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II. Uterine Fibroid Embolization: Technical Aspects

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Successful superselective catheterization of the uterine artery requires familiarity with female pelvic arterial anatomy, knowledge of effective catheter and guidewire combinations, and a few tricks. A learning curve can be expected for each of these elements, although it is assumed that the operator will already have experience in basic catheter techniques. Safe transcatheter delivery, understanding of embolization end points, and avoidance of nontarget embolization are essential. Equally important are knowledge of the properties of the embolic agents currently available and their indications for use. Uterine fibroid embolization unavoidably results in radiation exposure to the uterus and ovaries, and adherence to meticulous fluoroscopic technique is crucial to keep the absorbed dose as low as possible.

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Anatomic Considerations

Robert L. Worthington-Kirsch

The uterine artery (UA) is typically the first branch of the anterior division of the internal iliac artery (IIA), arising anteromedially (Fig 1).¹ However, there is wide variability in the branching pattern of the arteries of the pelvis, including the origin of the UA. Gomez-Jorge et al have described 5 distinct anatomic patterns (Fig 2).² The 2 most common are the classic pattern, which is the one most often depicted in anatomy texts, and the other is a trifurcation of the IIA, wherein the UA originates at the same point as the anterior and posterior IIA divisions. Rarely, there is absence of all or part of 1 or both UAs.

UA diameter can vary greatly, from as small as 1 to 2 mm to as large as 5 or 6 mm, but, typically, each is about 3 mm in diameter. The left and right UAs are usually comparable in diameter. The intrauterine branches of both UAs freely anastomose within the body of the uterus, with excellent cross-filling between the 2 circulations. This is why UFE must be successful on both sides for it to be effective.

Cannulation of the main UA can be challenging because of a sharp angle of origin from the parent trunk of between 45° and 90°. It is also quite common for the UA to share a common origin or short trunk with the inferior vesical artery, which can usually be identified as the straighter vessel. In some cases, it may be helpful to advance the catheter into the inferior vesical artery and pull back while injecting contrast to define the UA

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orifice. This maneuver may also better orient the catheter for selective cannulation.

The UAs are prone to vasospasm, which may prevent selective catheterization and embolization and increase the risk of complications such as arterial dissection or rupture. Spasm often occurs proximally in the vessel, near the origin, because of the straightening effect of the catheter on the sharp angle often encountered in that portion of the artery. Minimizing guidewire manipulation and the use of microcatheters may reduce the incidence of spasm. Waiting for a few minutes for the spasm to relax may be all that is needed, but the use of nitroglycerine for vasodilation may expedite the procedure. On occasion, slow injection of saline or contrast can break the spasm and allow resumption of flow. However, care should be taken to minimize maneuvers that mainly serve to increase fluoroscopy time.

Treatment with GnRH agonists such as leuprolide (Lupron) tend to make the UAs smaller and more spastic. Because there is no evidence of any benefit to pretreating fibroids with these agents before uterine fibroid embolization (UFE), it is advisable to wait beyond their expected duration of action, which may last as long as 3 months, to allow the UAs to return to their normal caliber.

The course of the UA, from proximal to distal, is divided into descending, transverse, and ascending segments (Fig 1). The UA first descends along the pelvic sidewall to the broad ligament, where it turns and courses transversely to the midline. As it approaches the uterus, the artery again turns to ascend. The descending segment of the UA, though sometimes quite tortuous, has no side branches.

The cervicovaginal branch of the UA usually arises from the mid- to distal portion of the transverse segment, but it can arise from the proximal portion of the ascending segment. In general, if the cervicovaginal branch can be excluded from the embolization field, it should be, although if it is unavoidable, there appears to be minimal risk of adverse outcome.

The ascending branch of the UA gives off branches that course over the surface of the uterus and the fibroids, which give rise to numerous centripetally oriented perforating vessels. The major tributaries of the uterine artery often have a saw-tooth appearance from the redundancy that allows them to accommodate an enlarging uterus during pregnancy. The arterial supply to individual fibroids is not usually apparent. Even if it were, given the tortuosity and sheer number of vessels involved, it would not be feasible to attempt selective catheterization and embolization of specific fibroids. Interestingly, despite their vascularity, fibroids are hypovascular relative to normal uterus, which accounts for their lower signal intensity on T1 weighted magnetic resonance images.

The ascending branch of the UA also has terminal branches

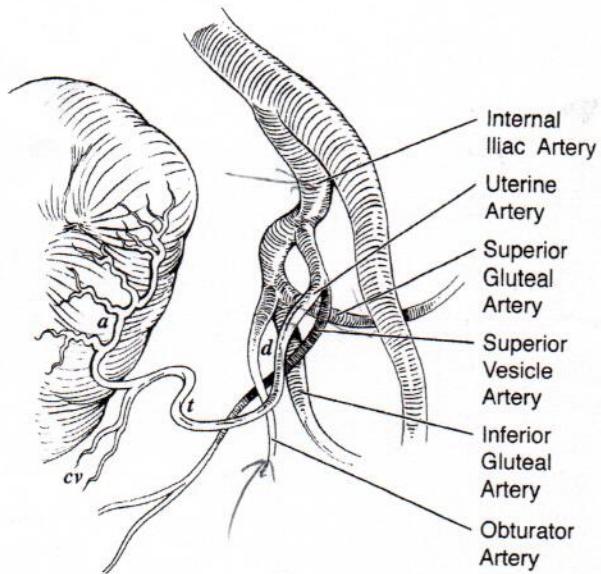


Fig 1. Conventional iliac artery branching pattern. The uterine artery usually arises as the first branch of the anterior division of the internal iliac artery, often at an acute angle of 90° or more. The uterine artery and superior vesicle artery often share a common trunk. Close observation of the downward path of the distal circulation will help distinguish the superior vesicle artery. The uterine artery typically has a descending portion (d), a transverse segment (t), which often gives rise to 1 or more branches to the cervix and upper vagina (cv) before angling cephalad to ascend (a) along the uterine body.

to the fallopian tube and the ovarian arteries (OA) (Fig 3). Communication between the UA and the OA can be demonstrated in approximately 46% of the population,³ but during selective angiography, this anastomosis has been visible in this author's experience in only 5% to 10% of cases. Approximately 3 to 4 cm lateral to the uterine-ovarian anastomosis, the parenchymal blush of the ovary can sometimes be discerned. In 4% of the population, the ovarian artery is absent, and the ovary is supplied exclusively by the UA.

Pelage et al have found that channels of the uterine-ovarian anastomosis measure about 500 µm in diameter.⁴ They advocate use of larger particle size for UFE (such as 700 to 900 µm) to avoid sending particles across the anastomosis into the ovary. Ironically, leaving the anastomosis patent potentially allows continued bloody supply to the fibroids after UFE. Visualization of reflux of contrast across the anastomosis during arteriography is unsafe. By choosing a sufficiently large particle size and not refluxing to the point that the main OA becomes opacified, long-term damage from nontarget embolization may be minimized.

Both OAs usually arise from the aorta a few centimeters below the origins of their respective renal arteries. The normal OA is about 1 mm in diameter and may not be seen on nonselective aortography. When the vessel supplies a fibroid uterus, it may be as large as 4 mm in diameter. Collateral flow to the fibroids from the OAs may occur even when the UAs are patent. Examples include women who have had previous pelvic surgery, a history of pelvic inflammatory disease, or a large fundal myoma. It may also result when there is complete or partial absence of a uterine artery, which is a normal anatomic vari-

ant in 1% to 2% of the population. On rare occasions (approximately 0.4%), both UAs are absent, and all supply to the uterus is from the OAs.⁵

From its origin, the OA usually makes a hairpin turn in a cephalad direction before coursing caudally into the pelvis. Its



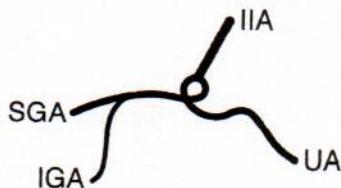
Type I- Uterine Artery is the first branch of the Inferior Gluteal Artery



Type II- Uterine Artery is the second or third branch of the Inferior Gluteal Artery



Type III- Internal Iliac Artery trifurcates into the Uterine, Superior & Inferior Gluteal Artery



Type IIIa- Internal Iliac Artery bifurcates into the Uterine Artery & Superior Gluteal Artery, with Inferior Gluteal Artery arising from the Superior Gluteal Artery



Type IV- Uterine Artery arises from the Internal Iliac Artery above its bifurcation

Fig 2. The branching pattern of the internal iliac artery. Five common branching patterns have been described. The pattern shown in Fig 1 is the most common, but a trifurcation, wherein the uterine artery arises at the same point as the anterior and posterior divisions of the internal iliac artery, is also quite common.

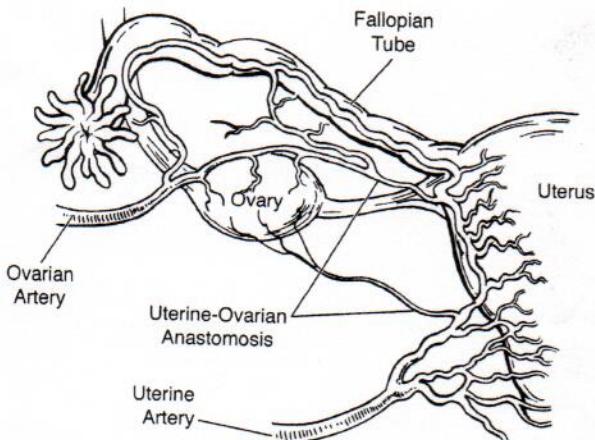


Fig 3. The anastomosis between the distal circulations of the uterine and ovarian arteries. The small vessels that provide intercommunication between these 2 territories have been shown to be smaller than 500 μm in diameter; use of particles, which are larger in size, may help avoid crossover into the ovarian circulation and injury to the ovary.

course may quickly become extremely tortuous, preventing passage of a selective catheter. When embolizing the OA, it is sufficient to position the catheter tip in the distal portion of the hairpin, above the segment of greatest tortuosity.

UFE is likely to fail if accessory blood supply is not also embolized. It has been shown that proximal embolization of both the UA and the OA with gelatin sponge or steel coils does not cause any apparent decrease in menstrual function or fertility.⁷ In fact, ligation and division of these vessels, which theoretically should devascularize both, has not been shown to cause any appreciable decrease in fertility.^{8,9} While embolization of the OA with small particles would certainly risk infarction of the ovary, proximal embolization with gelatin sponge pledges (in conjunction with particulate embolization of the UAs) ensures a good response to UFE without any apparent negative impact on menstrual function.

Occasionally, some fibroids, particularly those in the fundus, do not respond to UFE despite a technically successful procedure. These situations may be the result of parasitization of flow from mesenteric or omental vessels. This often occurs via an adhesion, a phenomenon that has been demonstrated by surgical exploration.¹¹ Even if these branches were to be identified arteriographically, embolization is contraindicated because of the risk of embolization of vital organs.

