Transcatheter Embolization: Prevention of Embolic Reflux Using Balloon Catheters

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Reflux of embolic material during therapeutic transcatheter embolization is a potential complication which can result in occlusion of distal vascular beds. The conditions under which reflux was demonstrated in laboratory animals include (1) low flow states, (2) overvigorous flushing, (3) selective contrast injections, and (4) placement of embolic material too proximally. Balloon occlusion of the orifice of the vessel undergoing embolization protects against reflux and allows more homogenous embolization. Because of experience gained in the laboratory, therapeutic transcatheter embolization is now performed in patients with balloon catheter protection. Preliminary clinical experience is described.

Reflux of embolic materials and infarction of distal organs is a potential, yet not well recognized, complication of transcatheter embolization. Published reports describe ischemic infarcts of the spinal cord [1] and the lower extremities [2] as a result of embolic material reflux. In one of our patients, during embolic occlusion of the hypogastric artery for control of bleeding from pelvic trauma, reflux of embolic material produced occlusion of the popliteal artery requiring emergency embolectomy (fig. 1).

We investigated the circumstances under which this complication occurs because of the increasing applications of transcatheter embolization: (1) for control of cerebral [3] and spinal [4] arteriovenous malformations; (2) for treatment of gastrointestinal [5] and posttraumatic bleeding [6] and arteriovenous fistulae [7]; and (3) for renal ablation for tumor [8, 9] and end-stage renal disease [10]. This paper describes our observations as well as methods to prevent embolic reflux.

Materials and Methods

Embolic Material

Pledgets of absorbable gelatin sponge (Gelfoam) approximately 2 × 2 × 2 mm were soaked in liquid iophendylate (Pantopaque) for 30-45 min and gently compressed to remove as much remaining liquid as possible [11]. They were then loaded into tuberculin syringes and suspended in 1 ml of heparinized saline. The pledgets were introduced into the catheter and embolizations were carried out by pressure on the plunger of the syringe. Additional 1 ml increments of saline were introduced as required to flush the catheter and obtained free flow.

Catheters

All embolizations were performed through a new polyethylene balloon-tipped catheter (no. 0B7/2/65, Medi-tech Corp., Watertown, Mass.) (fig. 2). This catheter is heat-formable with good memory retention and torque control. The inner diameter of the catheter is 0.89 mm; outer diameter, 2.3 mm. In animal experimentation the catheter was introduced via a femoral artery cutdown. In subsequent clinical use, it is introduced percutaneously with standard Seldinger [12] technique over a 0.889 cm guide wire. Partial inflation of the balloon during manipulation can impart some flow direction to the catheter and aid in selection of vessels and can increase the seating depth of the catheter tip.

Embolizations

An in vitro series of embolizations was performed by discharging the pledgets of Gelfoam into normal saline. The emboli were radiographed before introduction into the catheter, and then retrieved from the saline solution and reradiographed to determine the degree of retention of contrast medium in the embolized particles, and their size and shape.

An in vivo series of embolizations was performed in six dogs under light sodium pentothal anesthesia. After femoral artery cutdown, selective catheterization and embolization of both renal arteries was performed in each dog, while the procedure was recorded with cinefluorography at 64 frames per second. In each dog, one side was embolized without balloon occlusion, and the opposite side with the balloon inflated. The sides were alternated in each animal. The resulting cine recordings were analyzed with stop-motion viewing equipment.

Results

In the in vitro study, radiographs of the contrast-soaked Gelfoam obtained before embolization showed dense radiopacity of the material (fig. 3*A*). After passage through the catheter, the material broke up into multiple small pieces but remained densely radiopaque (fig. 3*B*). In the in vivo study, radiographs of a representative experimental animal demonstrated the dense radiopacity of the embolic material in the renal vessels and the refluxed material in the lower extremity vessels (fig. 4).

