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EMBOLIZATION

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INTRODUCTION

The standard treatments of postpartum hemorrhage are described throughout this book. When they are unsuccessful, however, percutaneous transcatheter arterial embolization (hereafter referred to as embolization) may be indicated. The main objective of embolization is to stop active bleeding from the uterus or the birth canal and to prevent

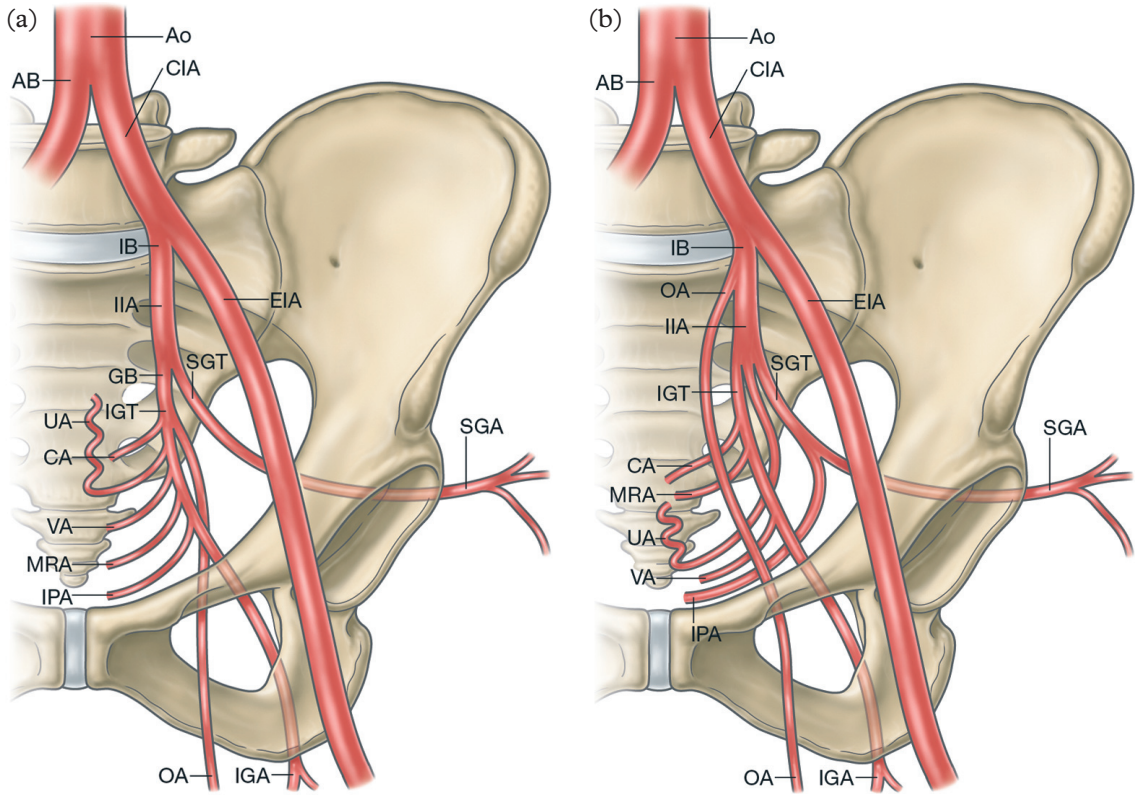


Figure 1 Branch patterns of the arteries to the uterus and the birth canal. (a) The most frequent pattern of branching. The internal iliac artery (IIA) is initially divided into the superior and inferior gluteal trunks (SGT and IGT, respectively), i.e. the gluteal bifurcation (GB). The uterine, vaginal and inferior pudendal arteries (UA, VA and IPA, respectively) are the branches of the IGT together with the obturator and cystic arteries (OA and CA, respectively). (b) Example of less common patterns include the uterine artery (UA) arising at the gluteal bifurcation, the obturator artery (OA) arising directly from the internal iliac artery (IIA) proximal to the iliac bifurcation, the internal pudendal artery (IPA) arising from the superior gluteal trunk (SGT). Ao, aorta; AB, aortic bifurcation; IB, iliac bifurcation; CIA, common iliac artery; EIA, external iliac artery; MRA, middle rectal artery; SGA, superior gluteal artery; IGA, inferior gluteal artery

recurrent hemorrhage. In case this is not possible, the last resort is to occlude the internal iliac arteries on a temporary basis to aid subsequent surgical intervention.

