Endovascular Therapy of Cerebral Arteriovenous Malformations and Aneurysms with a Proposed Scale for Neurological Outcome

Allan J. Fox

Endovascular therapy has become established as a useful approach to the management of cerebrovascular abnormalities. Much of the basis for this approach has been the development by Luessenhop and Rosa\textsuperscript{1} of flow-directed particulate embolization, by Serbinenko\textsuperscript{2} of detachable balloons, and by Kerber et al.\textsuperscript{3} of leak balloon navigation. The field has been further widened by the development of new microcatheter systems, real-time digital subtraction fluoroscopy, and new embolic materials. A number of centers around the world, including our own at University Hospital in London, Canada, have gained experience in the embolization of various lesions, especially brain arteriovenous malformations (AVMs) and aneurysms.

Cerebral AVMs

The original experience with embolizing brain AVMs was with particles. Our own series from 1976 to 1978 included 15 patients: six embolized with flow-directed plastic spheres via the femoral approach, and nine embolized with a mixture of Pantopaque and Gelfoam via direct operative catheterization of feeders. Follow-up angiography in patients in whom the AVM was not surgically resected invariably showed nidus refilling due to enlarged artery-to-artery collateral networks, recanalization of the Gelfoam mixture, or both. The goal of embolization was subsequently changed to attempt nidus obliteration, and liquid adhesive was used in most instances.

From 1978 to 1986 we treated a series of 115 patients with brain AVMs in various locations and of various sizes using acrylic tissue adhesives.\textsuperscript{4–6} Important basic experiences in the field were gained during this time,\textsuperscript{7–9} and an evolution in approach occurred. There was 4.3% mortality and a moderate or severe long-term morbidity of 9.4% after embolization in this series. The AVM was completely obliterated by embolization alone in 5.2% of these cases. The AVM was completely resected after embolization in 30% of cases.\textsuperscript{10}

Embolization of brain AVMs has been further stimulated by the develop-
ment of directable microcatheters and materials such as tissue adhesives and mixtures of particles and thrombotic materials. Our series from 1986 to mid-1990 included 43 patients. The results of this series indicate a 4.6% rate of serious complication due to the embolization. The series consisted of large, mostly complex AVMs that were difficult to remove surgically, although 70% were completely resected following the embolization. Mortality due to surgery was 4.6%, and 7.0% had serious neurological sequelae following the surgery. A positive Amytal test or a transient deficit produced by embolization influenced the decision to resect in 9.3% of cases.

Although our own practice has concentrated on embolization to enable surgery for difficult AVMs, other teams are embolizing a growing number of lesions before focused radiosurgery, and some centers have utilized embolization as the sole treatment, with a success rate as high as 18% complete obliteration.

To date, the following conclusions can be offered on the use of embolization for brain AVMs.

1. Small, one- or two-feeder AVMs can be completely obliterated by embolization alone using liquid adhesives.
2. Blockage of feeders alone, whether by particulate emboli or liquid adhesives, does not obliterate the AVM nidus and stimulates growth of artery-to-artery collateral feeders.
3. Embolization before surgery enables resection of large, complex brain AVMs by reducing operating time and bleeding. It can also block difficult-to-access feeders.
4. Incomplete AVM obliteration or removal has not been shown to be of benefit for the treatment of brain AVMs over the long term.

**Intracranial Aneurysms**

In many centers detachable balloon technology and therapy with preservation of the parent artery quickly became the primary treatment of choice for intracranial and neck fistulas. However, the detachable balloon treatment of brain aneurysms has not gained the same widespread acceptance.

Our own series using detachable balloons to treat patients with cerebral aneurysms has been restricted to aneurysms that were not easily clipped, most being giant aneurysms. Initially, during the late 1970s, we treated seven cases of carotid aneurysm with an intraaneurysmal balloon and preservation of the artery. It resulted in recurrence of the aneurysm and some disconcerting neurological complications. We therefore abandoned this approach and for many years used detachable balloons only for proximal parent artery occlusion. Our protocol, which includes a test occlusion in the awake patient protected by systemic heparinization, has been performed on 95 patients. In these cases after permanent occlusion of the parent artery 1% had