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Preembolization Superselective Angiography: Role in the Treatment of Brain Arteriovenous Malformations with Isobutyl-2 Cyanoacrylate

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Transfemoral and intraoperative embolization of arteriovenous malformations (AVMs) of the brain with isobutyl-2 cyanoacrylate may achieve complete and permanent occlusion of the AVMs. The preembolization superselective angiogram is an important source of information to decrease potential technical or clinical complications while seeking that goal. The information obtained from the angiogram of each individual feeder may be classified as anatomical, dynamic, and functional. This angiogram is performed either through a calibrated-leak balloon glued to a Silastic tubing, which is capable of negotiating cortical arterial curves, or through a short catheter directly placed into a feeder at surgery. In 64 patients, 175 preembolization superselective angiograms were obtained. Of those, 105 were obtained using the transfemoral technique, and 70 were obtained by direct catheterization after a craniotomy. Complications occurred in eight patients with only one permanent injury. Transient neurologic deficit occurred in five patients. One patient developed a permanent left monoplegia and one patient a subarachnoid hemorrhage without permanent neurologic deficit. In one patient, a delayed intracerebral hemorrhage produced a right hemiplegia and aphasia. The patient fully recovered in 6 months.

Isobutyl-2 cyanoacrylate (IBCA) is a fast polymerizing liquid agent that rapidly solidifies in contact with an ionic fluid. This property makes it suitable to reach and harden in the core of a brain arteriovenous malformation (AVM) if it is delivered close enough to it [1]. This procedure requires a controlled injection of IBCA in each arterial feeder supplying an AVM.

The intracranial superselective catheterization of brain arteries was made possible by the introduction of transvascular navigation techniques with balloons developed by Serbinenko [2], Kerber [3], Pevsner [4], and Debrun et al. [5]. They described different delivery systems and balloon catheters capable of negotiating the acute curves of the cerebral cortical arteries.

This report stresses the importance of obtaining a preembolization superselective angiogram of each individual AVM feeder before delivering the IBCA. Internal carotid and/or vertebral angiography (selective angiography) gives an overall idea of the size and topography of an AVM, the number and caliber of its arterial feeders, and the morphology of its draining veins. Selective angiography is also useful to guide in the preparation of calibrated-leak balloons of various sizes and with different leaks, depending on the morphologic characteristics of the feeders to be embolized [6]. This information, together with detailed anatomic, dynamic, and functional characteristics of the individual feeders, will influence the rate, type of injection, and the polymerization time of the IBCA injected at embolization [7].

Material and Methods

Eighty patients with brain AVMs, most of them difficult to resect surgically because of location or size, were treated with IBCA embolization at University Hospital, London, Ontario, from October 1978 to January 1984. This therapy was performed alone or in conjunction

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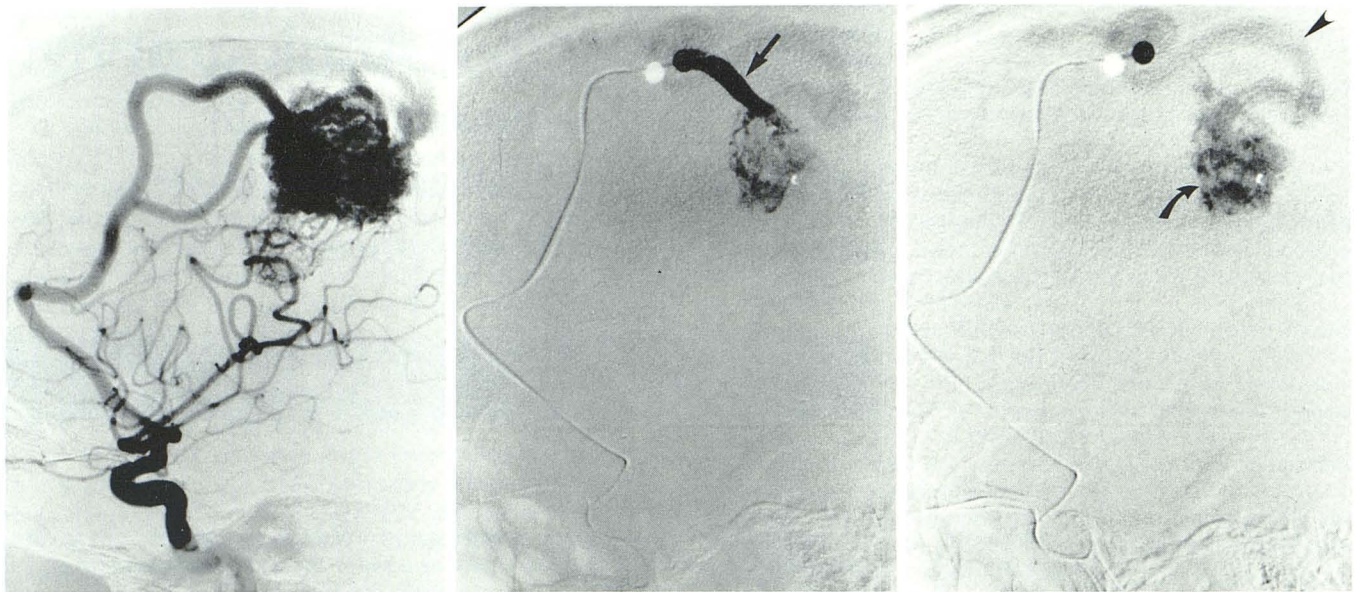


