures per injection; (3) devices to restrain the patient's head

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were radio-opaque; (4) access to brachiocephalic vessels by femoral cerebral catheterization was limited by radio-opaque operating tables (Bartal, Tirosch, and Weinstein, 1968; Bauer, 1984; Cahan and Rand, 1973; Deruty et al., 1985; Lazar, Watts, Kilgar, and Clark, 1971; Parkinson et al., 1978; Peeters and Walder, 1973; Smith, 1977; Vladhovitch, Frerebeau, and Ouaknine, 1969). In recent years, however, most of these problems have been addressed, and reliable, high quality intraoperative angiography can become a routine part of many cerebro vascular operations.

Intraoperative Portable Digital Subtraction Angiography

In 1986, we reported the adaptation of a portable digital subtraction unit (DXR-10 Angioplus, OEC-Diasonics Inc., Salt Lake City, Utah) to obtain intraoperative angiography (Foley, Cahan, and Hieshima, 1986). The unit can be easily placed into the operating room when desired. The radiographic unit consists of: (1) a portable C-arm fluoroscope with a 0.3 mm focal spot, kV range of 40 to 120, and mA range of 0.5 to 5.0 with 20 mA boost; (2) a dual mode 6 inch and 9 inch image intensifier; (3) a high resolution, low noise television camera; (4) two 15 inch video monitors; (5) an image processing system with real-time (30 frames/second) subtraction capabilities which produces a continuous visualization of contrast moving through cerebral vessels while automatically subtracting the background; (6) image store capacity using a hard disk, video cassette recorder and a video disk recorder which allows frame by frame review over a 20 second injection sequence. The components of the system are all under microprocessor control.

We have used intraoperative angiography on patients undergoing craniotomy for aneurysm or vascular malformation, carotid endarterecomy, open angioplasty of cerebral vessels, and extracranial-intracranial anastomoses. The patient was positioned on a radiolucent operating table when femoral cerebral catheterization was used and the catheter was positioned by the neuroradiologist in the operating room when the angiogram was required. In this way, the time that the catheter was in place could be limited. In other patients, when the vessel was directly exposed at surgery (for example, the carotid artery during endarterectomy), the vessel was punctured and iodinated contrast injected directly. A typical carotid study was done by the manual injection of 4 cc of 30% iothalamate meglumine. In vascular malformations in which local injection of liquid adhesive or local injection barbiturate anesthesia was planned, an angiogram was obtained by direct puncture of the feeding vessel. We have found that medium sized cerebral vessels can be cannulated with a 2F catheter for this purpose. Smaller cerebral vessels (e.g., lenticulostriates) can be punctured with small (28 or 30 gauge) lymphangiogram needles. Intra-arterial injections have been used in all patients. Some illustrative cases are presented below which show the usefulness of this technique.

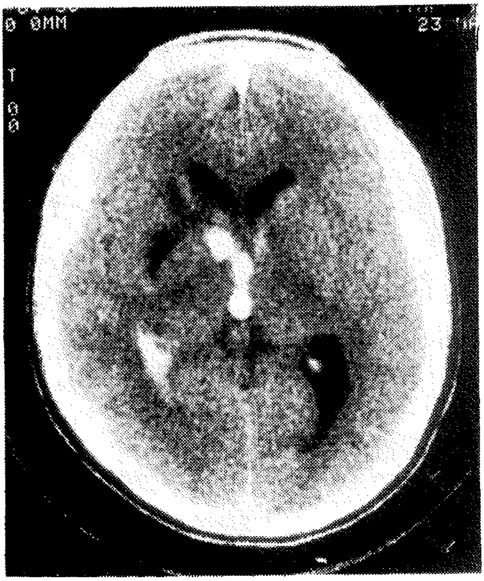

Figure 1A: Unenhanced CT scan showing hemorrhage in Right basal ganglia with blood also in third ventricle and right occipital horn. Evidence of previous hemorrhage (radiolucent area lateral to this hemorrhage) is also seen.

Case 1. This adolescent boy had repeated intracerebral and intraventricular hemorrhages from an arteriovenous malformation (see Figures 1A–1D). Cerebral arteriography showed a nidus supplied by lenticulostriate branches of the middle cerebral artery as well as supply from the posterior cerebral artery. On one of the lenticulostriate feeding vessels, an aneurysm was identified. At surgery, the M-1 segment of the middle cerebral artery was dissected and individual lenticulostriate vessels were cannulated with 28 or 30 gauge lymphangiogram needles and intraoperative angiography was conducted to demonstrate whether or not the vessels supplied the fistula. Liquid adhesive (bucrylate) was used to embolize those branches that fed the nidus and special care was taken to assure that the aneurysm was obliterated. Figure 1C shows an example of an intraoperative injection of a single lenticulostriate vessel. During the surgery, a second lenticulostriate vessel was found to also have an aneurysm which was not appreciated on the pre-operative studies. Intraoperative carotid angiography (Figure 1D) showed substantial decrease in the size of the malformation and obliteration of the aneurysms. Particle beam radiation therapy is planned to treat the remainder of the lesion.