Analysis of the films of the renal arteries embolized without balloon occlusion demonstrated that reflux of embolic material occurred almost immediately after obstruction of segmental vessels (fig. 4). Flushing of the catheter or test injections of contrast material were often responsible for dislodging emboli from the segmental vessels, even though the catheter tip was in the main renal artery. When embolic material was allowed to lodge in the proximal main renal artery, emboli were dislodged while being rocked to and fro by the aortic pulse wave. In addition, repeat arteriography performed after embolization demonstrated very inhomogeneous

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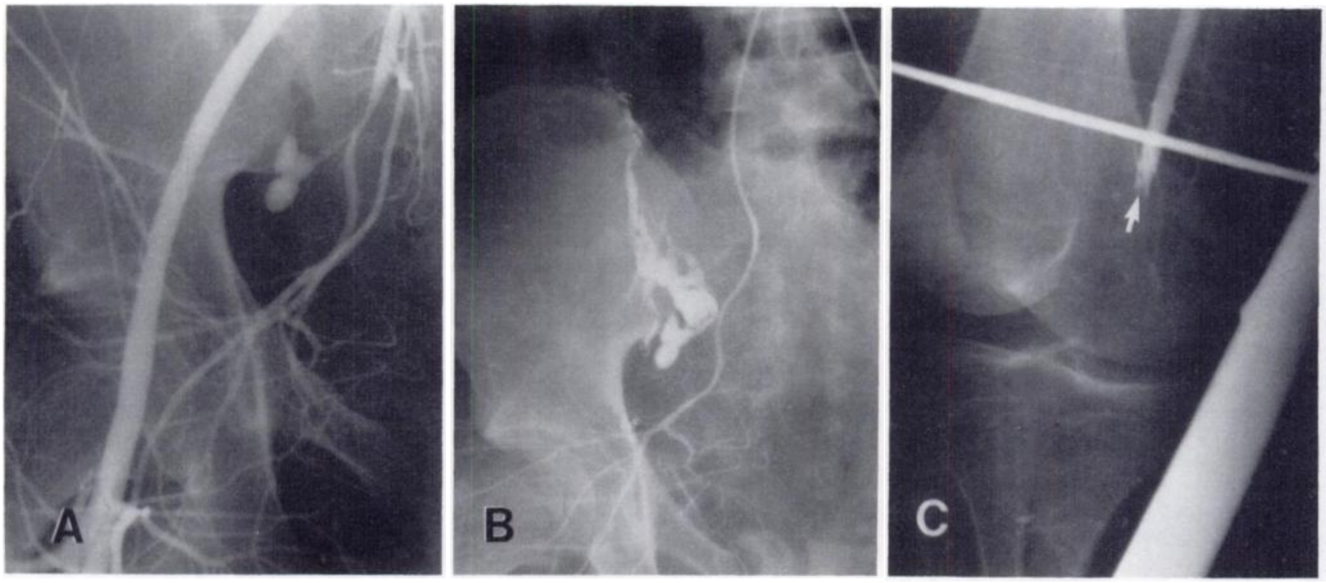

Fig. 1.—Popliteal artery occlusion from embolic reflux during therapeutic embolization. *A*, Selective right common iliac arteriogram demonstrating extravasation of contrast from branch of hypogastric artery. Note extent of pelvic fractures. *B*, Superselective arteriogram demonstrating extravasation from superior gluteal artery. Embolization was carried out from this position. *C*, Arteriogram showing complete obstruction of right popliteal artery, discovered when right dorsalis pedis pulse was lost. Note intravascular filling defect (*arrow*). At surgery (femoral embolectomy), 2 mm Gelfoam pledget was retrieved. Perfusion was successfully restored.

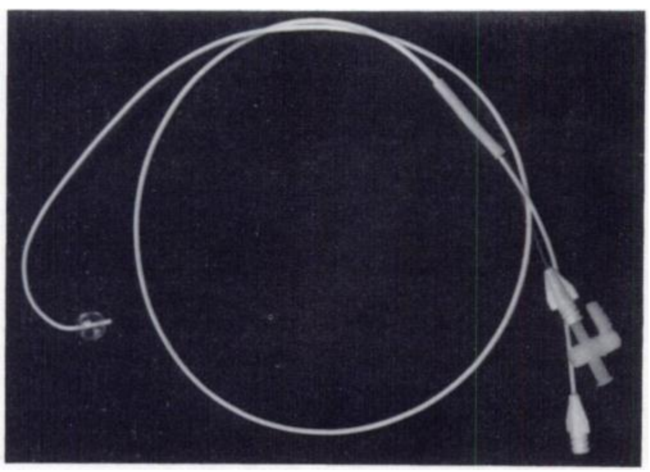

Fig. 2.—Medi-tech balloon catheter. Note curve formed at distal end of catheter.