Fig. 1.—**A**, Lateral view, left common carotid arteriogram. Large mesiofrontal AVM, mainly supplied by enlarged branches of callosomarginal artery. Early (**B**) and venous (**C**) phases of superselective angiogram. Arterial feeder (*straight arrow*), nidus (*curved arrow*), and corresponding draining vein (*arrowhead*).



Fig. 2.—**A**, Lateral view, superselective angiogram. Proximal location of balloon (*arrow*) in relation to nidus of AVM. This was considered too remote for safe injection of IBCA. **B**, Balloon has been repositioned in different feeder, closer to nidus of AVM, after inflation and deflation maneuvers with contrast medium.

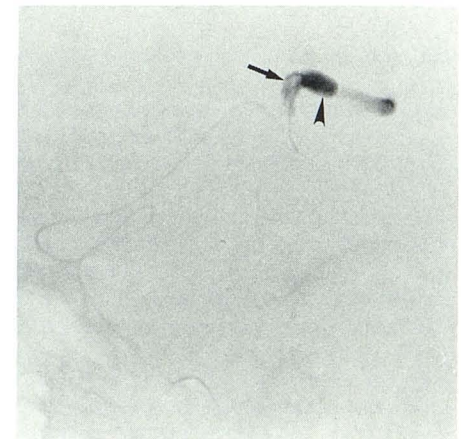


Fig. 3.—Superselective angiogram. Small lateral and posterior leak of contrast material (*arrow*). Radioopaque, inflated balloon (*arrowhead*) is distal to leak. This balloon is not safe for IBCA injection.

with postembolization surgical resection. Of the 80 patients, 64 had preembolization superselective angiograms. Of the 175 individual feeders selectively catheterized, 105 were examined through the transfemoral approach and 70 through direct cannulation at surgery. The type of calibrated-leak balloon and the delivery system used have been described by Debrun et al. [6]. The techniques of intraoperative catheterization of brain cortical feeders have been described by Girvin et al. [7].

When the calibrated-leak balloon (transfemoral technique) or the cannulating catheter (intraoperative technique) appeared to be in a suitable position for embolization, a preembolization superselective

angiogram was obtained. The rate of contrast medium injection and the degree of balloon inflation was carefully checked under fluoroscopic control, to avoid overdistension of the arterial feeder. The contrast medium (iothalamate meglumine 60%) was hand delivered, and the amount varied from 1 to 2 ml, depending on the size of the feeder to be opacified and the distance from the balloon to the AVM nidus. In the transfemoral technique, serial angiography with imaging of early arterial, late arterial, capillary, and venous phases was performed (fig. 1). In the intraoperative technique, the contrast medium injection was recorded on videotape and replayed slowly immediately before embolization.

Fig. 4.—**A**, Lateral view, left vertebral angiogram. Thalamic AVM mainly supplied by enlarged anterior thalamoperforating artery (*straight arrow*) arising from posterior communicating artery (*curved arrow*). **B**, Lateral view, superselective angiogram of anterior thalamoperforating artery feeding AVM. Vertical part of catheter is in basilar artery, and its horizontal part is in posterior communicating artery. Balloon (*arrow*) is at origin of anterior thalamoperforating artery.

