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Control and Placement of Intracranial Microcatheters

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Balloon-tipped microcatheters allow flow-guided entry into small vessels and permit selective angiography, selective drug infusion, temporary or permanent vessel occlusion, and controlled deposition of tissue adhesives. However, active directive techniques are not usually successful with balloon microcatheters, and more passive flow-directed maneuvering must be learned. Three conditions may be encountered. In the first, the vessel to be entered is large and exits at a small angle from the parent vessel. Flow and momentum carry the microcatheter toward the goal. In the second, the abnormal vessel exists at a large angle but is larger than the continuing vessel. Inflating the balloon until it is larger than the continuing vessel will cause the flow to carry it around even sharp bends. In the third, the abnormal vessel is small and also exits at a large angle. Two balloons must then be used. The first occludes the larger mainline continuing vessel, while a second is injected; flow then carries the second around the bend.

Microcatheters, with or without balloon tips, are accepted tools for occlusion of blood supply to vascular tumors and arteriovenous malformations [1–5]. They can be flow guided into place, occlude a vessel completely as a provocative ischemic test, then deliver some polymer for permanent occlusion; or the balloon may be detached and left in place. Because placing these devices in the desired location is not always easy, we wish to share the guidance techniques we have developed over the past 5 years using two of these devices [2, 4, 6].

Materials and Methods

We have placed 103 flow-guided microcatheters in the central nervous system of 29 patients to treat arteriovenous malformations and arteriovenous fistulas. We have also directed microcatheters into the visceral and carotid arteries of dogs during controlled experimental conditions. Our microcatheter system consists of a 5.8 French polyethylene thin-wall outer coaxial catheter, and a 1 mm balloon-tipped silicone microcatheter (Cook Inc., Bloomington, Ind.).

Entry into the vascular system is either via a common femoral, axillary, or, less preferred, direct carotid artery puncture. A 6 French Cordis sheath (Cordis Corp., Miami, Flo.) is placed percutaneously first to allow atraumatic insertion of the untapered 5.8 French polyethylene catheter; the sheath also permits rapid withdrawal of the polyethylene catheter after deposition of polymer without loss of the arterial entry site.

With fluoroscopic control, the tip of the 5.8 French polyethylene catheter is placed as close to the abnormality as possible. Some 2–4 cm of flexible guide wire leads the catheter, protecting the intima from the untapered tip. After double flushing with heparinized saline, final catheter placement is verified by localized injections of contrast agent.

Simple catheter curves are preferred since they lend themselves more readily to subsequent manipulation within the carotid artery. If simple curve entry into a carotid artery is prevented by an arteriosclerotic tortuosity, a compound curve catheter is placed into the carotid artery, then exchanged for a simple curve catheter over a 230 cm guide wire.

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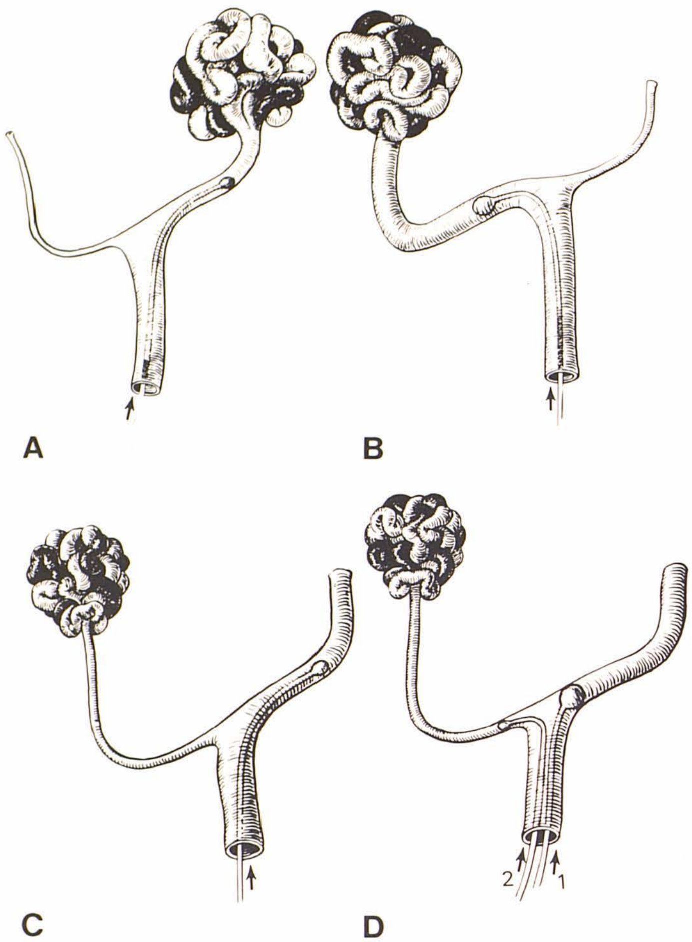

