Flow-Controlled Therapeutic Embolization: A Physiologic and Safe Technique

A feared complication of therapeutic embolization is loss of control of one or more particles with resultant ischemic infarction of normal tissues. To avoid passage of emboli into normal arteries, the delivery catheter may be wedged tightly into the artery or the artery completely occluded with a balloon catheter during embolus injection. These techniques, termed occlusion control, were a valuable forward step and significantly enhanced patient safety. However, occluding the vessel completely may cause spasm, and allows the operator to introduce fluid and emboli under higher than normal perfusion pressures which can open extra- to intracranial shunts and cause disastrous intracranial embolization.

A further refinement is suggested. First, the emboli are suspended in contrast agent; then the particles are introduced while arterial runoff of the contrast agent is watched so the acceptance rate of the artery is not exceeded. Normal perfusion pressures and flow then carry the embolus distally into the abnormality being treated. This technique is safe, easily learned, and gives the radiologist direct vision control over the embolization process. It has been used in 39 patients with only one serious complication.

Therapeutic embolization, the deliberate occlusion of the blood supply of vascular tumors and arteriovenous malformations is of value both as a primary treatment and as an adjunct to surgery when operative blood loss should be reduced [1-11]. Most complications of this technique occur when emboli pass to normal tissues and cause ischemic infarction [12-14].

To avoid this problem, some have advocated tightly wedging the catheter into the feeding vessel or occluding the artery completely with a balloon catheter [15]. We have developed, used, and favor a different, more physiologic technique of control and report its rationale and use.

Technique

A 4 standard, 5 standard, or 5.8 French, thin-wall, polyethylene catheter is directed into the artery to be occluded using percutaneous techniques and fluoroscopic control. Entry into the femoral or other artery is usually via a 6 or 5 French Cordis sheath. The catheter tip position is verified with cut films, fluoroscopy, or preferably instant electronic subtraction. Care is taken not to cause arterial spasm either with the leading guide wire or the catheter. The embolic material is prepared by suspending it in full strength Conray [16-18].

A contrast-filled syringe of the same size as that containing the emboli is connected to the catheter, and contrast agent is introduced while the arterial runoff is watched fluoroscopically. The angiographer thus learns the injection rate that will exceed arterial acceptance and cause contrast agent reflux. The syringe containing contrast agent and emboli is then attached to the catheter, and infusion under fluoroscopic control begins (fig. 1).

As more emboli occlude the abnormality’s vascular bed, vessel acceptance of contrast agent (and emboli) slows (fig. 1). It is this change that is sought on the fluoroscope. When the angiographer knows what to look for, the decreased flow
Fig. 1.—Photographs made from T.V. tape at 0.3 sec intervals during embolizaton of right glomus jugulare tumor through catheter (arrow) placed selectively in main feeding artery. Left (1–6). Flow during introduction of first 5–10 particles. At 0.3 sec, injection rate is maximal, completely filling artery. Higher introduction rate would exceed acceptance of contrast agent and emboli with reflux into normal tissues. At 0.6, 0.9, and 1.2 sec, infusion is slowed for greater margin of safety (done automatically by eye-hand cybernetic pathways). Emboli continue into tumor bed. Right (A–F). After about 200 particles, flow into tumor bed is slow. Even so, contrast agent still passes distally and there is no reflux.
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is obvious and the eye-hand coordination to slow the infusion is automatic, taking place via subconscious cybernetic pathways.

Complete blood flow obliteration is rarely necessary. If the therapist waits a few minutes, or occludes a second vessel and then returns to the original vessel to perform the follow-up angiography, the body's own clotting mechanism has usually completed the occlusion.

Care must still be taken when the infusion of emboli is judged complete. Particles may remain within the catheter or adapter. A guide wire effectively pushes these residual emboli through, but too rapid advancement of the guide wire can have the same effect as a too rapid push on the plunger of a syringe: emboli may enter the artery faster than they can be accepted, and reflux back alongside the catheter into normal organs. During introduction of the guide wire, contrast agent leaving the catheter tip is watched and the rate of wire advancement is slowed as necessary.