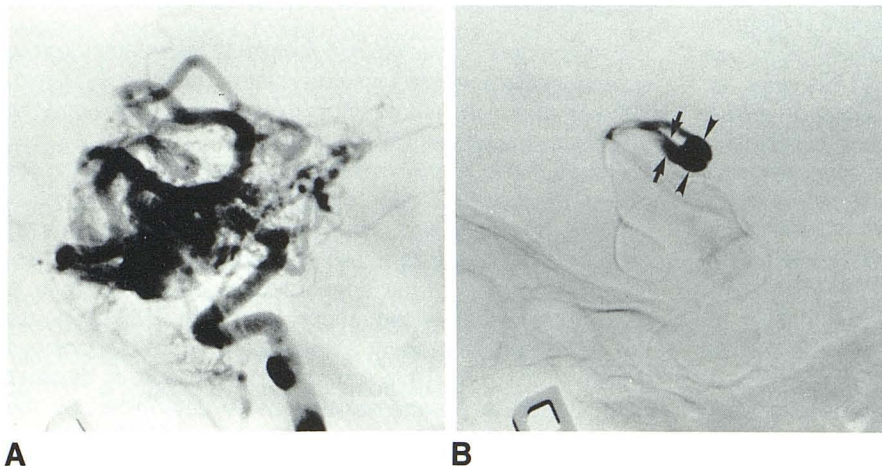
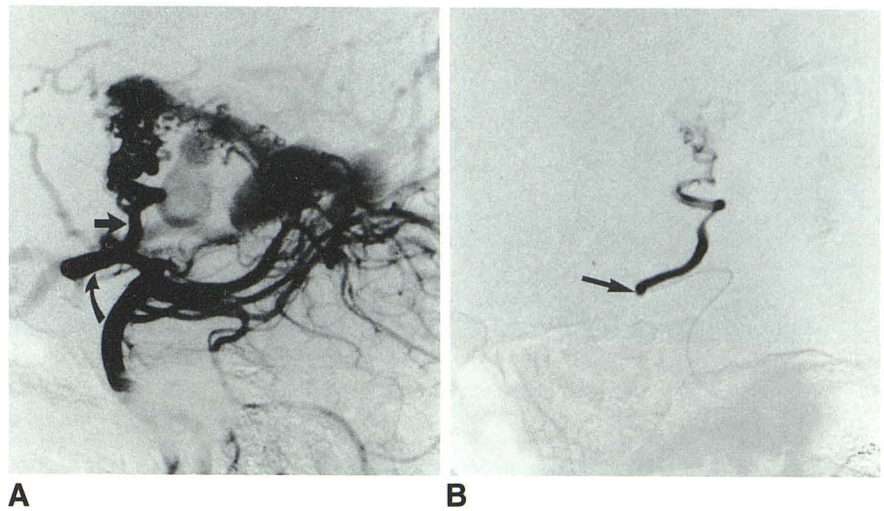


Fig. 5.—**A**, Lateral view, right carotid angiogram. Large frontal AVM supplied by several enlarged feeders arising from right middle cerebral artery. **B**, Accidental balloon overdilation during superselective angiography. Subarachnoid hemorrhage occurred immediately after this injection while films were being processed. Arrows show size of artery; arrowheads show overdilated balloon.

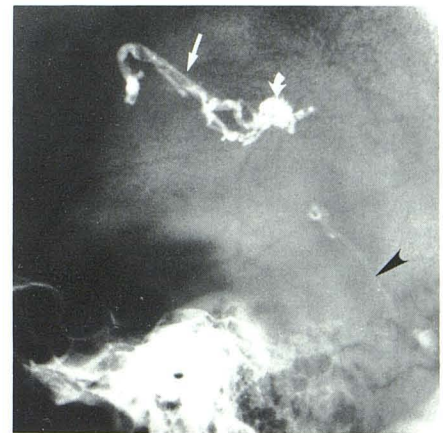


Fig. 6.—Lateral view of skull. Deposit of IBCA mixed with tantalum in AVM arterial feeder (*straight arrow*), nidus (*curved arrow*), and straight sinus (*arrowhead*).

In several cases, the superselective angiograms were repeated for an individual feeder, while more manipulation was done, until the balloon location was considered safe for embolization (fig. 2). The superselective angiograms were followed by a slow hand injection of 20 mg of amobarbital sodium and a neurologic assessment at the end of the injection [8].