When embolization is successful, on the other hand, the patient can rapidly recover without undergoing additional surgery. Embolization not only saves the life of the patient, but also the uterus and adnexal organs, thus preserving fertility. Significant radiation effect is unlikely, as described below. The procedure is also useful in those patients who cannot accept transfusion due to religious or other reasons (see Chapter 15). In those hospitals where embolization is available, it should be the procedure of choice for postpartum hemorrhage prior to surgical intervention.

High success rates in achieving hemorrhage cessation are possible. In an extensive review of the literature by Vedantham and colleagues in 1997[1], cessation of hemorrhage was reported in 100% of 49 cases after vaginal delivery and 89% in 18 cases after Cesarean sections. Other recent reports include 75%[2], 83%[3] and 100%[4].

VASCULAR ANATOMY ON IMAGING

The internal iliac artery is the first major branch of the common iliac artery, which descends into the pelvis (see Chapter 32). There is only minimal variation in the distance between the aortic and the iliac bifurcations, making the identification of the internal iliac artery easy. In contrast, a number of variations in the distribution of the branches of the internal iliac artery are possible[5,6]. The proximal bifurcation of the internal iliac produces two trunks that are commonly termed the anterior and posterior branches. The posterior branch supplies the superior gluteal artery, whilst the anterior supplies the remainder of the pelvis. In the majority of instances, the branches of this anterior trunk include the uterine, vaginal, superior cystic, middle rectal, obturator, internal pudendal and inferior gluteal arteries (Figure 1a). In 30% of patients, these arteries have more proximal origins at the level of the bifurcation of the anterior and posterior branches (Figure 1b). This is especially true with the obturator and uterine arteries. In addition, the internal pudendal artery may arise from the posterior branch that supplies the superior gluteal artery. To avoid confusion due to anatomical variation, we would like to refer to the anterior and posterior branches as the inferior and superior gluteal trunks, respectively. This nomenclature becomes more appropriate when performing angiography.

On angiographic images, the inferior gluteal artery is seen as descending laterally and extending lower than bony pelvis. The importance of this artery gives off the sciatic branch which supplies the sciatic nerve. Therefore, the accidental embolization of the inferior gluteal artery could result in transient or long-term injury to the sciatic nerve.

The intramural portion of the uterine artery has a distinctive tortuous configuration. However, its origin lacks any characteristic appearance and is often superimposed on other branches in the frontal projection. Therefore, oblique views of the inferior gluteal trunk are frequently required to clarify the branching point of the uterine artery. The superior cystic artery can be identified by superselective catheterization and manual contrast injection which demonstrates either the distal network of the artery in the bladder wall or sometimes the cystic artery on the opposite side. The internal pudendal artery, which is usually a branch from the inferior gluteal trunk, is harder to confirm, often requiring some guess work. Further difficulties may arise from the presence of a hematoma which can alter the appearances and distribution of these arteries.

The middle rectal and the inferior rectal arteries originate from the inferior gluteal and the internal pudendal arteries, respectively. These supply the middle and lower portions of the rectum, anal canal and the perianal skin. Theoretically, superselective embolization of the middle rectal or the inferior rectal artery may result in necrosis of these areas. However, surprisingly such serious complications have not been reported so far.

The vaginal artery may originate from the uterine artery at the level of the cervix or from the inferior gluteal trunk. In addition, the vagina is also supplied by branches of the internal pudendal artery.

TECHNICAL ASPECTS

Preparation

Unless it is an absolute emergency, obtaining a coagulation panel including the platelet count, APTT and PT (INR) is worthwhile (see Chapter 25). Deranged coagulation does not necessarily contraindicate arteriography or embolotherapy[7]; however, its correction may help in preparation for post-procedural hemostasis and the prevention of complications relating to this. Occult coagulopathy may also be revealed[8]. As embolization is an invasive procedure, informed consent from the patient is essential, with explanation and discussion of the possible complications, future fertility and the effects of the radiation. In situations where the patient is sedated or unable to consent, the appropriate consenting process should be considered. Ideally, the patient is kept nil by mouth for an appropriate duration prior to procedure in order to avoid complications from vomiting. Bladder catheterization is not essential, although it is helpful in preventing the bladder from filling with contrast-containing urine during the procedure.

Cross-sectional imaging

Localization and measurement of the size of the hematoma prior to arteriography and embolization can be extremely useful, although not essential. Confirming whether the hematoma is within or outside the uterus and its relationship to pelvic structures will dictate the course of the embolization (Figures 2a and b). Magnetic resonance imaging (MRI) is the best test of the pelvis, requiring a small number of examinations with different radiofrequency signal maneuvers (sequences), demonstrating the sagittal, coronal and axial cross-sections. It is recommended to include both T1- and T2-weighted sequences in two to three examinations, such as T1-weighted coronal and T2-weighted sagittal scans. Should MRI be unavailable, either computed tomography (CT) or ultrasound examination may be an option.

