One-stage excision of high-flow arteriovenous malformations

JOËL BONNAL, M.D., JACQUES-DANIEL BORN, M.D., AND POL HANS, M.D.

Departments of Neurosurgery and Anesthesiology, University of Liège, Liège, Belgium

The authors describe two cases of high-flow arteriovenous malformations which illustrate a new technique to reduce the risk of brain swelling and diffuse hemorrhage during or after operation. This technique, used in the latter of the two cases, includes occlusion of the shunt, followed by the progressive tightening of a Selverstone clamp placed on the cervical internal carotid artery, lowering of the systemic arterial pressure, and the use of barbiturate anesthesia. Clamping and anesthesia are maintained for a 24-hour period after surgery.

KEY WORDS arteriovenous malformation arteriovenous fistula perfusion pressure barbiturate anesthesia

On the basis of the normal perfusion pressure breakthrough theory, Spetzler, et al., Mullan, et al., and Nornes and Grip have suggested the gradual reestablishment of the cerebral perfusion pressure (CPP) after occlusion of high-flow arteriovenous malformations (AVM's). This progressive restoration of CPP has been managed in two ways: either by staged ligation of the large vessels feeding the AVM or by repeated embolization. Several authors have reported the failure of these methods, since they do not prevent and may even induce serious hemorrhages. For this reason, Deruty, et al., and Debrun, et al., suggested isobutyl 2-cyanoacrylate embolization under direct visual control, although it is difficult to determine the exact amount of adhesive to inject.

In accordance with the report of Mullan, et al., in 1979, we have used a new method to gradually restore CPP in cases of high-flow AVM's. Our experiences with an early case (Case 1), not treated by this method, and a later case (Case 2), in which the technique was used, are described below.

Case Reports

Case 1

This 12-year-old boy developed a classical intracranial hypertension syndrome in 1973. Examination disclosed nystagmus and a cardiac and carotid systolic murmur. The electroencephalogram (EEG) showed slow waves on the right side. Isotope brain scanning revealed left frontal hyperactivity. Bilateral carotid angiography on February 22, 1973, demonstrated stenosis of the left cervical internal carotid artery and the presence of a left frontal AVM fed by enlarged middle and anterior cerebral arteries (Fig. 1 left). The left anterior cerebral artery originated from the right carotid artery. There was early venous drainage into the superior sagittal sinus, and normal cerebral circulation was hardly visible.

On March 8, 1973, excision of the AVM was carried out with no difficulty. Upon recovery from anesthesia, the child was quiet. However, shortly afterward he became agitated, then aphasic, and by 20 hours postoperatively he had developed a right hemiplegia. The possibility of a postoperative hematoma led to a second surgical intervention, during which no hematoma was found, but brain swelling together with small hemorrhages were detected. The brain herniated through the craniotomy site, and it was necessary to carry out a wide frontal lobectomy. A few days later, the child recovered from his right hemiplegia and aphasia. Ten years after the operation, he is suffering from grand mal seizures and behavioral problems.

Angiographic control studies were performed in April, 1973, and again in March, 1976. These revealed persistence of the enlarged middle and anterior cerebral arteries that had fed the AVM and also showed abrupt narrowing of these vessels (Fig. 1 center and right).

Case 2

This 9-year-old boy had suffered since birth from adersive seizures and jerking movements of the left hand. He had moderate difficulties with his schoolwork.
Perfusion pressure in one-stage removal of AVM's

**FIG. 1.** Case 1. Left carotid angiograms, lateral views.  *Left:* Preoperative view showing frontal branches of the middle cerebral artery (MCA) feeding a prefrontal arteriovenous malformation. The superior sagittal and transverse sinuses are already seen in the arterial phase.  *Center:* Six weeks postoperatively, the frontal branches of the MCA and part of the anterior cerebral artery remain large.  *Right:* Angiogram 3 years later showing little change. Note the discrepancy between the lumen diameter of the enlarged MCA and anterior cerebral artery compared to the distal MCA and pericallosal artery.

**FIG. 2.** Case 2. Right carotid angiograms, lateral views.  *Left:* Preoperative angiogram showing a wide and twisting middle cerebral artery feeding a huge varix, which is drained by an enlarged Sylvian vein. The cerebrovascular circulation is poor.  *Center:* Postoperative angiogram after release of the Selverstone clamp.  *Right:* Brain circulation is improved postoperatively.

**Examination.** Neurological examination revealed a mild pyramidal and parietal deficit and some choreoathetosis-like movements of the left hand. The EEG showed left hemispheric theta waves. A computerized tomography scan showed a hyperdense lesion in the right rolandic area, which enhanced after contrast injection. Right carotid angiography revealed an arteriovenous fistula fed by an enlarged middle cerebral artery and draining into a correspondingly large Sylvian vein (Fig. 2 left). Cerebrovascular circulation was barely visible.