Fig. 1.—**A**, Large abnormal vessel feeding arteriovenous malformation originates from parent artery at small angle. Both high blood flow and catheter inertia make catheter follow straighter line. **B**, Feeding artery originates at large angle from parent vessel. With balloon inflation, it is larger than arteries feeding normal tissue. Flow carries it around sharp angle. **C** and **D**, Abnormality's feeder is small and exists at large angle from parent vessel. **C**, Balloon microcatheter enters larger and less angled artery preferentially. **D**, As second microcatheter is readied, first is brought back to origin of normal artery and inflated. Immediately, second microcatheter is injected. Since all flow is now into abnormality's feeder, catheter passes around bend.

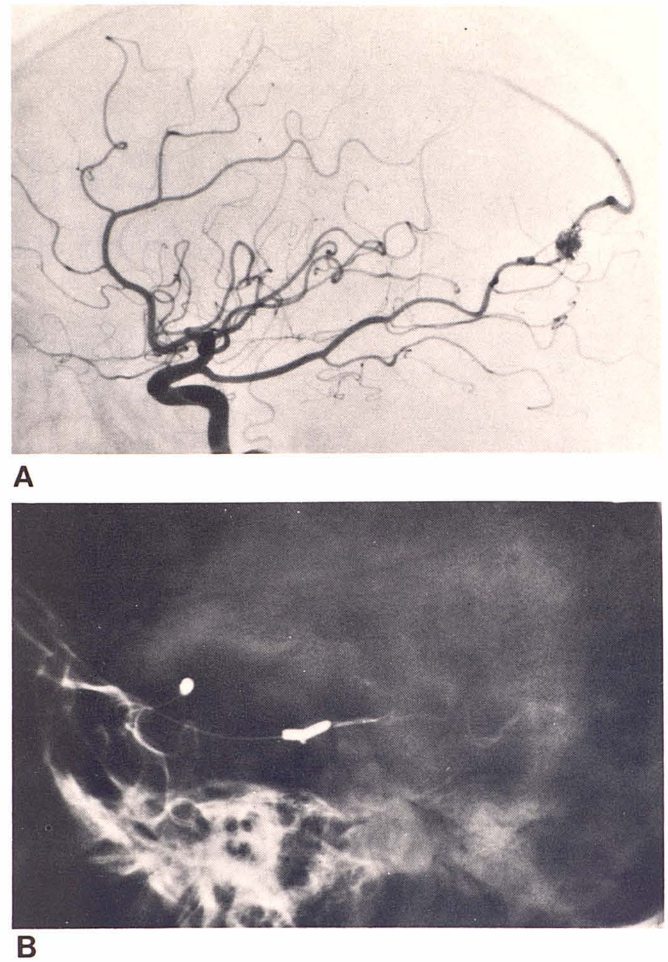

Fig. 2.—**A**, Patient has arteriovenous malformation fed by parieto-occipital branch of small posterior cerebral artery. This exits from internal carotid artery at about 90° angle. **B**, First microcatheter passed, as expected, into distal internal carotid artery, was inflated, and completely blocked artery. Then second catheter was injected and passed into posterior cerebral artery.

The balloon-tipped silicone microcatheter, packaged in its coil delivery system, is tested, filled with heparinized saline, and attached to the polyethylene catheter. The silicone microcatheter is simply injected from the delivery system through and into the outer polyethylene coaxial catheter using heparinized saline as a propellant [6]. When its forward progress is stopped by a vessel of smaller diameter than that of the balloon, the polyethylene catheter is withdrawn about 10 cm, then an additional 10 cm of the silicone catheter is advanced. The latter is removed from the delivery system, and affixed to the polyethylene catheter by passing it through a side-arm adapter (Cook Inc., Bloomington, Ind.) which permits the infusion of heparinized saline around the microcatheter. The catheter is moved by alternatively pushing and pulling the larger polyethylene catheter at the groin (or other entry site) while varying the degree of balloon inflation.