As a final safety measure, a syringe is attached to the catheter, and 4–6 ml of blood is withdrawn. The contents of that syringe are delivered onto an absorbent towel. Frequently, emboli are visible. When two successive syringes are free of emboli, it is assumed that follow-up angiography may be performed safely.

Results

In the past 5 years, 39 patients with 37 extracranial and two intracranial abnormalities have been treated with this technique. Multiple vessels were occluded in almost all patients. An abnormality near a major normal vessel was not considered a contraindication (fig. 2).

One serious complication occurred in this series, but was not related to this technique of flow control. A scalp slough occurred when nonselective catheter placement allowed emboli to occlude not only a middle meningeal feeder of a meningioma, but also a dominant superficial temporal artery [19]. Surgery the next day further devitalized the scalp.

The procedures were performed by fellows with neuroradiology staff supervision, or by staff alone. All radiologists reported ease in learning the technique and felt comfortable in its control.

Discussion

Complications from therapeutic embolization may result from the infarction of catecholamine-producing tumors, from passage of emboli through arteriovenous shunts into the lungs, from clot introduced through the manipulation of inadequately perfused coaxial catheters, and from passage of emboli through patent extra-to intracranial anastomoses [19–21]. But these are uncommon problems; the vast majority of complications are caused by the reflux of embolic materials out of the injected artery back into normal vascular beds causing ischemic infarction.

This problem has long been recognized [12–14], and to avoid embolus loss, tight wedging of the catheter into the artery or complete occlusion of the artery with a balloon-
tipped catheter has been advocated [15]. This technique is termed occlusion control of embolization because it depends on the complete blockage of the artery to prevent embolic reflux. Many safe embolizations have been performed by occlusion control and I do not suggest that the occlusion control technique should not be used.

Occlusion control does have certain disadvantages, however. Wedging a catheter into an artery frequently causes spasm, and wedging is not practical in vessels that are large and tortuous, such as arteries feeding arteriovenous malformations [16]. Balloon-tipped catheters are more complicated than simple straight catheters and add an additional technical maneuver to the procedure. However, the most severe criticism is that occlusion control stops forward flow of blood, contrast agent, and, most importantly, of emboli. Pressure in these blocked arteries may be high during injection, and the normal external carotid to intracranial artery shunts may be opened to allow passage of emboli intracranially [19, 21]. Blocking the artery during injection of material sacrifices a most important natural element of delivery: normal forces carrying an embolus distally.

Perhaps a better method is to place a catheter into a feeding artery gently so that no spasm is produced. Emboli may then be introduced into normally flowing blood, blood that will carry the embolus to a distal point, to impact itself there onto the arteriovenous malformation or tumor bed under normal perfusion pressures. With this flow-controlled technique, there is no chance of increasing intraluminal pressures beyond normal, and one may embolize even in the face of patent extra- to intracranial anastomoses (fig. 3).

Most importantly, with flow-controlled embolization, the angiographer feels secure. He can see instantaneously the change in vessel runoff and may slow his injection rate appropriately before reflux occurs. Large numbers of emboli may be introduced rapidly—but with control—since the fluoroscope shows real-time decreasing vessel acceptance.

Flow-controlled therapeutic embolization has shown itself to be an easily learned and safe technique. First, the particulate emboli are suspended in full strength contrast agent. Second, the feeding artery is gently catheterized so that no spasm is produced, and good runoff remains about the catheter tip. Finally, and most importantly, the ever-decreasing vessel acceptance of contrast agent (and emboli) is watched and the infusion slowed appropriately. With this simple set of maneuvers, particles flow under physiologic pressures to the tumor bed, no arterial spasm is produced, extra- to intracranial shunts are not forced open, and the radiologist has moment-by-moment control of the embolization process.

ACKNOWLEDGMENTS

I thank Gretchen Fischer for manuscript preparation, and Norman Rabinovitz and Joseph Weinstein for photographic assistance.

REFERENCES

1. Djindjian R, Cophignon J, Rey A, Theron J, Merland JJ, Houdart R. Superselective arteriographic embolization by the fem-