**Operation.** On February 4, 1981, a left frontal ventriculostomy was performed for intracranial pressure (ICP) monitoring, and a Selverstone clamp was placed on the right internal carotid artery in the neck. After craniotomy and clipping of the feeding artery, dramatic brain swelling occurred with hyperpulsation of the middle cerebral artery and the surrounding brain, despite carefully controlled systemic arterial hypotension (mean arterial pressure 60 torr). The Selverstone clamp was tightened until the hyperpulsion ceased and the brain was normally soft. To attain this, it was necessary to turn the clamp screw five times (the clamp is completely closed after seven turns). When the clamp was loosened, brain hyperpulsation recurred in spite of a mean arterial pressure of 60 torr. Therefore, we decided to maintain the clamp screwed down five turns. The draining vein was then ligated and the malformation removed. Hemostasis was carefully checked and, as a precaution, was verified after slight loosening of the Selverstone clamp for a short time.

**Postoperative Course.** The follow-up course was uneventful. Postoperatively, the patient was maintained on thiopental anesthesia for the first 24 hours, during which time he remained in a normal awake state with normal blood pressure and oxygen saturation. The patient was discharged in good condition on the 10th postoperative day.
which time his ICP remained normal. After 36 hours, the Selverstone clamp was opened slightly. After 48 hours, the boy was awakened and the clamp was unscrewed a little more. On the 14th postoperative day, right common carotid angiography demonstrated patency of the internal carotid artery in the neck and improved cerebral vascularization compared with the preoperative angiograms (Fig. 2 center and right). The clamp was then removed. The patient was discharged on the 21st postoperative day with the same mild pyramidal deficit as preoperatively. However, 3 years later he is making major intellectual progress and is growing well.

Discussion

In order to use an appropriate strategy in the treatment of high-flow AVM’s, the risk of normal perfusion pressure breakthrough must be anticipated before surgery. We expected this problem in our Case 2, whereas Case 1 is a typical example of failure to anticipate this danger. In our opinion, the proper treatment of these lesions depends upon the clinical data, EEG studies, and, most importantly, angiographic findings.

On clinical grounds, the risk of normal perfusion pressure breakthrough is increased if the patient exhibits a progressive neurological deficit or an intracranial hypertension syndrome not related to prior bleeding. Diffuse EEG slowing could also be a valuable predictive sign. In two patients with large unruptured AVM’s, we have previously observed generalized slow waves which were attributed to diffuse brain hypoxia. The angiographic warning signs of the syndrome include the presence of a high-flow arteriovenous shunt with large and tortuous feeding arteries, near absence of normal cerebral circulation, and early drainage via enlarged veins. Recently, Pertuiset, et al., described hemodynamic factors that can assist in the prediction of the consequences of shunt closure.

There are three major complications that can occur during or after a one-stage removal of high-flow AVM’s. Two of these — acute intracraniy hematoma and adjacent brain-tissue ischemia — are well known. A good surgical technique tends to eliminate the possibility of these problems. However, this is not true for the third complication; that is, brain swelling with massive multifocal bleeding. Spetzler, et al., explained this dramatic complication occurring after removal of an AVM as being the result of the sudden diversion of blood into the abnormally dilated and non-autoregulating small vessels of the adjacent, chronically ischemic brain. In agreement with their interpretation, Mullan, et al., and we have noted the occurrence of intensified cerebral pulsations just after occlusion of the feeding arteries of the AVM and before the appearance of brain swelling.

To prevent brain swelling and massive multifocal bleeding, we prefer graded, reversible, controlled narrowing of the internal carotid artery, such as we obtained using the Selverstone clamp, rather than lowering of the systemic arterial pressure, because such a preventive procedure must last for several days and then be gradually tapered off. The tightening of the clamp is considered to be sufficient when brain pulsatility decreases and the brain appears normal. In cases of high-flow AVM’s, Pertuiset, et al., have advised a 50% reduction of the lumen of the common carotid artery for 5 days.

As has been suggested by Day, et al., we combined our operative method with prolonged barbiturate anesthesia. Among other advantages, this latter measure assures complete immobility of the patient and prevents increases of arterial pressure and the potential for postoperative bleeding. Also, during the postoperative period, we think that it is wise to continuously monitor the systemic arterial pressure and ICP.

We have not yet had the opportunity to try our method in other patients. The use of this procedure is evidently limited to AVM’s that are principally fed by the middle cerebral artery. More experience is needed before definite conclusions can be drawn.

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Address reprint requests to: Joël Bonnal, M.D., Clinique Neurochirurgicale, Hôpital de Bavière, 66, Boulevard de la Constitution, B4020 Liège, Belgium.