Catheters and Catheterization Techniques

Robert T. Andrews

Selective catheterization of the uterine arteries is among the most technically challenging aspects of the UFE procedure. These vessels, even when dilated by increased blood flow to the fibroids, remain relatively small arteries prone to spasm. They frequently arise at a sharp angle from the ITA and can be remarkably tortuous over their length. These problems are compounded by the superimposition of numerous other arterial branches in the lateral pelvis, which makes fluoroscopic identification of the uterine origin difficult. On the other hand, most patients who undertake elective UFE are young, otherwise healthy women. As a result, they generally have little atherosclerotic disease and iliac arterial tortuosity. Thus, although UA catheterization can be challenging, catheter manipulation is rarely impeded by underlying arterial pathology.

Catheter and Wire Selection

Primary catheters

The choice of a primary catheter for UFE varies significantly with operator preference and experience. Most are 4 or 5 French (Fr) in outer diameter and share the following features: a soft atraumatic tip, high visibility, and positive torque control. Some have additional features such as tapered tips, hydrophilic coating, and braiding. A Berenstein or cobra shape is often used for contralateral catheterization, while ipsilateral catheterization generally requires a recurred or pull-down shape (Fig 4). Recently, a catheter was introduced that was designed specifically for UFE, ie, a recurred catheter with a braided shaft that tapers from 5 to 3.8 Fr (Roberts UA catheter; Cook, Inc, Bloomington, IN) (Fig 5).

Microcatheters

Initial descriptions of the UFE procedure included the routine use of coaxial microcatheters for entry into the UA. Many operators continue this practice, though most now reserve microcatheters for specific clinical circumstances that are discussed later.

A microcatheter occupies a relatively small percentage of the cross-sectional area of the uterine arteries and, being softer and more flexible than standard catheters, may reduce the likelihood of catheter-induced spasm. Both of these features promote antegrade flow—especially in small UAs—which in turn facilitates the flow-directed distribution of particulate emboli to the fibroids. In addition, microcatheters can be advanced further into the UA than standard catheters and thus may be particularly useful in preventing nontarget embolization (such as to the cervicovaginal branches). Another significant advantage of coaxial microcatheters is that inadvertent catheter occlusion by embolic material can be resolved without abandoning access to the UA: One simply advances the outer catheter into the UA and then exchanges the occluded inner catheter for a new one.

In addition to their cost, which is not insignificant, microcatheters have the disadvantages of being more difficult to see under fluoroscopy, and their smaller luminal diameters often require a more dilute embolic suspension and a slower infusion rate, which increases fluoroscopy time.

Guidewires

In contrast with catheter selection, guidewire options for UFE are relatively fewer because of the need for directional control and a soft, atraumatic tip. In addition, because ipsilateral catheterization requires a recurred shape on the catheter that can be lost with use of a wire that is too rigid, the wire must be sufficiently flexible. Most operators use some type of hydrophilic wire, such as the Terumo glide wire (Boston Scientific Corp, Watertown, MA).

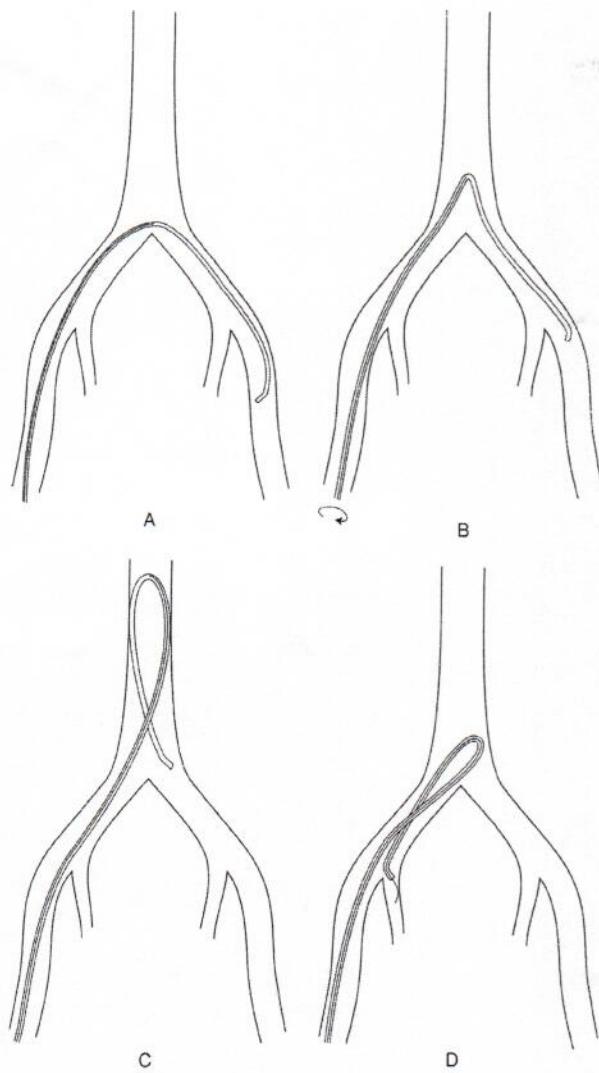


Fig 4. The Waltman loop technique. (A) A catheter is advanced into the contralateral iliac artery and a guidewire positioned with its tip at the aortic bifurcation. (B) The catheter and wire are advanced together as the catheter is rotated, causing the catheter to (C) form a loop in the distal aorta. (D) The looped catheter can then be directed into the ipsilateral iliac artery with use of a soft guidewire.

Catheterizing the UA: Step-by-Step

Arterial access

The right common femoral artery is the access site most often used for vascular access during UFE. As with similar percutaneous procedures, this approach is the most comfortable and easiest for a right-handed operator. With unilateral right femoral access, selective catheterization and embolization of the contralateral left UA is an “up-and-over” procedure, while catheterization of the ipsilateral right necessitates a sharp reversal of catheter direction (eg, a Waltman loop). This portion of the procedure can be quite difficult and time consuming, resulting in an increase in procedure time and patient radiation dose. In some patients with unusually complex anatomy, ipsilateral

catheterization is simply not possible. In such cases, a second access is required, usually via the opposite femoral artery.

In fact, some advocate bilateral femoral access on a routine basis.¹² There are several theoretical advantages to this approach. In addition to eliminating the need for a potentially difficult ipsilateral catheterization, the technique allows selective angiography of both UAs to be performed simultaneously. This in turn helps decrease the total number of imaging sequences, potentially reducing patient radiation exposure.¹² Bilateral access also gives one the option of alternating between left- and right-sided embolization without giving up access to either artery. For instance, 1 side may take more time to “set up” or stabilize. The operator can then reevaluate each side and apply more material where needed. Of course, bilateral catheterization doubles the risk of local femoral complications and, by overlapping 2 catheters in the distal aorta and the common iliac arteries, potentially increases the risk of thromboembolic events.

Another approach that eliminates the difficulty of an ipsilateral catheterization is access through the axillary, brachial, or radial artery. Upper extremity access also facilitates patient mobility in the immediate post-UAE period and reduces radiation doses to the operator. Despite these advantages, however, upper extremity access for UFE is uncommon. The brachial and radial arteries are smaller in caliber and are more prone to catheter injury. The axillary artery, while generally large enough for safe catheter introduction, can be difficult to compress after catheter removal, and axillary hematomas are well known as being associated with brachial plexus injury.¹³ Furthermore, any access from the arm requires the catheter to remain in position across the origin of the left vertebral artery (with left-arm access) or all 4 cerebral vessels (with right arm access) throughout the case. This in turn increases the risk of thromboembolic cerebral injury.

Approaching the UA origin

As described elsewhere in this text, the uterine artery normally arises from the medial aspect of the anterior division of the internal iliac artery. Placing a catheter from a transfemoral approach into the contralateral internal iliac artery is generally quite simple. A cobra-shaped or similarly angled catheter can usually be advanced directly across midline and into the iliac artery with a directional guidewire. The ipsilateral iliac artery, by comparison, requires a recurved catheter. For this reason, most operators treat the contralateral uterine artery first and then use the aortic bifurcation to create the recurve shape for ipsilateral catheterization. Forming the recurve can be done by exchanging the contralateral catheter for a preshaped catheter like that from Cook or by converting the original catheter to a pull-down configuration using the Waltman loop (Fig 5)^{14,15} or Cope suture techniques.¹⁶

Identifying the UA

The proximal aspect of the UA is frequently obscured by overlying structures on frontal projection imaging. Thus, angiographic demonstration of the vessel origin generally requires an oblique image projection. The ideal angle varies widely among individuals, and several different projections (including the lateral) may need to be evaluated, which adds to radiation dosages, to clearly delineate the UA origin in a given patient. Fortunately, the need for such detailed imaging is rare.

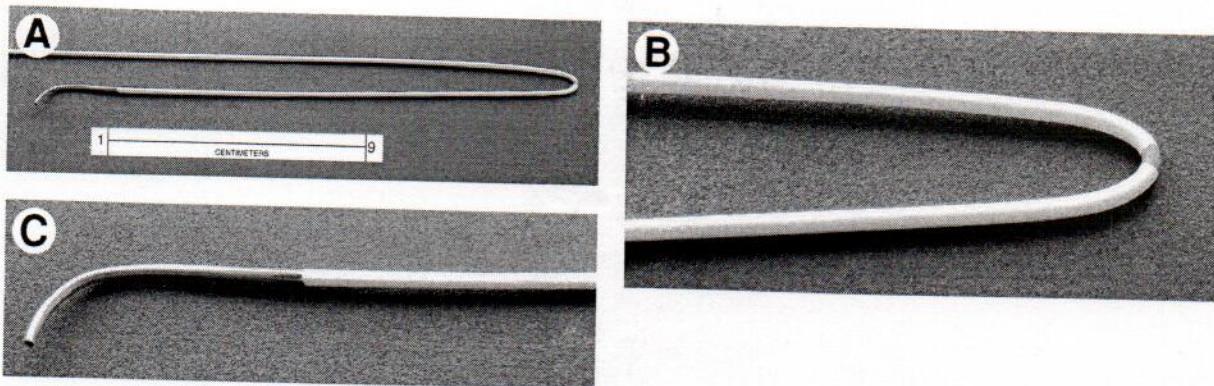


Fig 5. Roberts uterine artery catheter (Cook, Inc). (A) A commercially available catheter, with a long recurved limb, which facilitates catheterization of the ipsilateral uterine artery. Detail views demonstrate (B) a radiopaque marker (arrow) for positioning the apex of the curve at the aortic bifurcation and (C) a catheter tip that tapers from 5 to 3.8 French.

Because the UA is generally sizable in patients with fibroids, a guidewire occasionally enters the vessel preferentially. Therefore, once the IIA has been accessed, it is useful to gently probe with a soft-tipped wire and simply watch its course. If it turns medially in the lower third of the pelvis, it may already be in the UA. However, the UA is not the only vessel to course medially—so, too, do the vaginal, hemorrhoidal, and other branches. Inadvertent entry into 1 of these arteries can often be determined without contrast injection (which can be painful) by examining the path of the wire. When in the UA, a wire will travel several centimeters medially, usually in a serpentine manner, and then turn cephalad. In the other branches, it will generally advance only a few centimeters and take a straighter path.