Figure 1B: Magnified right internal carotid arteriogram showing arteriovenous malformation supplied by lenticulostriate vessels. An aneurysm on one of the feeding vessels is present. The location of the aneurysm correlates well with the site of hemorrhage detected on CT scan.

Figure 1C: Intraoperative subselective angiogram. A 30 gauge lymphangiogram needle was used to puncture lenticulostriate vessels. This film shows opacification of one such vessel.

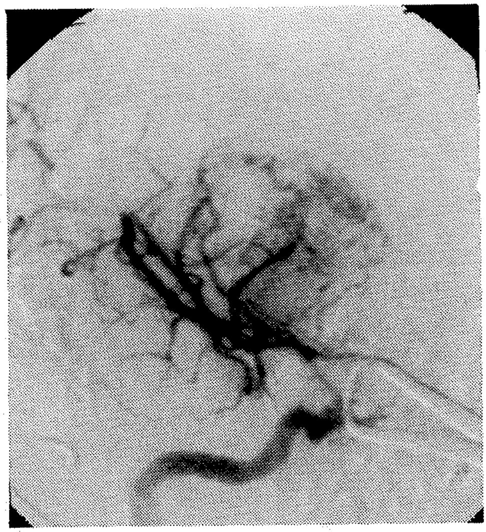

Figure 1D: Intraoperative internal carotid arteriogram showing substantial reduction in the lenticulostriate flow to the malformation and obliteration of the aneurysm following embolization with 2-isobutyl-cyanoacrylate.

Case 2. This middle aged woman had an arteriovenous malformation in the right parietal lobe adjacent to motor cortex supplied by middle cerebral artery branches. There was only a minimal hemiparesis preoperatively (Figure 2A–2D). At surgery, a major feeding vessel was dissected and cannulated with a 2 French catheter. Because the lesion was so close to sensory motor cortex, we wanted to minimize the possibility of worsening the patient's neurologic deficit. Therefore, anesthesia was reversed and the patient awoke during the operation. Through the catheter, brief acting barbiturate was injected to assess the neurologic result (Girvin, Fox, Vinuela, and Drake, 1984). The drug induced no hemiparesis and thus we felt it was safe to embolize the vessel. Anesthesia was resumed. Arteriography of the injected vessel showed that it supplied a great deal of the nidus of the malformation and that no normal cerebral vessels seemed to be supplied. Subsequent embolization with bucrylate obliterated most all of the nidus. Intraoperative carotid arteriography showed some nidus remained; conventional excision of the small remaining nidus led to complete resection of the lesion without neurologic deficit (see Figure 2D).

In most patients, the intraoperative angiogram study added about 1 hour to the operative time. In many patients, the use of the intraoperative study obviated the need for conventional post operative studies. In some patients,

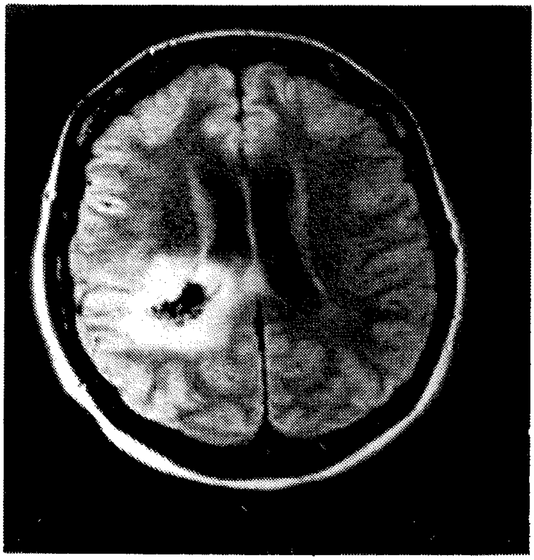

Figure 2A: MR scan showing an arteriovenous malformation with surrounding cerebral edema in right parietal lobe.

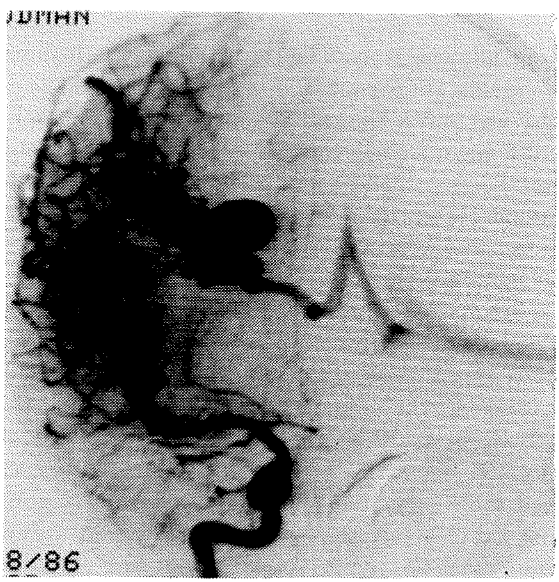

Figure 2B: AP right internal carotid arteriogram showing the vascular malformation preoperatively.

the intraoperative study significantly altered the operation. In one patient, a second nearby aneurysm which had not been anticipated was seen on the angiogram after positioning a clip on an anterior communicating aneurysm.