Results

The information obtained by superselective angiography was of three types:

1. *Anatomic*: distance between the balloon and the AVM nidus; occlusion of the cortical feeder by the balloon; depiction of normal branches distal to the balloon; approximate proportion of AVM nidus opacified by comparison with the baseline angiogram. Superselective angiography also showed small lateral leaks of the balloon unnoticed on fluoroscopy (fig. 3).

2. *Dynamic*: approximate arteriovenous transit time, obtained from a serial angiogram with two films per second for 5 sec in the transfemoral approach, and from videoangiography in the operating room.

3. *Functional*: appearance of neurologic deficit during or immediately after the contrast medium injection and injection of amobarbital sodium.

Feeders arising from the anterior cerebral, middle cerebral, and posterior cerebral arteries, as well as the deep perforators supplying AVMs in the thalamus, mesencephalon, and basal ganglia, were also catheterized (fig. 4).

The superselective angiogram was immediately followed by a transient neurologic deficit in five cases, visual field defect in two, and left monoparesis, cortical dysesthesia, and memory loss for recent events in one case each. One patient developed an episode of sudden fear after the superselective injection of 20 mg of amobarbital into a normal medial pos-

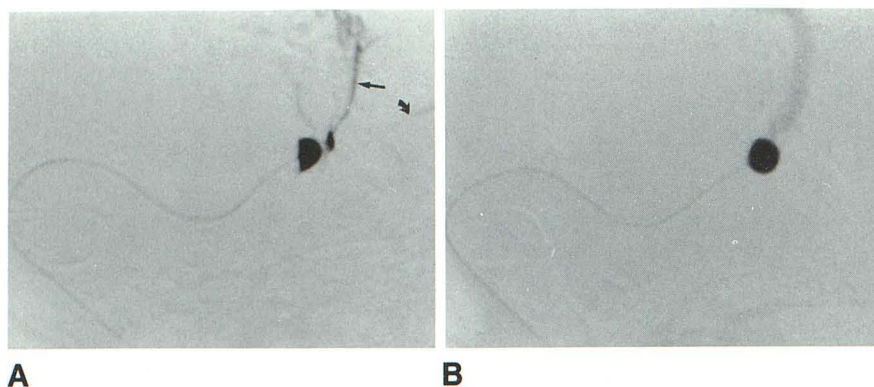


Fig. 7.—**A**, Superselective angiogram. Partial filling of AVM feeder (straight arrow) and normal temporooccipital branch (curved arrow). **B**, Exclusive visualization of AVM feeder after repositioning of calibrated-leak balloon.

terior cerebral artery. In one case, overinflation of the balloon during the injection of contrast medium ruptured an arterial feeder, causing a subarachnoid hemorrhage (fig. 5). The patient did not develop a focal neurologic deficit from this event, and the AVM was removed surgically 3 months later. One patient with an apparently safe superselective angiogram of the pericallosal artery developed a postembolization permanent leg monoplegia after IBCA injection. In this case, the preembolization angiogram elicited subtle neurologic manifestations that were misinterpreted by the therapist (dysesthesia of the foot and questionable heaviness of toe movements). Also, two small cortical arteries were not seen on the angiogram and were inadvertently embolized.

Radiographic evidence of IBCA embolization of the venous component of the AVM was seen in seven cases (fig. 6). In six cases this was clinically silent, but in one patient an intracerebral hemorrhage occurred 12 hr after the embolization. This event may have been related to partial occlusion of the venous drainage of the AVM. The patient developed an aphasia and right hemiplegia that completely resolved in 6 months.

In all patients the IBCA polymerization time was modified by adding iophendylate to the IBCA/tantalum mixture, as described by Cromwell and Kerber [9]. In figure 1, the arteriovenous transit time measured on the superselective angiogram was about 2 sec. This particular feeder was embolized with a mixture of 1.0 ml of IBCA, 0.4 ml of iophendylate, and 1.0 g of tantalum powder. This 60%/40% concentration of IBCA/iophendylate polymerizes about 2 sec after contact with blood. In figure 4, the arteriovenous transit time was about 3 sec, and 0.2 ml of a mixture of 1.0 ml of IBCA, 0.8 ml of iophendylate, and 1.0 g of tantalum powder was injected through the calibrated-leak balloon. In this particular case, the IBCA/iophendylate/tantalum powder mixture was bolused with dextrose so that the proximal part of the feeder was preserved.