Premedication

The interventional radiologist needs to decide the type and quantity of agents for premedication. If no interacting drugs have been administered, the authors recommend the combination of opiate and sedative antihistamines, such as pethidine 50–100 mg i.m. (in two divided doses if more than 50 mg is given) and promethazine hydrochloride 25–50 mg i.m.

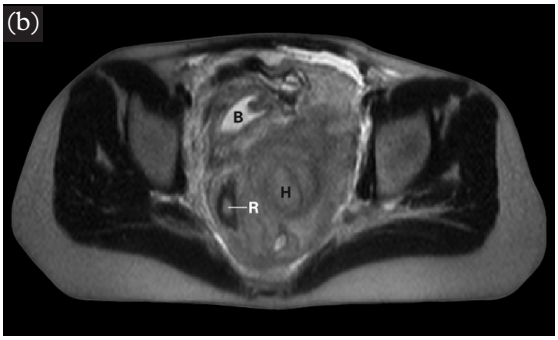
Location for embolization and arterial puncture

The best location for embolization is the interventional suite where vascular procedures routinely take place. However, interventional radiologists may be requested to perform procedures in surgical theaters in some emergency situations.

The optimal method in embolization is to achieve superselective catheterization of the arterial branches that are the sources of hemorrhage, such as the uterine arteries on both sides. When this is not possible, temporary occlusion of the internal iliac arteries using balloon catheters is an option to stabilize the patient's condition and facilitating subsequent surgical procedures. Removal of a uterine compression pack may be attempted under such transient arterial occlusion. If the temporary occlusion has been performed outside the angiography suite (such as in the operating theater) in an emergency, the patient could be subsequently transferred to the angiography suite for proper embolization. In some cases, temporary bilateral occlusion of the iliac bifurcations may be performed using angioplasty balloon catheters placed and inflated at the iliac bifurcation bilaterally. Acute ischemia of the lower limbs will occur as a result. The risk of injury to the nervous and muscular systems of the lower limb is minimized by shorter occlusion time of external iliac arteries. Occlusion times of less than 1–2 h are safe; irreversible injury may occur if it is more than 6 h.

The order of arteriogram and catheter maneuvers

At the puncture site in the groin, an introducer sheath is used to stabilize the arterial entrance. The standard diameter of the sheath is 5 French gauge; a 6 French gauge sheath is necessary for balloon occlusion.