Results

Typically, one of three conditions may be encountered.

1. *Vascular supply to the malformation arises as a mainline continuation of the parent vessel (fig. 1A).* Tortuosity of the feeder's origin is usually slight and the angle of origin from the parent vessel is relatively small. The balloon-tipped silicone microcatheter generally passes directly into the region of the malformation, because even without balloon inflation the high blood flow and straighter course control it. Fortunately, this is the most common situation.

2. *The origin of the feeding vessel forms a narrow angle but its lumen is larger than the normal continuing vessel (fig. 1B).* The vessel feeding the abnormality exits from the parent artery at more than 60°. In these cases, the balloon is inflated until it is larger than the normal continuing vessel. It cannot enter the smaller artery; blood flow carries it around the acute bend into the desired vessel.

3. *The feeding vessel forms a narrow angle with a parent vessel and its lumen is equal to or smaller than the continuation of the parent vessel.* In these cases the catheter tends to bypass the origin of the desired vessel; inflation of the balloon provides no help. Thus, use of two microcatheters is necessary. The first is allowed to enter the undesired artery (fig. 1C). Then a second catheter, placed through another puncture site, is readied. The lumen of the undesired artery is momentarily occluded by the first balloon

while the second catheter is injected (fig. 1D). Blood flow carries the second catheter past the obstructed artery, even around sharp angles and bends.

Figure 2A demonstrates such a problem. A small posterior cerebral artery supplies an occipital lobe arteriovenous malformation. The posterior cerebral artery originates from the internal carotid artery at a 90° angle. To enter the posterior cerebral artery, the first balloon was placed just beyond its origin, then inflated, completely occluding the internal carotid artery. Immediately, a second balloon-tipped catheter was injected via second puncture site. Final placement of the second catheter is seen in the posterior cerebral artery in figure 2B. This double-balloon technique has also been used to cross the anterior communicating artery to treat a left hemispheric malformation via the right carotid artery, and to enter a low flow internal carotid artery to cavernous sinus fistula.

Discussion

The placement and control of microcatheters into terminal branches of the brain's vascular tree is difficult. The vessels feeding arteriovenous malformations and vascular tumors frequently become tortuous, and are often far removed from the puncture site. Active direction of a catheter tip by placing curves in it, by rotation, and by causing it to follow guide wires—techniques used with standard catheters—are usually not effective when dealing with microcatheters. To overcome these problems, we have developed more passive maneuvers which depend on blood flow and modification of balloon size.

Variations in the final placement technique are governed by the morphology of the vessels feeding the malformation to be treated. When the main supply to the malformation arises as a direct continuation of the parent vessel (type 1), little or no manipulation of the microcatheter is necessary to gain access into the feeding pedicle. This pattern is most commonly encountered. Subsequent manipulation of the microcatheter is performed to obtain a more distal location in the same vessel and to confirm the absence of slack loops in the catheter before deposition of polymer.

Occasionally the feeding pedicle arises at an angle that requires a sharp bend of the microcatheter to achieve vessel entry (types 2 and 3). Momentum frequently carries the microcatheter into the more direct continuation of the parent vessel. Usually the lumen of the vascular supply to the malformation is larger than the normal branch (type 2), and minimal manipulation allows entry into the feeding artery. Only rarely have we encountered the more technically difficult type 3 morphology. Then it was necessary to maneuver two microcatheters in the vascular tree simultaneously. The safety of this latter technique depends on the presence of a well trained team, proficient in using whichever system is used. Fortunately, this proficiency may be developed in the laboratory or on models.

Generally, we do not place polyethylene catheters above C2 in the carotid or above C4 in the vertebral arteries. In the past, serious arterial spasm has resulted from repeated mechanical stimulation of the distal internal carotid intima. Our patients are not systemically heparinized, but the space between the catheters is perfused with heparinized saline (1.5 ml of heparin 1:1000/500 ml saline) at a rate of 30–60 drops/min.

These maneuvering techniques are not perfect as shown by our results. Of more than 100 catheter explorations, in only 33% were we satisfied enough to deposit adhesive. Still, the techniques are of value and have allowed a surprising degree of exploration of the intracranial vessels.

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