Alternatively, the wire may repeatedly pass into the lower pelvis or thigh (obturator or inferior gluteal arteries) without engaging the UA. If so, a second technique for locating the UA is to advance the catheter distally, well below its expected origin, and then inject contrast as the catheter is slowly withdrawn. When the UA origin is reached, contrast will be seen coursing medially in the characteristic pattern. At the first visualization of contrast in the UA, catheter position is maintained, the guidewire is reintroduced, and gentle probing begins along the medial aspect of the parent vessel.

Adjunctive use of roadmap imaging can be extremely helpful. In fact, many operators routinely proceed directly to roadmap-guided access once the IIA has been catheterized. As discussed above, identifying the ideal projection angle for the roadmap can be difficult and require multiple attempts, with increasing radiation dose to the patient. As will be discussed later, the use of roadmap imaging can increase dose rates relative to conventional fluoroscopy in some angiographic suites.¹⁷

Entering the UA

The UA is prone to spasm, even with the gentlest manipulation. In addition, such small arteries can become significantly obstructed by a catheter in the absence of spasm. Preventive measures must be taken to avoid conditions that can reduce or occlude antegrade flow.

Once guidewire access to the UA has been achieved, the catheter should be advanced gently into the vessel no more than 1 to 2 cm, after which the guidewire should be removed for

initial uterine arteriography. Some operators drip saline into the catheter hub or submerge the hub in a bowl of saline during guidewire removal to reduce the chance of air being drawn into the catheter if significant spasm or obstruction is already present. If little or no antegrade flow is seen, it may be necessary to coaxially introduce a lower profile microcatheter and withdraw the primary catheter into the IIA. It may also be necessary to infuse a spasmolytic agent such as nitroglycerin (NTG, 100 to 200 µg). Some operators use these agents in every case, but others do so only when spasm is encountered.

Once the above steps have been completed, more distal catheterization can be undertaken. The ideal position for the catheter tip during embolization is at the medial aspect of the horizontal segment of the UA, past the cervicovaginal branch if it can be identified. The risk of new or additional vasospasm is increased if one advances the catheter or wire through very tortuous arterial segments, so the ideal position cannot always be reached. In these cases, safe embolization is still possible, but greater care must be taken to avoid reflux or nontarget embolization.

Putting It All Together: One Operator's Technique

The right femoral artery is accessed without a sheath. A 4-Fr pigtail catheter is advanced to the level of the renal arteries (to opacify any OA collaterals) and a nonselective arteriogram is performed with imaging centered over the pelvis. The pigtail is then used to direct a long-taper Terumo glide wire over the aortic bifurcation and into the left iliac artery. The pigtail is exchanged for a 4-Fr Berenstein catheter (Cook, Inc), which is then directed into the proximal aspect of the contralateral UA with roadmap imaging. The artery is evaluated angiographically, after which either the 4-Fr catheter or a coaxial microcatheter is advanced distally into the artery to an appropriate point for embolization. Nitroglycerin is only used if spasm is identified. Once embolization is complete, a Waltman loop is formed in the 4-Fr Berenstein catheter. The catheter is then redirected into the ipsilateral UA using the soft end of the glide wire. Initial angiography, followed by more selective catheterization and embolization, are performed in a manner identical to the contralateral side.

Embolic Agents

Gary P. Siskin

Transcatheter embolization represents an integral component of most contemporary interventional radiology practices. Therefore, most interventional radiologists are comfortable with a wide range of embolic agents and have the skills to apply them to a variety of clinical circumstances. With the sustained enthusiasm for UFE, there has been a renewed interest on the part of many to develop new embolic agents and to gain a better understanding of how the established agents work and in what manner they are best applied for this indication.

At the present time, polyvinyl alcohol (PVA) is the most commonly used embolic agent for UFE, based on substantial evidence attesting to its safety and efficacy (Fig 6A). The intravascular administration of PVA initiates a local inflammation and thrombosis that results in target-vessel occlusion. There has been some recanalization reported to occur several months after embolization.¹⁸⁻²¹ Recanalization tends to occur within the interstices of the lumen that contains thrombus and not the latticework of PVA particles, which is not biodegradable.²²

Tris-acryl collagen-coated microspheres (Embospheres, Biosphere Medical, Rockland, MD) are a recent addition to the list of available embolic agents (Fig 6B). They are hydrophilic and nonabsorbable. Intravascular administration of embospheres causes a thrombotic reaction that is similar in nature to that induced by PVA.²³ Extensive experience with embospheres as a preoperative means of devascularizing meningiomas, craniofacial tumors, and arteriovenous malformations has been highly successful.²³⁻²⁵ Published experience with embospheres is as yet limited for UFE²⁶; however, outcomes after use in this area, too, have been very positive to date.

Gel foam (Pharmacia and Upjohn Company, Kalamazoo, MI), a temporary agent, has enjoyed decades of widespread use for pelvic applications, such as obstetrical hemorrhage and trauma.^{18,27} Histologically, gel foam initiates an acute arteritis of the arterial wall that ultimately induces thrombosis.^{28,29} Studies have shown that resorption of gel foam typically occurs by 6 weeks after embolization, with minimal tissue reaction.²⁹⁻³¹ Some authors have chosen gel foam for UFE, specifically because the goal of the procedure is to induce acute ischemia in

the fibroids for a short period of time while preserving uterine function in the long term.³² Nevertheless, gel foam has not been widely adopted for UFE.

With 3 embolic agents capable of producing arterial occlusion, ideally, criteria should be established for selecting 1 or more of these agents for the different clinical situations one may face when performing UFE. These criteria are unlikely to be available for several years because there have not yet been studies that compare the effects of these different agents or the effects of this procedure on specific patient populations. Until that time, choosing an embolic agent derives from whatever published information exists and individual operator comfort with the properties and theoretical advantages of 1 agent versus another.

If basing the selection of an embolic agent for UFE solely on the published literature, the choice becomes simple. All of the major studies supporting the claims that UFE is an effective treatment option for women with symptomatic fibroids have been based on procedures performed with PVA as the embolic agent. These papers support the success of UFE in many hundreds of patients with follow-up of up to 6 years.³³⁻³⁶

The published experience with embospheres for uterine fibroid embolization is limited to the Phase I data reported by Spies et al in 30 patients, 29 of whom had follow-up data available at 6 months.²⁶ This single study does suggest that embospheres will prove to be an effective alternative to PVA. Additional objective studies with longer follow-up are required before definitive long-term statements can be made. Data supporting the use of gel foam for UFE are also limited at the present time.^{32,37-39}

If basing the selection of an embolic agent for UFE on the properties inherent to a particular agent, then the choice becomes more complicated. While the use of PVA has led to the heralded success of UFE, there are characteristics that cast doubt on whether this is the best available agent for this procedure. In their present form, PVA particles are somewhat jagged and tend to clump together during intravascular administration, which makes their effective size larger than it would otherwise be for individual particles. This leads to more proximal embolization and potentially allows collateral vessels to bypass

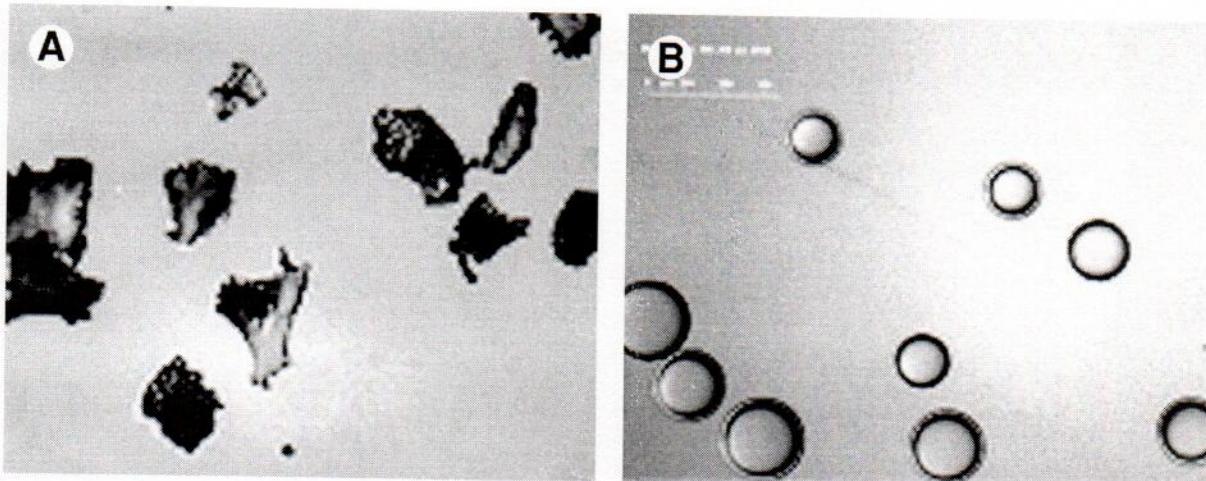


Fig 6. Photomicrographs of (A) PVA and (B) embospheres, demonstrating the morphologic differences between the 2 embolic agents.

the embolic occlusion. Reducing the tendency for particulate aggregation by greater dilution may improve distal embolization and may also lessen the difficulties encountered when administering this agent through a microcatheter.^{40,41} A second potential problem with PVA results from the manufacturing process, which involves milling a sheet of PVA plastic and then passing the particles through successively smaller sieves. Smaller particles than intended may initially cling together in the dry state but disaggregate in solution. This may lead to a more distal embolization and possibly unintended organ infarction and/or nontarget delivery.⁴²

These theoretical disadvantages attributed to PVA have been largely responsible for the recent interest in embospheres. When comparing embospheres with PVA, there are definite differences in the biomechanical properties of the 2 agents in terms of surface structure, shape, and deformability.⁴³ It is the gelatin-like nature of these hydrophilic spheres that makes them softer and more deformable than PVA and easier to administer through a microcatheter. These characteristics also lead to a reduced tendency for clumping and aggregation after intravascular administration.⁴⁴ This is supported by the observation that embospheres tend to form chains in smaller vessels.²³ These spheres have the property of truly being flow directed and can course through the target organ until they reach an artery that is the same size or smaller than the sphere itself.

In the case of UFE, embospheres may theoretically tend to flow toward the richly vascular fibroids and potentially spare the vasculature supplying normal myometrium. This may serve to reduce myometrial ischemia, which can in turn affect the amount of pain experienced after UFE. In addition, the manufacturing process responsible for producing these spheres assures uniformity within given size ranges, leading to a closer correlation between the diameters of the spheres and those of the occluded vessels. As histologic data regarding the vasculature that bridges the uterine and ovarian circulations become available, the ability to embolize with a more size-specific agent may reduce the risk of unintended ovarian infarction and premature menopause after UFE. While these remain, at best, theoretic advantages of embospheres, they are nonetheless attractive reasons to further investigate this agent.