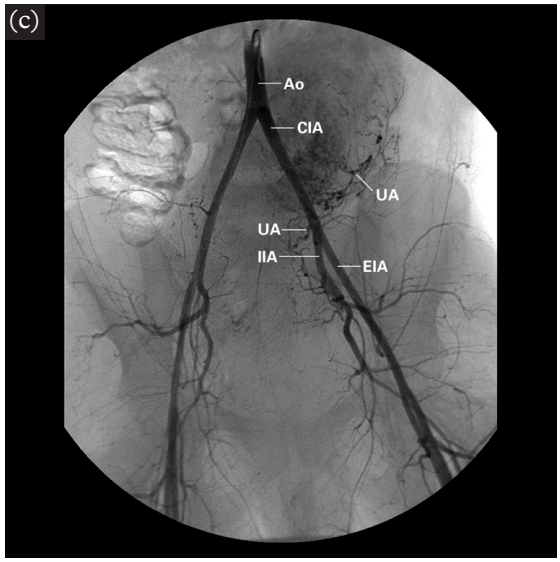


Figure 2a–g Case study: a 23-year-old woman, who had been diagnosed to have double uterus and double vagina, with the right uterus having been removed several years before. Following vaginal delivery at full term weeks, she became anemic, with the hemoglobin measuring approximately 6.0 g/dl. Intrapelvic pain was reported, mainly on the left. Hemorrhage per vagina was only of a moderate degree. (a and b) T2-weighted magnetic resonance images of the pelvis, in coronal (a) and axial (b) cross-sections. A hematoma (H) is detected in the left pelvic floor. The right side of the pelvis is preserved. R, rectum and adjacent tissue; B, bladder. It was anticipated that left-sided embolization would achieve hemostasis based on these images. (c) Whole pelvic arteriography. The right common femoral artery was punctured and a 5 French gauge hook-shaped catheter was inserted to the distal aorta (Ao) where radiological contrast was infused. The outline of the common, internal and external iliac arteries (CIA, IIA and EIA, respectively) and their major branches are demonstrated. The intramural branches of the uterine artery (UA) distribute both above and within the pelvis. The hematoma is shown as a relatively hypovascular zone (H). (d) Left internal iliac arteriography in the left anterior oblique position (LAO). Identification of the uterine and vaginal arteries (UA and VA, respectively) is achieved: the origin of the uterine artery (UAO) is shown. The superior and inferior gluteal trunks are superimposed (*). This falls into the category of vascular anatomy shown in Figure 1b. A 5 French cobra-shaped catheter is used. (e) Left uterine arteriography. Superselective catheterization was achieved using a 3 French gauge catheter inserted through the 5 French cobra-shaped catheter. The intramural branches with their characteristic tortuosity are shown. Although no extravasation is demonstrated, unilateral and partial embolization using grated particles of gelatine sponge was performed in view of increased hemorrhage per vagina and the anatomical communication between the uterine artery and the arteries to the upper vagina. (f) Left vaginal arteriography. Extravasation is clearly revealed (arrowheads) on hand injection of radiological contrast through the 3 French catheter (arrow). Embolization was performed using grated particles of gelatine sponge until the extravasation was barely detectable. (g) Left inferior gluteal arterial trunk post-embolization. The uterine artery (UA) and a smaller number of its intramural branches are opacified, the vaginal artery and the branches to the hematoma are no longer opacified. Following embolization, the hemorrhage per vagina reduced to within normal losses; hemoglobin increased to 11 g/dl on the next day and 12 g/dl on the following day. The patient was discharged 2 days post-embolization without undergoing any other intervention; outpatient follow-up confirmed satisfactory recovery

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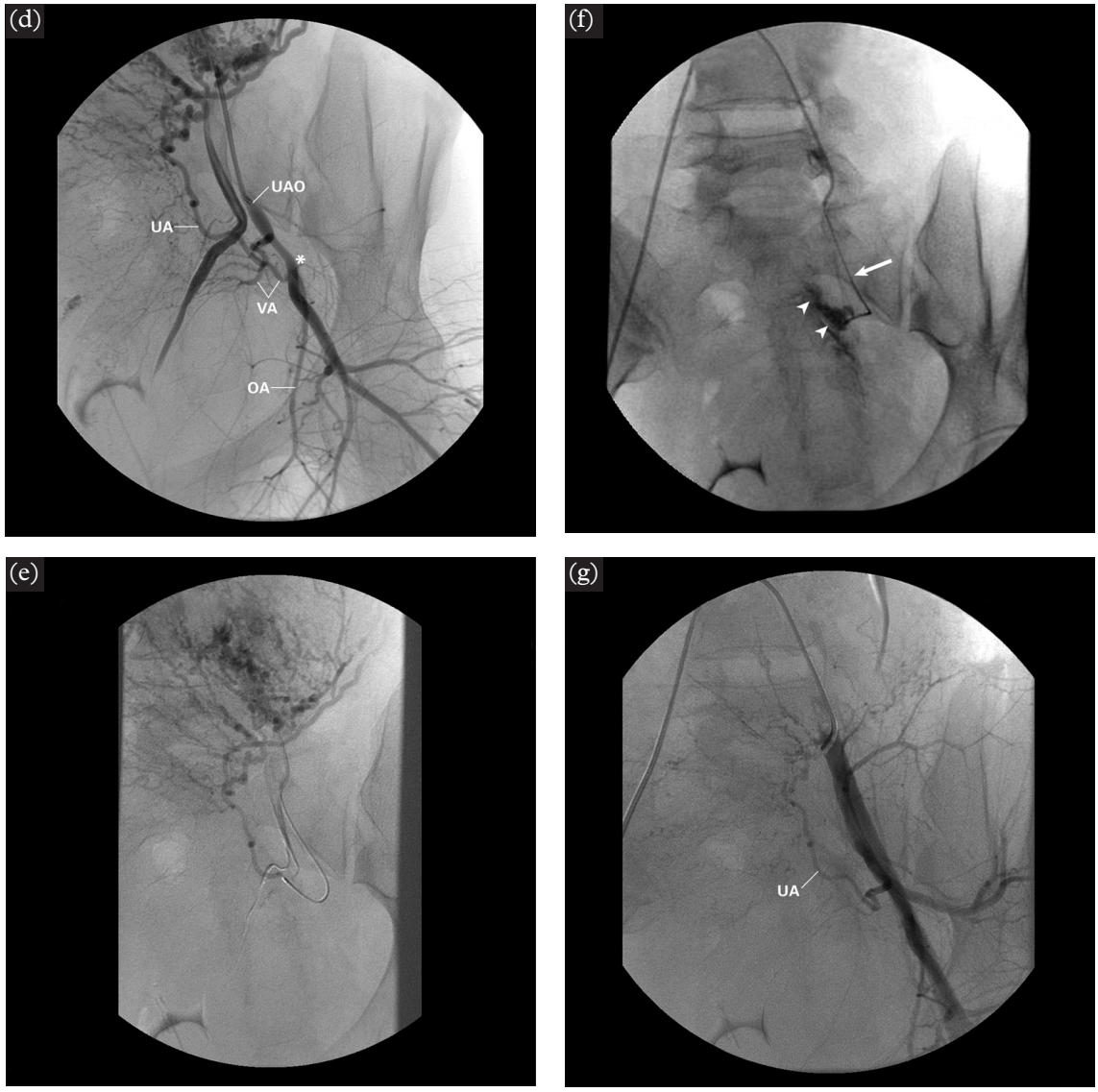