Role of Angiography in Stereotaxic Surgery

In the past decade, advances in CT and MR scanning have stimulated renewed interest in stereotaxic surgery. Stereotaxic approaches are used in several ways. Functional neurosurgery for epilepsy and movement disorders can be performed using CT and MR guided placement of probes to record brain activity. CT and MR guided biopsies of intracranial mass lesions are now commonplace in most neurosurgical departments. CT and MR stereotaxis has allowed the investigation of interstitial radiation therapy for certain brain tumors. Finally, some innovative surgeons have adapted stereotaxis to robots or lasers to open a new era in which major intracerebral operations can be done with most manipulation of instruments performed by microprocessor (Young, in press).

In all these stereotaxic procedures, the surgery is done through small openings in the skull; one of the major hazards is intracerebral bleeding. Stereotaxic operations are done through 2 mm twist drill openings or 1 to 2 cm burr holes and there is no way for the surgeon to visualize intracerebral veins or arteries which may follow the path of the probe, electrode, biopsy needle or radioactive seed which is being inserted. Practically every major series of stereotaxic centers includes a low but definite incidence of serious intracranial bleeding. For example, in a series of almost 200 patients in whom deep brain electrodes were placed within mesial temporal structures to record partial seizures, there were two fatalities from intracerebral hemorrhage (Cahan et al., 1984).

Methods to incorporate preoperative cerebral angiography with stereotaxic surgery are now being evolved. In the UCI program for implanting depth electrodes to record seizure onset for patients with medically intractable seizures, the following technique is being developed and is based upon a procedure used by Dr. Olivier at the Montreal Neurological Institute. Electrodes are placed bilaterally and symmetrically in a transverse direction through the middle temporal gyrus into the basolateral amygdala, pes hippocampus and parahippocampal gyrus. This route was selected because it involves the shortest distance to these targets, traverses a relatively avascular region, and encompasses the sites of most common microscopic pathology. Previously, coordinates for these targets were selected by using air and positive contrast ventriculography to visualize the temporal horn according to the method of Tailarach (Engel, Crandall, and Rausch, 1983). Using the newer procedure, the patient's head is secured in an MR compatible head holder (Tipal Instruments, Montreal Canada) and coordinates are calculated from the

Figure 2C: Intraoperative injection of a feeding vessel of the malformation prior to bucrylate injection.

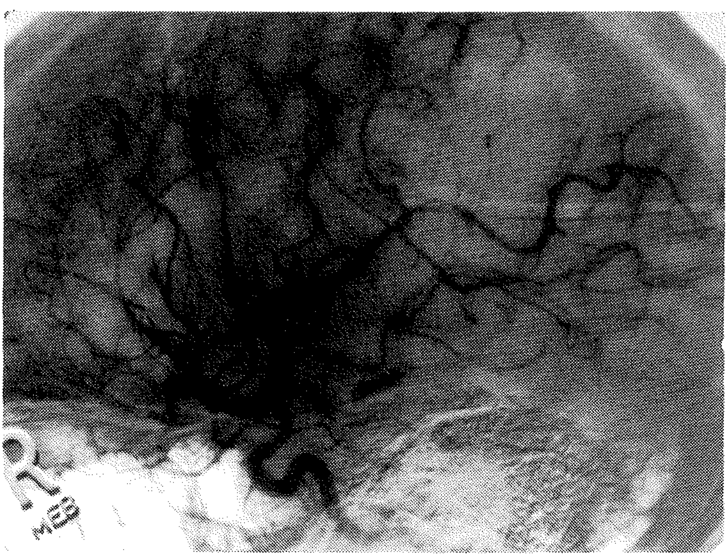

Figure 2D: Postoperative conventional lateral carotid arteriogram showing complete obliteration of the vascular malformation.

MR scan. The patient then undergoes digital subtraction angiography with the stereotaxic head frame still in position. The software of the digital unit is used to superimpose arterial and venous phases of the angiogram, to correct for magnification, and to verify that no intracerebral vessels lie along the proposed trajectory of the electrode. In this way, we hope to minimize the risk of intracerebral bleeding from electrode placement.

Conclusions

Advances in neurosurgery over the past decades have largely been one of advances in technology. Neurodiagnostic advances in angiography, CT, MR and ultrasound have clearly lessened the cost and dangers of evaluating neurosurgical patients. Improved instrumentation is easing some of the technical complexity of surgery. The advent of portable high quality angiograms to the neurosurgeon will undoubtedly become a routine part of the neurovascular surgeon's armementarium in the decade to come.

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