The choice of an embolic agent for patients who desire to preserve fertility remains the most difficult choice to make at this time. In fact, even the decision to perform UFE in this population remains controversial. The experience with UA embolization for a variety of indications other than fibroids reveals that pregnancies have occurred in many patients undergoing this procedure.²⁷ In these settings, gelfoam has been the most commonly used agent because of its potential to preserve fertility. While gelfoam seems to be as effective as other agents for UFE for the short term, its long-term success for treatment of uterine fibroids is unknown.^{32,37,39} However, the ability for gelfoam to be resorbed may allow the uterus to meet the increase in demand for arterial blood during pregnancy; this makes it an even more attractive option for patients who are looking to preserve their fertility.

The current practice at our institution is to use gelfoam for patients wishing to preserve fertility who are not candidates for or do not wish to undergo myomectomy. Anecdotally, we have had 2 pregnancies among 16 patients who wished to preserve fertility. Without knowing in larger numbers whether there is an impact on those intending to get pregnant, recommenda-

tions for choice of agent remain speculative. Interestingly, there have also been several published reports of pregnancies after UFE using PVA as the embolic agent.⁴⁵⁻⁴⁷ Therefore, the use of a possibly permanent agent does not preclude future childbearing. At the present time, the application of embospheres in this patient population is entirely unknown.

In conclusion, choosing an embolic agent for individual patients undergoing UFE remains challenging, with each agent possessing features that are both positive and negative. Understanding their physical properties is a key to making a rational selection. Comparative long-term trials are needed to provide the answers to the many questions that still exist regarding which embolic agents are best suited to UFE.

Adjunctive Medications

Richard Shlansky-Goldberg

The most common intraprocedural medications during UFE include the nonsteroidal anti-inflammatory ketorolac (Toradol) and prophylactic antibiotics such as cefazolin (Ancef). These drugs are used to reduce the incidence of postembolization pain and infection, respectively, and are described elsewhere in the next section. Drugs that are less commonly used for UFE are intra-arterial (IA) lidocaine for pain, sublingual (SL) nifedipine and/or nitroglycerin IA for arterial spasm, and IA or systemic heparin for preventing premature main UA thrombosis.

Teleologically, the UAs are probably structured to be more prone to develop spasm as an adaptation to prevent excessive hemorrhage during menses or after childbirth. During UFE, spasm is very easy to induce with a guidewire, catheter, or simply by injection of contrast. Spasm in the distal circulation can reduce the efficacy of embolization by limiting the delivery of embolic particles. If spasm develops along the catheter, there may be such loss of antegrade flow that premature thrombosis occurs in the larger uterine vessels. It may also cause enough stasis of flow that the main UA thromboses, possibly leaving the distal branches patent when the spasm finally relaxes.

Without antegrade arterial flow, it is also difficult to determine the appropriate end point for embolization. In this setting, it is not unusual to see the artery distend with each injection of contrast and to see prompt filling of regional veins. One may also see retrograde filling of the OA if the pressure generated during injection exceeds that of the inflow from the OA. This puts the ipsilateral ovary at risk for embolic injury in this setting.

Strategies to prevent spasm include the use of iso-osmolar, nonionic contrast and microcatheter techniques. Pharmaceutical strategies include the use of nifedipine SL, nitroglycerin IA, and heparin intravenously. Nifedipine, a calcium channel blocker, has been used for years to reduce postangioplasty spasm.⁴⁸⁻⁵⁰ It blocks smooth muscle contraction by interfering with the movement of ionic calcium into the smooth muscle cell cytoplasm through calcium channels. Its action results in the inhibition of smooth muscle contraction.

For peripheral angioplasty, nifedipine is usually given as a sublingual 10-mg administration. Although nifedipine may cause coronary ischemia in older patients with heart disease, this should not be a problem for most women undergoing UFE. Nitroglycerin may also be given in 100- μ m aliquots intra-arterially in an attempt to prevent or break spasm. One potential drawback with the use of an arterial vasodilator is that it may

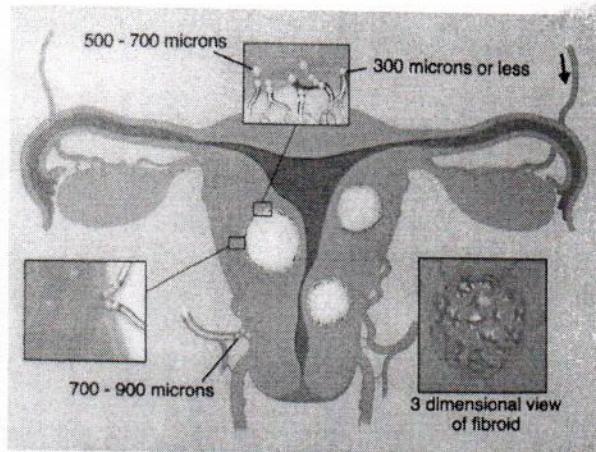


Fig 7. Schematic diagram of a myomatous uterus. Magnified areas at points in the perifibroid plexus target show optimal particle size to be in the 500- to 700- μm range to avoid embolization across the utero-ovarian anastomosis.

also dilate the small branches that anastomose with the ovarian circulation, which theoretically increases the risk of nontarget embolization to the ovaries.

The use of heparin helps prevent the tendency for spasm to induce thrombus to form around the catheter, and hopefully a balance is achieved between adequate embolization of the perifibroid plexus and rapid recanalization of the treated vessels. Some authors have added heparin to the syringe containing the embolic particles while others have administered it intravenously as a 3,000- to 4,000-U bolus.

Other potential adjuncts include the intra-arterial injection of lidocaine to reduce postembolization pain. The initial report of UFE in the United States described using intra-arterial lidocaine,⁵¹ but this practice has been abandoned for several rea-

sions. Most postembolization pain begins shortly after the procedure has concluded. It increases in intensity for several hours, which is long after the lidocaine effect has worn off. More important, a double-blind, prospective, randomized trial showed that not only did lidocaine fail to decrease postprocedure pain, as compared with a control group, but its use was also associated with moderate to severe vasospasm.⁵²

Embolization Endpoints

John C. Lipman

Most interventional radiologists (IRs) who have past experience with UA embolization learned these techniques using gelfoam. For UFE, particulate emboli are the preferred agents, most notably PVA. Fortunately, learning UFE required no additional training because PVA has been available for nearly 3 decades, and most IRs have a great deal of experience with it.

The embolic target is the uterine perifibroid plexus (Fig 7). These arteries have been shown to be approximately 500 μm in diameter.⁴⁴ The use of particles smaller than 355- μm particles is contraindicated because of compelling evidence in humans and animals of the increased risk of uterine infarction and nontarget embolization to the ovaries.⁵³⁻⁵⁵ On the other hand, if UA embolization is performed too proximally (eg, with coils) or only unilaterally, the result will almost certainly be failure because the blood supply to the uterus has a variety of collateral pathways.

The PVA particle size for UFE is generally 355 to 500 μm , 500 to 710 μm , or a combination of both, injected into both UAs at or beyond the level of the horizontal segment⁴ (Fig 8). Early experience was to embolize to near-total or complete stasis and, in some cases, even proximally occlude the UAs with gelfoam plugs or metallic coils. However, capping the artery produced such postembolization pain in almost every patient that, when there wasn't significant pain afterward, the concern was that a less than optimal outcome would result. The severity

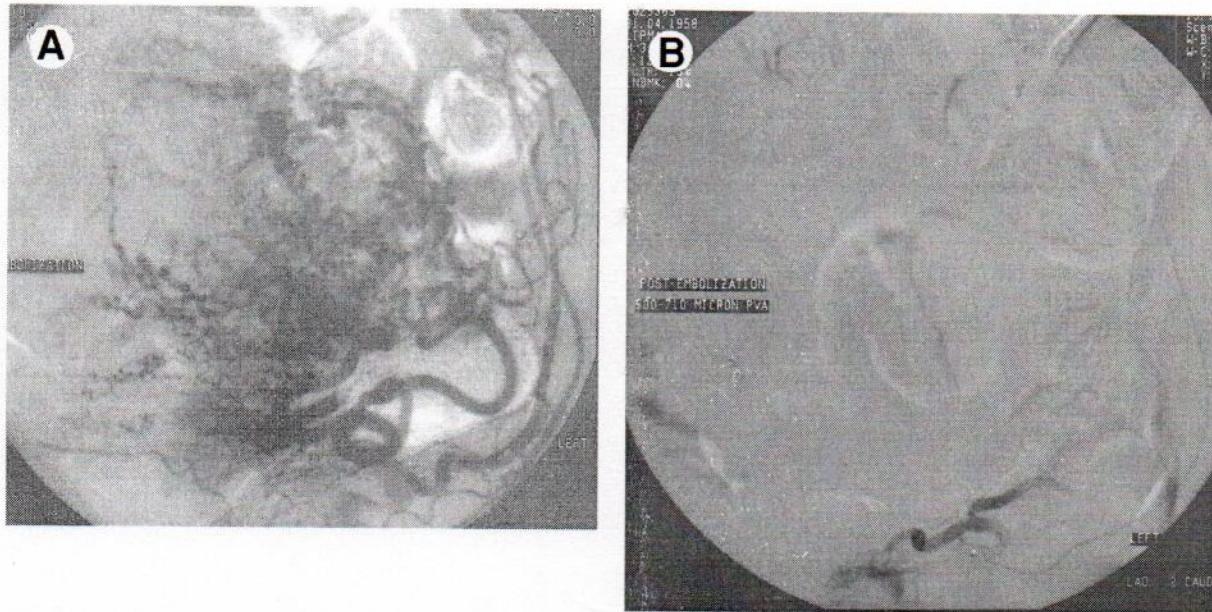


Fig 8. (A) Preembolization arteriogram of the left uterine artery with PVA. (B) After embolization with PVA, there is only a stump left of the remaining transverse portion of the artery.

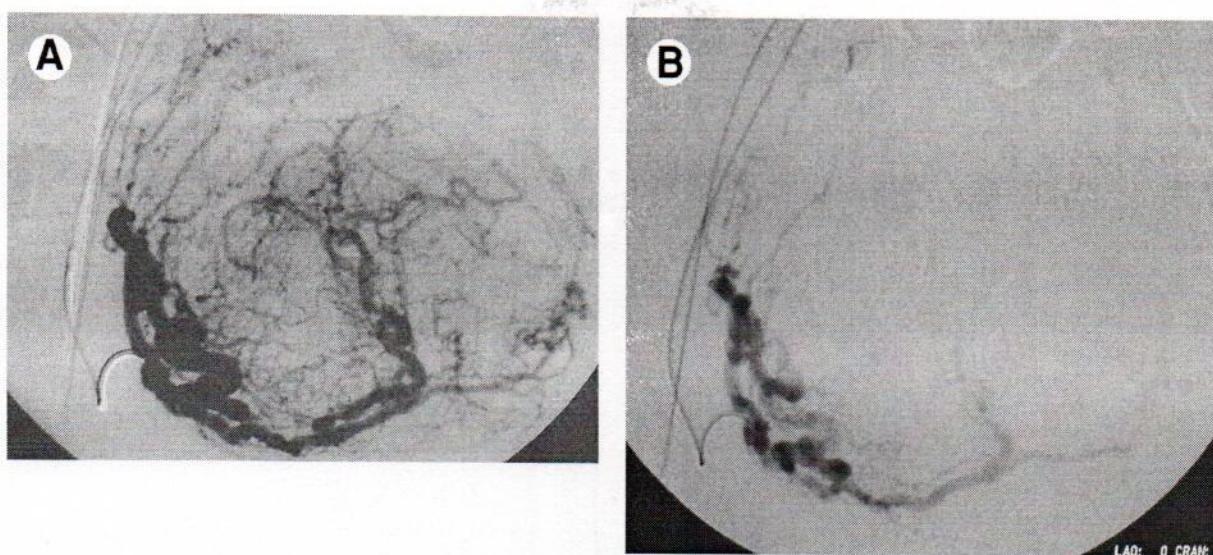


Fig 9. (A) Preembolization of right uterine artery with embospheres. (B) After embolization, the ovarian branches have been markedly pruned. Note the preservation of proximal flow including ovarian supply.

of symptoms also necessitated aggressive pain regimens. Some IRs began to use spinal anesthesia or enlist the aid of an anesthesiologist to perform epidural anesthesia.