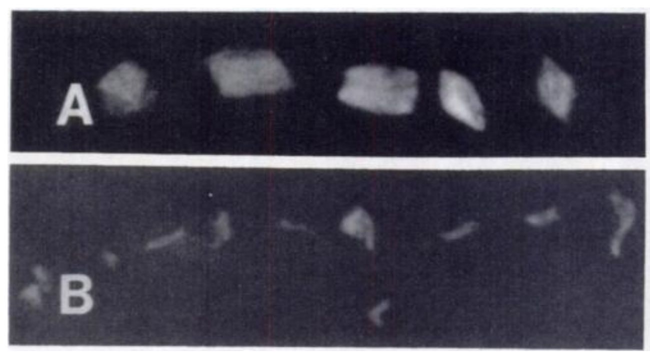

Fig. 3.—Radiographs of Gelfoam pledgets in vitro. *A*, Gelfoam pledgets (original size 2 × 2 × 2 mm) after being soaked for ½ hr in liquid iophendylate (Pantopaque). *B*, Same pledgets of Gelfoam after being extruded through Medi-tech catheter. Gelfoam is now broken up into pieces about size of catheter orifice. They have retained dense radiopacity. (Photograph reproduced to same scale as *A*.)

distribution of vessel occlusion; no further embolic material could be introduced to more completely occlude the renal circulation because all additional material refluxed into the abdominal aorta.

In renal arteries embolized with balloon occlusion, no reflux of material occurred. However, in every case in which emboli were deposited more proximally than the segmental vessels, saline flushing of the catheter or selective injection of contrast medium after balloon deflation produced immediate reflux of most of the embolic material remaining in the main renal artery. Embolic material deposited in the main renal artery with the balloon inflated could be forced distally with repeated saline flushing while balloon occlusion was maintained. Aortography performed at the end of the procedure adequately documented the degree of embolic occlusion of the renal vessels without producing reflux. In addition, embolization was far more homogeneous when balloon occlusion was used.

Discussion

The experimental observation that embolic material refluxed after introduction was originally made by Lalli et al. in 1971 [13]; they were able to prevent reflux with balloon occlusion. More recent reports of embolic com-

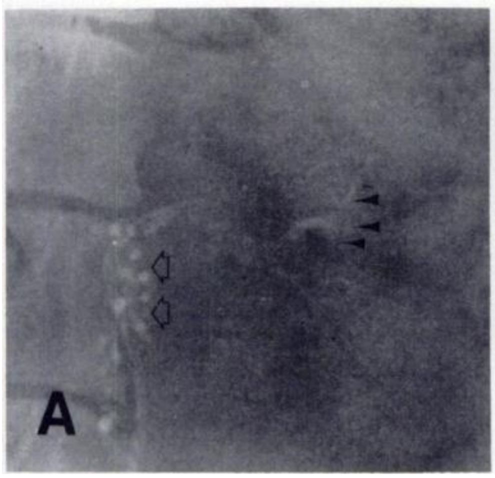

Fig. 4.—Demonstration of embolic reflux. *A*, Representative cine frame obtained during early embolization of Gelfoam in renal artery of dog. Radiopaque material obstructs segmental branches in renal hilum (*arrowheads*). There is massive reflux of embolic material into aorta (*open arrows*). *B*, Radiograph of dog's leg at end of procedure demonstrating large quantities of radiopaque Gelfoam trapped in thigh vessels.

plications of renal embolization have been limited to patients undergoing embolization in end-stage kidney disease. These reports implicate the reduced flow to the kidneys, due to their reduction in volume, along with obliterative intimal fibrosis as the responsible factors [1]. Our investigations confirm that embolic reflux occurs in a low flow state, such as after partial embolization of the renal circulation or during hypotension. In addition, we demonstrated clearly that *spontaneous* reflux of embolic material may occur if material is deposited too close to the orifice of the vessel being occluded.