The rate of injection of the IBCA is predetermined by repetitive injections of 1.0 ml of pure Conray 400 through the calibrated-leak balloon. Several rates of injection are tested until the fastest rate of injection that occludes the arterial feeder without jeopardizing its integrity is selected. The amount of IBCA injected is regulated by the progression of the radiopaque IBCA column observed on fluoroscopy. When

this column stops progressing and starts getting closer to the balloon, the balloon is rapidly deflated by aspiration and withdrawn to avoid gluing it in place.

Discussion

The anatomic, dynamic, and functional information from a superselective angiogram can be obtained in about 5–10 min. Valuable information that affects the rate of injection and the polymerization time of IBCA is obtained.

The anatomic information is precise when the balloon occludes the arterial feeder during the injection of contrast material. This maneuver avoids a rapid dilution of the contrast material with concomitant loss of image sharpness and resolution. Occlusion of the arterial feeder with the balloon is also important before the embolization with IBCA, because this decreases the amount of glue delivered into the venous system of the AVM. This complication is less likely to occur when the IBCA polymerization time is determined by the arteriovenous transit time of each individual feeder. The arteriovenous transit time and the IBCA polymerization time are only approximations, and radiographic evidence of IBCA embolization of the venous outlet of the AVM was seen in seven cases. Perhaps more rapid film sequencing than two frames per second would improve the accuracy of the transit time assessment.

Bolusing the IBCA with dextrose was used in the embolization of the lenticulostriate and the anterior and posterior thalamoperforator arterial feeders (deep, small feeders supplying eloquent areas of the brain) to prevent proximal occlusion of the feeding arteries and accidental embolization of the proximal middle and posterior cerebral arteries.

In five cases, the superselective angiograms elicited transient neurologic deficits. These neurologic manifestations were related to the cerebral territory supplied by the feeder undergoing the superselective angiogram and were probably produced by a direct neurotoxic effect of nondiluted contrast material injected into a small cortical artery supplying eloquent brain tissue. The episodes did not last more than 5 min and they were followed by complete functional recovery. In four of these cases, the superselective angiogram showed normal cortical feeders distal to the balloons (fig. 7). The balloons were repositioned, and subsequently successful embolization

was carried out. In one case, the subtle neurologic manifestations were ignored, and the arterial feeder was embolized with IBCA. During the IBCA injection, two small cortical branches unnoticed on angiography were blocked by the glue. The patient developed an immediate leg monoplegia. This "false-negative angiogram" was probably produced by the "sump effect" of the AVM collecting most of the contrast material. This case stresses the importance of performing the IBCA embolization as close as possible to the AVM nidus.

The functional test produced by the injection of pure contrast material in a small feeder is now complemented by the injection of 20 mg of amobarbital sodium after the completion of the angiogram. The purpose of this test is to produce a transient neurologic deficit if the arterial feeder to be embolized also supplies eloquent brain tissue. This injection of amobarbital sodium has been performed in 32 AVM arterial feeders, and the only injection that produced a demonstrable effect occurred when the catheter slipped into a normal branch. This patient had a deep thalamic AVM and developed an episode of sudden fear immediately after the injection of 20 mg of amobarbital sodium. The superselective angiogram obtained immediately before the amobarbital sodium test showed a normal mesiotemporal artery probably involved in the blood supply to the left amygdaloid complex and limbic system. The episode of fear lasted for a few seconds; after repositioning of the catheter and embolization of other vessels, it did not occur again. In those cases in which the amobarbital sodium test was negative, the arterial feeders were embolized and no false-negative results have been recorded. Our experience includes the embolization of lenticulostriate and anterior and posterior thalamoperforating arteries. Our preliminary experience has led us to conclude that a negative amobarbital sodium test probably indicates that the catheter is in good position for embolization.

In conclusion, preembolization superselective angiography is very useful for collecting anatomic, dynamic, and functional information that has immediate application at the precise moment of IBCA embolization. The safety of the procedure and the valuable information obtained from it far outweigh the additional time spent in obtaining the angiogram. Nonvisualization and accidental embolization of eloquent small cortical branches are decreased by positioning the balloon as close as possible to the nidus of the AVM.

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