This practice also potentially increased the chances for severe uterine ischemia and necrosis. Consequently, we never adopted this strategy of capping the artery and feel that we have gotten the same results with significantly less pain. Most of our patients go home the same day as the procedure, obviating the need for overnight admission.

A new step in the evolution of UFE came in April 2000 with the introduction of embospheres to the United States. This agent offers the theoretical advantage of not aggregating too proximally in the UA, which allows for a more targeted embolization. With PVA, embolization is often carried out to virtual stasis of the horizontal segment of the UA. With embospheres, the strategy is to embolize until the fibroid hypervascularity is eliminated, leaving flow in the main UA sluggish but patent, sometimes likened to the pruning of a tree (Fig 9). With embospheres and a new endpoint for embolization come the added potential benefits of less uterine ischemia.

In our experience with embospheres, there does appear to be less postprocedure pain with PVA, and the results appear to be equivalent. With less uterine ischemia, there should also be fewer complications. With more precise particle size, there should be a lower risk of nontarget embolization to the ovaries. The typical amount of embospheres needed is 2 mL per side, and very little contrast is needed for optimal suspension of particles for injection even through a microcatheter. These features translate to potentially lower volumes of contrast, shorter injection times, and decreased fluoroscopy dose. These theoretical advantages await comparative study.

Flow Redistribution

John C. Lipman

As mentioned previously, in order for UFE to be successful, embolization must be done bilaterally (Fig 10). Two techniques will help maximize chances for a successful outcome. The first

is to use a 4-Fr (rather than 5-Fr) catheter system to minimize the tendency to cause vasospasm. My preference is to select a 4-Fr Cobra-2 for the left uterine artery and a 4-Fr Simmons-1 catheter for the right side. The other is to take advantage of a phenomenon that occurs during embolization, namely flow redistribution.⁵⁶ As flow is occluded in 1 uterine artery, there is a rapid shift to maintain uterine flow by vasodilatation of the contralateral uterine artery. The ovarian arteries may also become involved in this process. Flow redistribution can be a useful phenomenon to exploit in other procedures as well, such as the hepatic arteries during chemoembolization.⁵⁷

I begin every UFE with a pelvic arteriogram, which provides an initial survey of the sizes of the uterine arteries and the distribution of fibroid hypervascularity. Correlation is made with preprocedural imaging studies in regard to size and location of the dominant fibroids. If there is a discrepancy, I look carefully to see whether 1 or both of the ovarian arteries may be supplying blood to the fibroids.



Fig 10. Left uterine artery angiogram, demonstrating retrograde filling of the contralateral uterine artery.

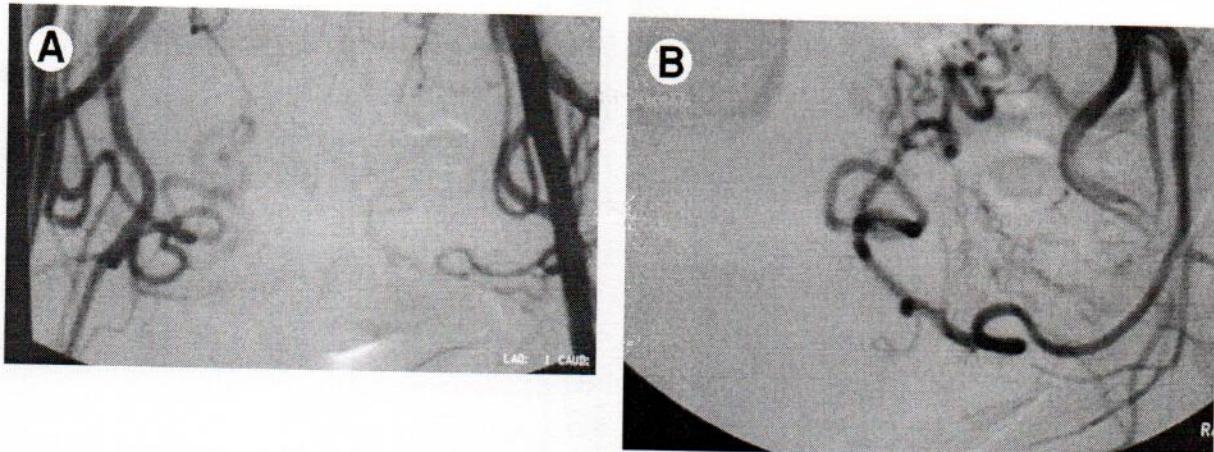


Fig 11. (A) Pelvic angiogram prior to UFE. The right uterine artery was embolized first due to its larger size. (B) After embolization, an angiogram reveals flow redistribution to the left uterine artery that facilitated catheterization.

The larger uterine artery is then embolized first. As flow redistribution occurs, the contralateral uterine artery becomes more prominent and easier to catheterize (Fig 11).⁵⁶ Because of the intercommunication between the right and left uterine artery circulations, occasionally retrograde filling of the opposite side may be seen during the initial embolization. As a result of this cross filling, the amount of embolic agent needed for embolization of the contralateral side is often less.

Pelvic or abdominal aortography prior to embolization may demonstrate large ovarian arteries in up to 25% of cases.⁵⁸ After embolization of both uterine arteries, the flow in the ovarian arteries may increase, persist, or decrease. In 1 study of this interesting latter phenomenon, nearly two thirds of the ovarian arteries that were initially visualized were no longer seen after embolization (Fig 12).⁵⁸ Possible explanations include a reduction in the sump effect of the hypervascular fibroid mass, retrograde occlusion of the ovarian artery through the uteroovar-

ian anastomosis, or both. If the ovarian artery is still prominent after UFE, embolization may be indicated.

Radiation Dosages Robert T. Andrews

Like other fluoroscopically guided interventional procedures, UFE exposes the patient to ionizing radiation. Unlike many other procedures, however, UFE requires that the uterus and ovaries be placed directly in the imaging beam for periods of time that can be quite prolonged. This fact is particularly noteworthy because the specific goal of UFE is to preserve these radiosensitive organs and potentially maintain fertility.

The risk of radiation-induced malignant degeneration increases with dose in a stochastic manner (ie, without a recognized threshold for safety).⁵⁹ Because a woman's ovaries contain at birth the entire complement of oocytes that she will ever



Fig 12. (A) Abdominal aortogram prior to UFE, with prominent right ovarian artery (arrowheads), which supplied the right fundal region. (B) Following embolization, the artery no longer opacifies.

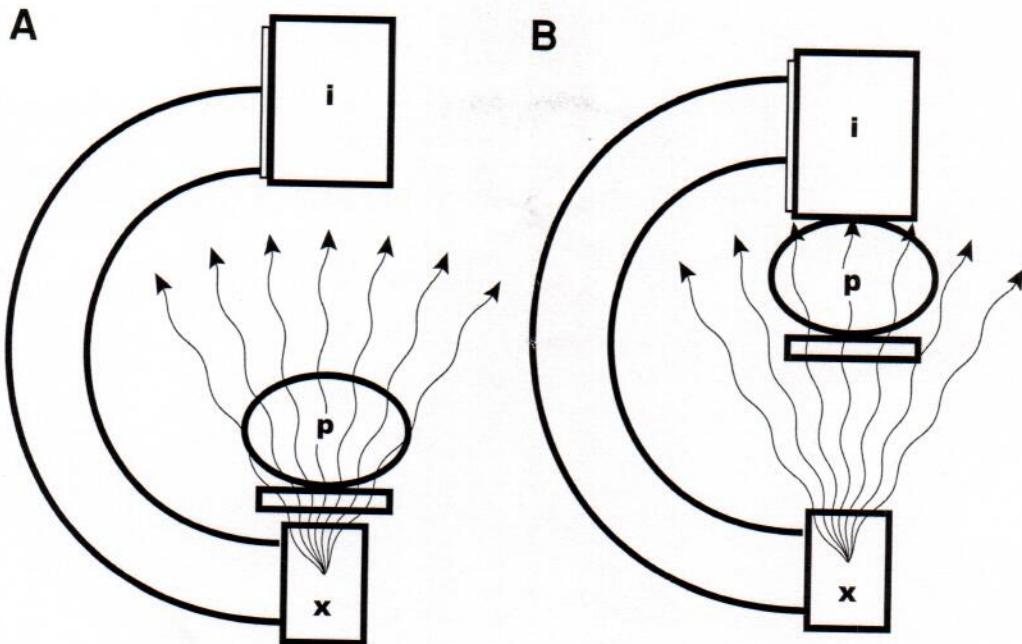


Fig 13. Effect of table configuration upon dose. Schematic diagrams of (A) less favorable and (B) more favorable table configurations show that the patient (p) absorbs significantly more radiation (curved arrows) when close to the x-ray source and far from the source and close to the intensifier.

produce, the potential for genetic injury to her offspring also varies in a similarly stochastic manner.⁶⁰ In clear contrast, the risks of ovarian failure and clinically detectable injury to skin at the beam entry site are nonstochastic, occurring at thresholds of roughly 400 cGy and 200 cGy, respectively.^{61,62}

Published studies indicate that the doses absorbed by a patient during UFE can be kept far below these levels.^{12,17} In fact, patient exposures can be low enough to be comparable with those of abdominal/pelvic computed tomography and certain other diagnostic imaging studies.¹⁷ Accomplishing this, however, requires careful attention to radiation safety.

Variables Beyond Operator Control

Some of the factors that influence patient dose are inherent in radiographic imaging and cannot be directly manipulated by the operator. An awareness of these issues is nonetheless useful, and they are briefly discussed in the next several paragraphs.

Imaging equipment

The conversion efficiency of the imaging chain—its ability to convert radiant energy to a useful fluoroscopic image—has a direct impact on patient dose. To maximize safety, the radiographic equipment used for UFE or any other interventional procedure must be well maintained and regularly inspected by qualified personnel. It is not appropriate to use fluoroscopic equipment designed for any purpose other than angiography.