Kerber [14] suggested that careful fluoroscopic monitoring of the progress of embolization can prevent reflux. However, rather high pressure producing high flow can be required to extrude the embolic material from a partially obstructed catheter, exceeding the flow rate even in high flow vessels. In addition, we observed clinically that Gelfoam particles are rapidly washed free of water soluble contrast material by blood flow or flush solution, and do not reliably remain radiopaque in vitro or in vivo. Finally, an increased load of contrast material is required by his technique, an important consideration in patients with reduced renal function and, especially, prior to nephrectomy.

Levin et al. [16] demonstrated in the laboratory that embolization without balloon protection could be carried out using a special procedure with extremely careful placement of catheters in the center of the arterial lumen "as long as intermittent contrast injections demonstrate continued patency of the catheterized artery and forward flow of contrast material. Once the artery and its major branches become subtotally occluded further embolization is risky." While following their recommendations eliminates the need for additional catheter materials and eliminates use of balloon catheter protection, the degree of vessel occlusion produced, we believe, is suboptimal and may lead to early vessel recanalization. Further, the escape of even one fragment of embolic material has potentially disastrous consequences. Occlusion of the orifice of the embolized vessel with a balloon-tipped catheter followed by embolization through this catheter is a safer, more practical method of preventing complications of embolic reflux, increasing the completeness of embolization, and controlling the proximity of deposition of material to the vessel orifice.

Of equal importance is the demonstration that reflux of embolic material occurs with vigorous flushing of catheters or selective injections of contrast material. As a result of these findings, we have adopted the following protocol for clinical embolization of main aortic branches (fig. 5):

1. Control arteriography is selectively performed through the balloon catheter with the balloon deflated.
2. The balloon is inflated. All further flushing or selective arteriography is carried out prior to deflation.
3. Embolic material is not allowed to lodge proximal to the first major division of the embolized vessel. This can be controlled by flushing the catheter with the balloon inflated, which drives the material peripherally.
4. Hand injections of contrast material with the balloon inflated are performed to determine the completeness of occlusion. These may be documented on film if necessary.
5. For documentation of the embolization, the balloon catheter is exchanged for an aortography catheter, and aortography is performed with the side holes positioned just above origin of the embolized vessels.

On a few occasions, we have used balloon catheter occlusion of the renal artery rather than embolization prior to tumor nephrectomy [15]. However, we feel that is less satisfactory because: (1) the balloon may be dislodged or the femoral artery traumatized during positioning of the patient; (2) prolonged catheterization is necessary under less than ideal conditions; (3) the dislodged balloon could, in theory, be carried by flow into another vessel, with potentially disastrous consequences; and (4) the catheter or balloon may interfere with vessel occlusion during surgery.

Using this technique, no embolic reflux has occurred during preoperative embolization of 11 renal cell carcinomas. With regard to embolization of other vessels, the procedure used depends on the vessel under considera-