Body habitus

The percentage of incident radiation absorbed by a patient depends on the volume and density of tissue through which the beam passes. Patients with a greater abdominal girth will therefore absorb more radiation during UFE than will those who are thinner. In addition, patients having a larger mass of fibroid

tissue (which increases density) will also absorb more than patients having less fibroid tissue. Therefore, while dose-reducing strategies are important for all patients, they are especially so for obese patients and those with very large fibroids.

Operator experience

Uterine fibroid embolization, like any interventional procedure, requires a certain level of operator experience before it can be performed in a reproducibly short period of time (which translates directly to fluoroscopic time).¹⁷ This learning curve cannot be eliminated, but its slope can be significantly improved with effective training. Thus, it is in the best interest of the patient, the physician, and the institution if formal, supervised training is obtained before beginning a clinical practice in UFE. At the very least, the operator should have previous expertise with superselective catheterization, including the use of microcatheters, and be experienced in particulate embolization techniques.

Variables That Can Be Controlled

A careful operator can significantly affect the dose delivered to his or her patient during UFE. Some of the techniques discussed here are self evident, but other parameters are often poorly understood and adaptations are therefore underutilized.

Table configuration

Raising the patient as far from the beam source as practical while simultaneously minimizing the distance between the patient and the image intensifier (Fig 13) can decrease the dose rate for fluoroscopy and imaging runs by up to 50%.^{17,63} In addition to being somewhat awkward, this configuration increases under-table scatter to the operator, and one should

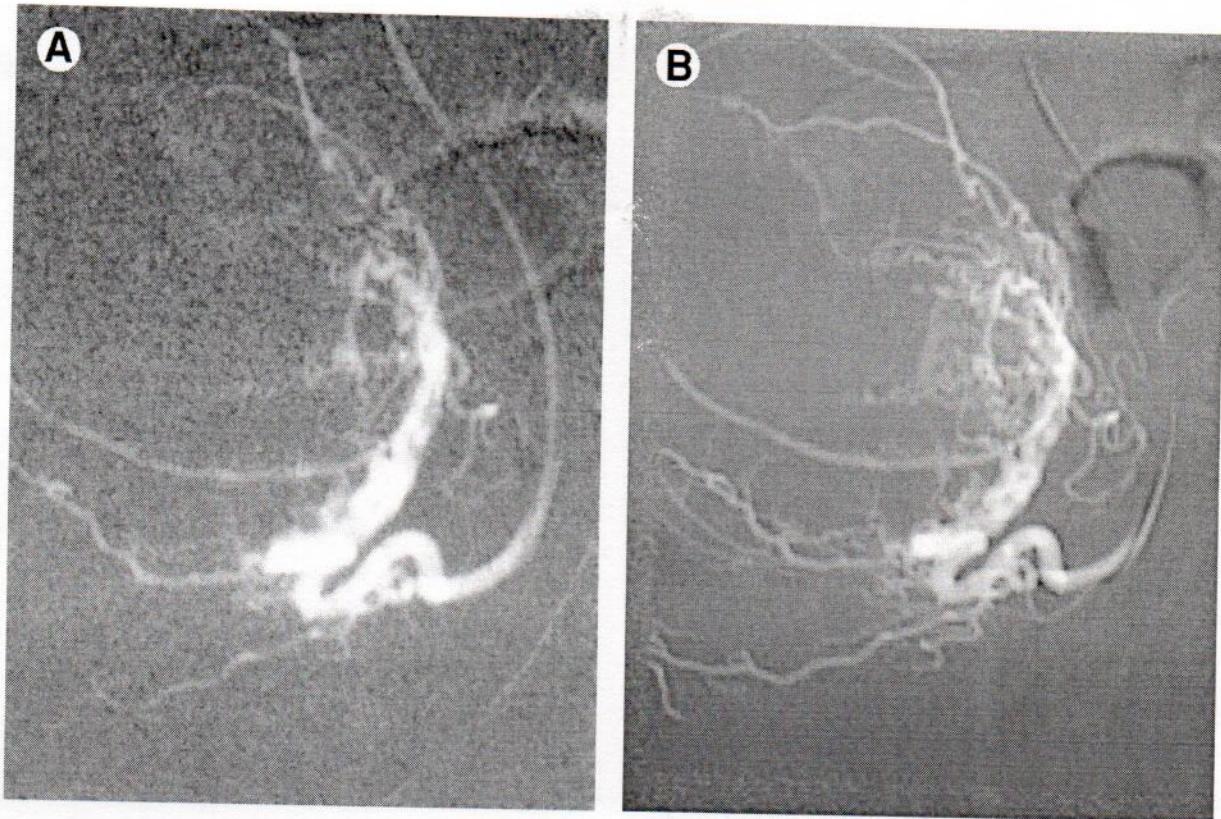


Fig 14. Reduced-dose imaging. Comparison of a roadmap image (A) obtained with 4 seconds of fluoroscopic time to an image obtained with standard digital subtraction (B). The roadmap image has lower resolution and less detail but is adequate for documentation and delivers significantly less radiation to the patient.

consider the use of additional floor-level shielding when it is employed.⁶⁴

Fluoroscopic mode

Most modern angiographic machines have the capacity for generating low-dose and/or pulsed fluoroscopic beams. The former is created by interposing various filters into the beam within the tube housing, while the latter results from delivering interrupted power to the tube at rates of 4 to 30 pulses per second (PPS). Pulsed fluoroscopy has the additional benefit of reducing motion-related blur. These features are activated at the discretion of the operator and can reduce the fluoroscopic dose by more than 50%.^{12,17,63}

In some situations, high-frequency (30 PPS) pulsed fluoroscopy can actually generate a higher patient dose than a continuous beam.¹⁷ In addition, many angiographic machines are modified after delivery to generate other special dose modes at the push of a button. These doses can be, in some instances, much higher than standard fluoroscopy. Therefore, before one begins to employ modified-dose fluoroscopy in a given angiography suite, it may be useful to have these features specifically evaluated by a radiation physicist.

Imaging projection

The origin of the uterine artery is often obscured by overlying vasculature in a direct frontal projection. However, while an oblique view may facilitate catheterization, it has been reported

to increase the delivered dose by up to 30%.⁶⁵ This, in turn, may increase scatter dose to the operator. Therefore, once catheterization has been achieved, the imaging configuration should be restored to a frontal projection.

Roadmapping

Roadmap imaging—the superimposition of a stored image over a live fluoroscopic image—can be extremely useful in selective catheterization of the uterine artery or, as described later, in avoiding the reflux of embolic material. In many cases, roadmapping can be turned on and off without any change in dose. However, in some angiographic machines, activation of the roadmap feature simultaneously disables any low-dose or pulsed fluoroscopic modes that may be operating. In such cases, an operator using low-dose or pulsed mode may unknowingly increase fluoroscopic dose rates by over 200% when activating the roadmap feature.¹⁷ Because the change in beam quality may be unannounced, it can easily go unrecognized. As with pulsed and low-dose fluoroscopy, a specific evaluation by a radiation physicist may be required before one can determine whether this process is occurring in a given angiographic suite.

Magnification

Given the sometimes difficult process of uterine artery catheterization and the relatively small target area for embolization, it is tempting to use a magnified image throughout the UFE procedure. However, this technique results in significantly el-

evated radiation doses to the patient: Depending on the angiographic equipment used, full magnification can increase the dose by 31 to 154%.^{17,63,65}

Magnification should certainly be employed as required to facilitate catheter placement and to visualize reflux, especially if doing so allows the total fluoroscopic time to be reduced. However, when not absolutely necessary, magnification should be avoided. A useful technique for recognizing reflux without the use of magnification is digitally subtracted fluoroscopy, or reverse roadmapping. The operator activates the roadmap feature and generates a blank, or mask, image without the infusion of contrast. Thereafter, when the fluoroscopic pedal is depressed, injected contrast is clearly seen as dark material against a bland background, and reflux can be recognized quite easily. (As discussed previously, roadmap imaging can itself increase dose in some angiographic suites and should be used with caution in such cases.)

Images acquired

Most operators perform at least 1 dedicated digital acquisition sequence during every UFE procedure. Usually a nonselective aortogram, centered over the pelvis, is obtained to delineate the uterine arteries and to identify collateral blood supply. Other sets of images including selective uterine injections before and after embolization can substantially increase the radiation dose because image acquisition results in markedly higher doses than fluoroscopy. In fact, a single digital image can expose the patient to the same dose as 50 seconds of fluoroscopic time.¹⁷

Clearly, extraneous images and imaging sequences should be eliminated. A simple mechanism for accomplishing this is to film the fluoroscopic "last image" whenever possible rather than obtaining a dedicated spot radiograph. To do so, one injects contrast during fluoroscopic observation and steps off the pedal when the desired level of vascular opacification has been achieved. This can be done with or without activation of the roadmap feature. In most angiographic suites, the resulting image can be stored and filmed. While the image quality is relatively poor, it is generally adequate for documentation (Fig 14). When dedicated acquisition sequences cannot be avoided, these studies should be performed with the slowest acceptable imaging rate (0.5 to 1 frames per second rather than the usual 3 to 4). The use of bilateral femoral artery catheterization can also be useful in this regard by allowing simultaneous bilateral uterine arteriography with a single filming sequence.¹²

Conclusions

The factors influencing patient radiation exposure during UFE are many and varied. Techniques for dose reduction can be subtle and occasionally conflicting. Nonetheless, an experienced operator using careful technique can expect very little risk of radiation-induced complications.

Panel Discussion

Q: Do you have a preferred catheter choice or approach and why?

Dr Lipman: I use a right femoral approach and prefer a 4-Fr system. I use a 4-Fr Pigtail for diagnostic angiography, followed by selective catheterization with a 4F Simmons 1 on the right and a 4-Fr Cobra glide catheter for the left. This combination

can be used in the large majority of cases. Occasionally, one will need a microcatheter to get selective enough, and any of the standard ones will do the job with 1 important caveat. If you are using 700 to 900 μm embospheres, you cannot use a regular sized Tracker microcatheter (eg, Tracker-18) but need one with a larger inner diameter (Fast-Tracker 325, Mass Transit, etc.).

Dr Worthington-Kirsch: I usually start with a 5-Fr Levin I catheter from the right femoral approach. I am able to perform over 85% of cases with this single catheter. If I am unable to catheterize the uterine artery with this catheter, I switch to a 5-Fr Osborn II curve, which suffices in almost every case.

Dr Andrews: I use a 4-Fr glide catheter because it is soft and has a low profile. I only use coaxial microcatheters if the primary catheter is too large or causes spasm. My microcatheter of choice is a very inexpensive and low-tech 3-Fr catheter from Cook.

Dr Siskin: I prefer unilateral access from the right common femoral artery and typically use a 5-Fr Cobra-2 Glide catheter with or without a microcatheter (approximately 50% of the time, a microcatheter is required due to the occlusive or subocclusive nature of the 5-Fr Cobra catheter). In my experience, most if not all cases can be completed successfully using these catheters from unilateral access.

Dr Goodwin: My preferred approach is the right groin approach. My primary catheter is a Levin-1 from Cook. I routinely use a large-bore microcatheter, usually the Boston Scientific Corporation FasTracker 325. I usually use the Taper 22 wire from Boston Scientific Corporation along with this microcatheter. I use the Levin-1 catheter because it has enough of a primary and secondary curve to usually allow catheterization of the contralateral common iliac artery but not enough curvature to cause the tip to dig into the side of the arterial wall once the internal iliac artery is catheterized. I use a microcatheter routinely to avoid spasm in the uterine artery, which can be occlusive and fairly refractory to vasodilators.

Dr Bonn: My recipe is as follows: 4-Fr sheath, 4-Fr Cobra into contralateral internal iliac artery, road map 40° RAO, 3-Fr microcatheter into uterine artery to reduce spasm risk, uterine arteriogram through the microcatheter, embolize. Waltman loop, Cobra into ipsilateral internal iliac, road map 40° RAO (yes, the same as the contralateral side), 3-Fr microcatheter into uterine artery, arteriogram, embolize.

Dr Shlansky-Goldberg: The 2 primary catheters I use are a 4-Fr hydrophilically coated, angled catheter for most uterine arteries that do not arise at a sharp angle to the main anterior division trunk. For sharper angles, the 4-Fr Roche Inferior Mesenteric catheter is ideal. A single groin puncture is made. For selecting the ipsilateral uterine artery, we form a Waltman loop with 4-0 Tevdek (see Journal of Vascular and Interventional Radiology 12:997-1000, 2001). In addition, the use of microcatheters helps to reduce spasm.

Q: What is your choice of embolic agent (including size) and why?

Dr Lipman: For permanent occlusion, my embolic agent of choice is embospheres. By targeting the perifibroid plexus, you achieve the goal of embolization with less collateral ischemia to the surrounding myometrium and ovaries while keeping the same technical success. Less ischemia should cause less pain to the patient and allow this procedure (as it has been in our hands) to be an outpatient procedure. There should also be less postembolization syndrome and fewer infections. Intuitively, with less global ischemia, ovarian failure rates may not be as

high (with concomitant positive effect on the fertility rate). It is also much easier to use with a microcatheter.

Dr Worthington-Kirsch: I currently use either PVA (300 to 500 μm) or embospheres (500 to 700 μm). These provide embolization at the 500- to 600- μm level, which is the diameter of the vessels in the perifibroid plexus. Larger PVA is more likely to clog the catheter.

Dr Andrews: Until recently, I had been using 300- to 500- μm PVA because it was with that agent that most authors have reported the outcome data to which we all refer. I have lately switched to 500- to 700- μm embospheres. I like the way these particles handle and I am able to use less material. In addition, there is anecdotal data (including my own experience) to suggest that patients have less pain with embospheres. The size is based on observations in the neurointerventional literature that 300 to 500 PVA and 500 to 700 embospheres seem to target similar-sized vessels.

Dr Goodwin: I usually use PVA 300 to 500 μm . I used 500- to 700- μm PVA in approximately my first 58 patients. I based my initial program on the French work, although they were using smaller particles. I knew that particle sizes above 300 μm usually allowed for collateral flow in the precapillary arterioles. I went up 1 size from 300 to 500 μm to allow for an extra margin of safety, as there was no prior work in the United States at that time. After the first 58 patients, I was satisfied with the safety of the procedure and I switched to 300- to 500- μm PVA, hoping that there would be additional efficacy with no additional safety issues, although I anticipated increased pain. I was not able to demonstrate that this change in size decreased safety, increased efficacy, or worsened the pain syndrome.

When embospheres came on the market, I discussed both agents with patients and allowed them to make the choice. Most patients chose PVA because of its longer history of safety and efficacy. A few patients did choose embospheres. I find embospheres to be easier to inject. However, additional material may be needed to reach the same end point. Many investigators do not use the stasis endpoint, but leave the lower uterine artery segment intact. I have been concerned that this may lead to lower efficacy in the long run.

Dr Bonn: Embospheres. They do not clump or occlude even in a Turbo Tracker.

Dr Shlansky-Goldberg: Currently there is no convincing data to suggest that one agent is better than another. Using a delivery syringe system with a 1-cc syringe, 3-way stopcock, and a 10-cc syringe as a reservoir enables one to easily inject particles into the microcatheter. The pressure from the 1-cc syringe prevents plugging of the catheter. Injection with 355- to 550- μm PVA is easy, and that particle size has produced good results in multiple studies.

Q: Do you perform your entire embolization with a single particle type and size, or do you start with small particles and increase over time, or use gelfoam after PVA or embospheres to "cap" the artery?

Dr Lipman: I routinely start with 2 ml of 500- to 700- μm embospheres and will upsize to 700- to 900- μm particles after that. The routine case will require ~6 ml (3 vials). I don't cap the artery.

Dr Worthington-Kirsch: I do not use gelfoam as a supplement. When using embospheres, I use no more than 6 ml of 500- to 700- μm particles in any one vessel. If I still need more emboli after 6 ml, I will upsize to the 700- to 900- μm size.

Dr Andrews: With embospheres, I use a single size (500 to

700 μm). When I was using PVA, I would embolize to near-stasis with 300- to 500- μm particles and then completely occlude flow with a slurry of gelfoam.

Dr Shlansky-Goldberg: I use the same particle size until stasis. I look for the contrast column not to move past the first turn of the uterine artery (the parametrial portion) for 5 heartbeats as a method of defining my end point.

Dr Goodwin: I routinely use PVA 300 to 500 μm until stasis or near stasis. In most cases, I have capped the PVA embolization with several pieces of gelatin sponge.

Q: Is there a role for using gelfoam in certain circumstances, eg, for patients who specifically indicate a desire to preserve future fertility?

Dr Lipman: Yes, I believe there is, until we have more data.

Dr Worthington-Kirsch: No. I have done repeat angiograms on 9 women who were embolized with PVA supplemented by gelatin sponge (3 months to 2 years post-UFE). Seventeen of 18 uterine arteries remained occluded. I feel that an embolic material that has a high risk of causing enough inflammatory response that the vessel is cicatrized should not be used, especially in young women who may need a repeat UFE several years later.

Dr Andrews: Gelfoam will probably turn out to be as effective as all other particulate agents. It may be preferable in women who desire fertility because it may improve subsequent uterine flow. For now, I do not routinely use it as a primary agent in UFE because we know that PVA and embospheres work well and there are no comparative data for gelfoam.

Dr Hovsepian: I do not use gelfoam, primarily because it can be difficult to inject gelfoam pledges through the small catheters needed for UFE without them emerging explosively from the catheter and possibly causing nontarget embolization.

As regards the theoretical advantage to uterine health by using a resorbable agent such as gelfoam, occasionally, the inflammatory response to gelfoam is so vigorous that the artery will fail to recanalize. On the other hand, vessels embolized with PVA have also been shown to partially or completely recanalize as the thrombus is resorbed, leaving the scaffold of particles still lodged in the vessel. Embospheres are deformable spheres that may wedge into the arteries so completely that recanalization cannot occur. They may be the only truly permanent agent.

Dr Siskin: We utilize gelfoam either at the request of a patient or for patients expressing a strong desire to preserve fertility after embolization who are not candidates for or do not wish to undergo a myomectomy. To date, we have treated 22 patients with gelfoam and have found it to be equivalent to PVA in its ability to cause significant improvement in symptoms and significant reductions in uterine volumes.

In light of the clinical success we have seen with this agent, we believe that the historical ability of gelfoam to preserve fertility and the tendency toward resorption and arterial recanalization make gelfoam an attractive option for patients looking to preserve their fertility. This is the current practice at our institution for patients wishing to preserve fertility and, anecdotally, we have had 2 pregnancies in our gelfoam population of 16 patients wishing to preserve fertility.

Dr Bonn: I don't think so. However, the cost of embospheres for very large fibroids can be considerable, which might be reduced by the supplemental use of gelfoam.

Dr Shlansky-Goldberg: The theoretical advantage of embolizing with gelfoam is that the uterine artery may recanalize

after the fibroids have infarcted. However, the disadvantage of gelfoam is that it is hand-cut and particle size is variable. The result may be a suboptimal (proximal) occlusion. Arteries embolized with PVA may also recanalize, to a lesser extent than gelfoam, and PVA has a proven track record for UFE. Patients have also had successful pregnancies after uterine artery ligation, which suggests that recanalization may not even be an issue. I prefer to use PVA in all cases in order to get the best outcome, with my end point being 5 heart beats without contrast moving past the first bend in the parametrial portion of the uterine artery.

Q: Do you look prospectively (MRI or angio) for ovarian arterial contribution?

Dr Hovsepian: I obtain an MRA on all patients beforehand as part of their MRI examination (if the insurance company authorizes the scan). It is intended to evaluate the uterine arteries, but knowing that there is accessory blood supply in advance allows us to discuss ahead of time the issues involved in embolizing 1 or both ovarian arteries. The preprocedure MRA saves on time, contrast, and radiation.

Interestingly, the identification of 1 or both ovarian arteries may or may not indicate an important contribution of flow to the fibroids. It has been postulated that seeing the ovarian arteries prior to embolization may represent abnormally increased flow due to a "sump" effect by the uterine arteries on the ovarian circulation. After embolization, flow in the ovarian arteries might return to normal. Therefore, some investigators would advocate obtaining an aortogram only *after* embolization.

Dr Goodwin: I have not done this routinely. I think the data now show that ovarian arterial contribution to the fibroids may occur in 10% of patients. The question that I feel has not definitively been answered is whether these patients should have their ovarian artery embolized initially or whether they should be followed to see if their symptoms resolve and have a follow-up angiogram and embolization only if they fail to improve. My current thinking is that if the uterine arteries do not appear to feed the entire uterus on angiography then, it is probably worthwhile to look for ovarian supply on angiography and embolize at least 1 ovarian artery with gelatin sponge if the patient has agreed to this preprocedurally.

Dr Shlansky-Goldberg: We perform Gadolinium-enhanced 3-D acquisitions for arterial anatomy. MRA has been very good for documenting the uterine arteries, but ovarian collaterals have been difficult to prospectively detect due to their circuitous course.

Dr Bonn: No, I save the exposure, contrast, and time for clinical failures.

Dr Lipman: I perform a diagnostic pelvic angiogram first. I correlate the size of the uterine branches and amount/distribution of the hypervascular branches with what I would expect based on the pre-embolization MRI exam. If the size is rather small or the distribution appears incomplete, I know that I will need to look for ovarian collaterals. I like the idea of Dr Hovsepian's to look with MRA prospectively for these collaterals, but as of yet, I have not incorporated that into my practice.

Dr Siskin: We look for ovarian arterial contribution in all patients *after* both uterine arteries have been embolized. We have discovered significant ovarian artery contributions, which we have embolized, fearing that not occluding them might lead to treatment failure. We do not, however, consider embolizing these vessels in younger patients desiring fertility preservation.