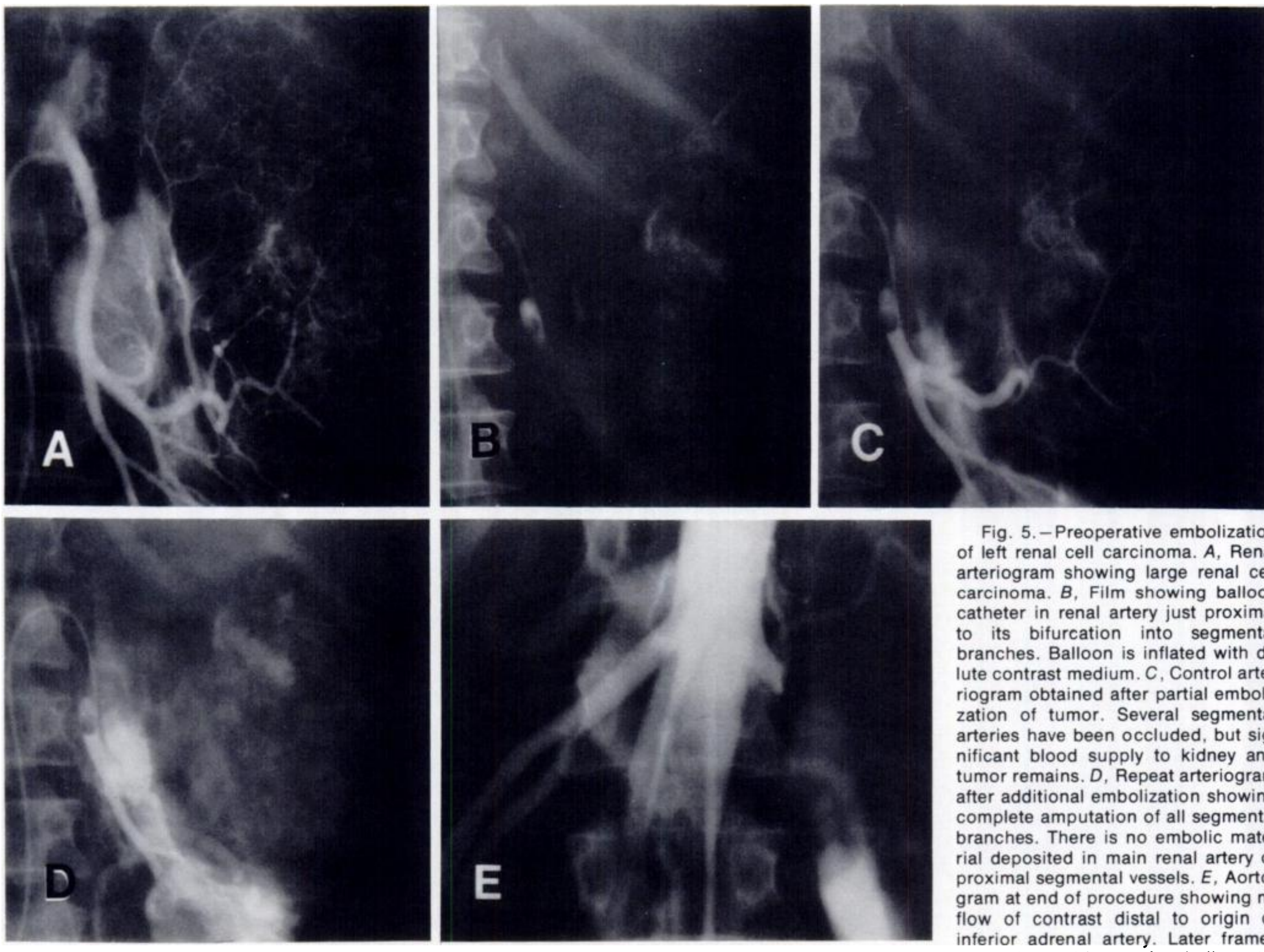

Fig. 5.—Preoperative embolization of left renal cell carcinoma. *A*, Renal arteriogram showing large renal cell carcinoma. *B*, Film showing balloon catheter in renal artery just proximal to its bifurcation into segmental branches. Balloon is inflated with dilute contrast medium. *C*, Control arteriogram obtained after partial embolization of tumor. Several segmental arteries have been occluded, but significant blood supply to kidney and tumor remains. *D*, Repeat arteriogram after additional embolization showing complete amputation of all segmental branches. There is no embolic material deposited in main renal artery or proximal segmental vessels. *E*, Aortogram at end of procedure showing no flow of contrast distal to origin of inferior adrenal artery. Later frames showed no evidence of embolic material in other aortic branches. Nephrectomy was subsequently carried out without incident.

tion. When second- or third-order branches of the aorta are being embolized with superselective catheterization, balloon protection may not be possible with present balloon catheter technology. In these situations, coaxial catheterization allows placement of emboli as peripherally as possible, with the outer catheter occluding the more proximal vessel orifice. Using this method we have safely embolized the left gastric artery on multiple occasions, have selectively embolized a bleeding intralobar renal artery, and have safely embolized a gastrojejunostomy bleeding from the jejunal side with selective occlusion of the single vasa recta supplying the bleeding site. Our experience with embolization will be documented more fully in a subsequent communication.

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