Q: Do you use any measures to reduce or eliminate vasospasm?

Dr Lipman: I have rarely encountered vasospasm after switching to a 4-Fr (vs 5-Fr) system and catheterizing the larger side first (based on a diagnostic pelvic angiogram). This strategy takes advantage of the flow redistribution phenomenon.

Dr Andrews: I do not routinely use antispasmodic agents. However, if spasm develops, I inject 50 to 100 µg of nitroglycerine directly into the artery (the dose depends on patient size and baseline blood pressure). It has been my observation that spasm is more likely if I advance a catheter or wire beyond the horizontal segment of the uterine artery, so I try to avoid doing so.

Dr Shlansky-Goldberg: Sublingual 10 mg nifedipine is given at the beginning of the procedure. Occasionally, intra-arterial nitroglycerin 100 µg is given, but there is the concern that it may also dilate collateral vessels to the ovaries. Heparin 3,000 to 4,000 units are also given after the puncture to reduce premature proximal thrombosis due to spasm.

Dr Siskin: No, we do not use any measures to reduce vasospasm. We typically catheterize all but the smallest uterine arteries with a 5-Fr catheter and only exchange for a microcatheter if the 5-Fr catheter causes a diminution of flow.

Dr Goodwin: I use a microcatheter in every case. In some cases, the initial wire and primary catheter have been placed in the uterine artery prior to angiographic visualization of the uterine artery. If the uterine artery is large and no significant vasospasm occurs, I will embolize through the primary catheter. I do not use vasodilators prophylactically. If vasospasm occurs, I use the usual measures of intra-arterial nitroglycerin, intra-arterial Priscoline (tolazoline), and sublingual nifedipine. In some cases, these measures are not helpful, and you either have to embolize in the face of occlusive spasm or wait.

Q: Where do you position the catheter tip?

Dr Bonn: Just distal enough not to embolize a large cervico-vaginal branch but not so distal that I miss a proximal branch to the fibroid(s).

Dr Shlansky-Goldberg: The tip of a microcatheter is positioned in the horizontal segment of the uterine artery just at the genu with the uterine body. This allows ample room to prevent reflux from embolization into other anterior division vessels and allows for efficient embolization.

Dr Lipman: I position the catheter tip in the horizontal segment of the uterine artery, beyond the cervicovaginal artery origin (unless it has a separate takeoff).

Dr Worthington-Kirsch: Ideally, I place the catheter tip in the proximal to midportion of the transverse segment of the uterine artery. If I can easily get the tip distal to the origin of the cervicovaginal branch of the uterine artery, I do so.

Q: How do you handle the common situation of sharp angulation (90°-180°) at the right uterine artery origin?

Dr Goodwin: I would not limit this situation to the right uterine artery. Very difficult angulations can also be seen on the left. What is helpful here is a primary catheter that points directly into the origin of the uterine artery to serve as a brace against which the microcatheter/microwire can be pushed. In some cases, I have utilized a 5-Fr angled glide catheter. The degree of angulation with this catheter has occasionally still not been sufficient. For these cases, I will cut off the reversed curve of a Sos-Omni catheter so that I have a very short-radius, tight-angled catheter. I then use it to engage the origin of the uterine artery and then advance the microcatheter and microwire from there.

Dr Bonn: I will try different 0.018" wires other than my usual 70° gold-tipped glide wire. Or advance the 4-Fr Cobra into the anterior division, injecting contrast while retracting it until the uterine artery is seen, then torque the Cobra directly into the uterine origin to support the 3-Fr microcatheter and wire. I have rarely intentionally buckled the microcatheter into the anterior division and engaged the uterine artery while retracting the buckled catheter.

Dr Siskin: We have found that the vast majority of right uterine artery catheterization are able to be made from an ipsilateral approach using a Cobra-2 glide catheter. When the catheterization time becomes prolonged, we turn to the use of a microcatheter and appropriate guidewire to directly catheterize the uterine artery. Our next catheter choice is a 5-Fr Berenstein catheter or a 5-Fr Simmons 2 catheter. If these catheters are unsuccessful, then we puncture the left groin and attempt catheterization from the contralateral approach. We have had to do this in less than 1% of our cases.

Dr Shlansky-Goldberg: A 4-Fr Roche inferior mesenteric artery will engage vessels with sharp angulations and will allow a microcatheter to pass.

Q: What antibiotic regimen do you use?

Drs Lipman, Goodwin, Hovsepian, Shlansky-Goldberg: Ancef (cefazolin) 1 g IV, to cover skin contaminant organisms at the time of the procedure. If PCN allergic, I substitute Vancomycin.

Dr Worthington-Kirsch: I give a single pre-UFE dose of antibiotics, either Ancef 1 g or Cleocin (clindamycin) 300 mg.

Dr Andrews: My patients receive a single dose of cefotaxime (1 g IV) at the start of the procedure.

Dr Siskin: We administer 1 g of Cefazolin before every procedure. We then discharge our patients on a 5-day regimen of Levaquin 250 mg qd.

Q: Do you routinely inject intra-arterial lidocaine?

Dr Lipman: No. It increases vasospasm and therefore can make the procedure more difficult. While I routinely use intra-arterial lidocaine in hepatic chemoembolization, this has not been necessary for UFE in my experience.

Dr Goodwin: No. I tried this early in my experience but encountered increased pain and in a small series of patients. The use of intra-arterial lidocaine has also been observed to result in more severe spasm problems by other investigators.

Dr Bonn: No. I recall seeing data on UFE and on chemoembolization describing that intra-arterial lidocaine doesn't reduce embolization pain.

Dr Shlansky-Goldberg: No, especially given the reports of spasm associated with it.

Q: What (if any) radiation safety precautions do you use?

Dr Lipman: I use pulsed fluoroscopy (7.5 pulses/second). I try to limit the amount of magnification and nonoblique fluoroscopy in addition to limiting the number of runs/exposures.

Dr Bonn: We take the following steps: don't do a routine aortogram; obtain relatively few images during selective uterine arteriography; cone down tightly during embolization; use pulsed fluoroscopy; and step in to help fellows if they are struggling.

Dr Andrews: I raise the table to its highest position, use tightly collimated unmagnified low-dose or pulsed fluoroscopy, and take very few pictures. In fact, documentation of my entire case is based on filming the last-image-hold fluoroscopic image.

Dr Goodwin: Pulsed fluoroscopy, limited fluoroscopy, and

limited angiography. I usually obtain 6 short angiographic runs, which include pre-embolization runs of both internal iliac arteries and pre- and postembolization runs of the uterine arteries.

Dr Shlansky-Goldberg: Collimation and pulse fluoroscopy during the embolization; we use pulse fluoroscopy 7 to 15 fps when possible. The number of vials of PVA needed for embolization determines the length of exposure, so we try to minimize the amount of fluoroscopy.

Q: Do you record radiation exposure? If so, which of the following measures do you use: fluoroscopy time, dose-area product, specific dose (eg, with TLDs), or other?

Dr Andrews: I record fluoroscopic time and dose-area product (the latter fractionated into acquisition and fluoroscopic contributions).

Dr Siskin: At our institution, we record the fluoroscopy time for all cases but do not make any other dose-specific measurements.

Dr Hovsepian: We place a radiation dosimetry badge underneath all patients and position it so that it will be in the field of view regardless of angulation. These readings are recorded, as is the fluoroscopy time, dose-area product, and the total (estimated) absorbed dose.

Dr Goodwin: We carefully measured radiation exposure in a subset of our first 58 patients. Once we established that the levels received were in a safe range, we went back to a less rigorous method, which is fluoroscopy time, which we record in every patient.

Dr Shlansky-Goldberg: Only fluoroscopic time is recorded.

Q: Do you routinely employ leg-compression devices or anticoagulant/antiplatelet therapy to prevent pelvic DVT after UFE? Does fibroid size factor in your decision?

Dr Lipman: Not routinely. I have used these devices on occasion where I was concerned about the possibility of a pulmonary embolus. These situations include patients who are overweight, receiving hormonal therapy (especially if they are smokers), and/or there is a history of previous DVT or even PE. I will also use a vascular hemostasis device in these patients to allow for quicker mobilization. My decision to use them is not based on fibroid size.

Dr Goodwin: I do not specifically use leg compression devices or anticoagulant/antiplatelet therapy. Patients do get some degree of antiplatelet effect depending on which nonsteroidal anti-inflammatory is utilized in their postprocedural care. What I do is try to get the patients to ambulate starting 6 hours after the procedure.

Dr Shlansky-Goldberg: We heparinize during the procedure to prevent premature thrombosis due to spasm and remove the catheter when the ACT is less than 200 seconds. Usually, no additional heparin is given unless the patient needs to be restarted on heparin or coumadin because she is hypercoagulable or requires long-term anticoagulation due to prosthetic heart valves or for treatment of DVT/PE.

Scenario: During UFE in a 45-year-old woman, pelvic angiography demonstrates absence of the right uterine artery. Aortography shows that the right ovarian artery supplies about one third of a fundal fibroid.

Q: Would you embolize the ovarian artery in this setting? What agent(s) would you choose?

Dr Andrews: If I were able to advance a microcatheter beyond the ovary, I would embolize with 500- to 700- μ m embo-

spheres. If not, I would embolize the ovarian artery from its origin with large pieces of gelfoam.

Dr Siskin: I would consider embolizing this vessel if it clearly represents a dominant source of supply to the fundal fibroid. In this case, I would embolize this vessel and would not consider embolizing the contralateral ovarian artery, no matter what contribution it made to the vasculature of the fibroid. I have made attempts in these patients to advance a microcatheter beyond the ovarian branches but have been successful in doing so only once (due to the tortuosity and length of the ovarian artery). Therefore, more often than not, I have embolized ovarian arteries from a proximal catheter position and have done so with PVA particles measuring 500 to 710 μm in diameter.

After finding ovarian arterial contribution in many patients, I have made it a routine part of the preprocedure consultation in an attempt to understand what each patient would want if this decision needed to be made during the procedure. In our practice, most premenopausal patients have had no issue with embolizing 1 ovarian artery if shown to be a dominant source of supply to the fibroid(s).

Dr Bonn: I would embolize only if I had made certain that I had discussed the risks of early menopause with the patient during the consent discussion. I would engage the ovarian with a Simmons or SOS catheter and pass a 3-Fr microcatheter about one third of the way in to allow for safe reflux when near arterial stasis. I would inject embospheres through the microcatheter.

Dr Shlansky-Goldberg: At the conclusion of the procedure, we obtain an aortogram to evaluate gonadal supply to the uterus and fibroids. We try not to embolize the gonadal arteries at the initial time of the UFE if they do not supply a moderate to large portion of the fundus and wait to observe the degree of resolution of symptoms. If there is a large gonadal artery that clearly supplies a large portion of the fundus, I will generally use gelfoam to embolize the vessel. If a large portion of the fibroid is supplied by the ovarian artery, then I will occasionally embolize with PVA. I try to discuss these issues prior to the procedure so that the patient is aware of the possibility of gonadal embolization and its risk of inducing menopause.

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