Figure 2a–g *Continued*

The first arteriogram is an image of the pelvis from the aortic bifurcation to the groins, in order to obtain a global view of the pelvic arteries (Figure 2c). A range of hook-shaped catheters are useful, as they are helpful in accessing the common and internal iliac arteries on either side (Figure 3). Subsequently, the internal iliac artery is selectively catheterized and its arteriogram should be obtained (Figure 2d). Oblique views may aid demonstration of the uterine artery origin and facilitate its catheterization.

A 4 or 5 French gauge Cobra tip is a suitable standard catheter for superselective access to the uterine artery and other smaller branches, if the hook catheter is inadequate for superselective catheterization (Figure 3). It is preferably made of soft polyurethane. 5 French gauge catheters have a risk of causing spasm when inserted into the uterine artery and other branches of the inferior gluteal trunk. This can be prevented and treated by nitrate vasodilators, such as isosorbide dinitrate 0.05–0.20 mg per branch. Where suitable 4 French gauge

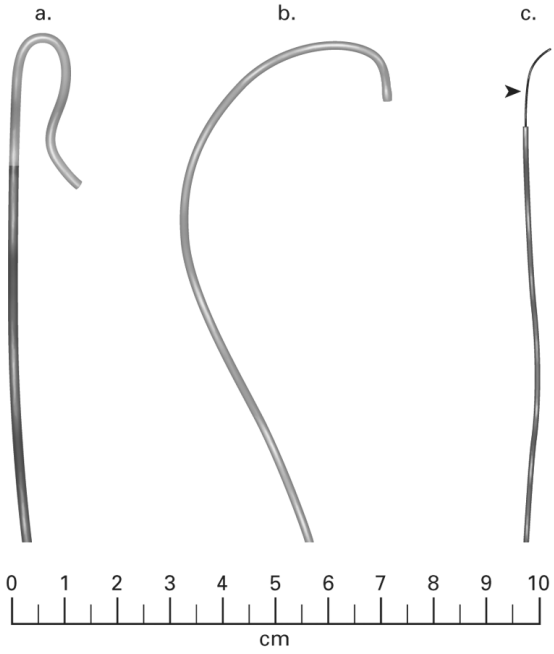

Figure 3 Standard catheters of use in embolization. (a) A 5 French gauge hook-shaped (Modified hook 2 catheter, Merit Medical, USA); (b) a 5 French gauge cobra-shaped (Terumo, Japan) and (c) a 3 French gauge microcatheter which goes through 5 French gauge catheters (Terumo, Japan): this catheter is coupled with a hydrophilic polymer-coated floppy guidewire with an angled head (arrowhead)

catheters are available, they would reduce the risk of vasospasm. Guidewires with angled tips and hydrophilic coatings are also extremely useful tools. For difficult branches with steep angulation and tortuosity, finer catheters (less than 3 French in diameter) with their own specific fine and floppy wires are indicated (Figure 3), although they are costly in general. These are fed through the standard catheters and preferably have an angled tip.

Targets of embolization

The prime target of embolization is the source artery of hemorrhage. Commonly, this is the uterine artery when the source of hemorrhage is in the myometrium, cervix or endometrium (Figure 2e). If the hemorrhage is due to laceration of the birth canal below the level of the uterus, the source is likely to be a branch such as the vaginal or internal pudendal artery. If branches other than the uterine artery are the source of hemorrhage, superselective catheterization and arteriogram of each branch are required to assess the extent of extravasation (Figure 2f). The advent of smaller diameter catheters and hydrophilic coated guidewires has made such superselective catheterization less challenging. Extravasation is unlikely to be demonstrated on non-superselective angiograms such as the global pelvic arteriogram and the internal iliac arteriogram.

In case extravasation is confirmed, embolic material is infused to occlude the artery (Figures 2f and g). If extravasation is not proven, embolization of each of the branches supplying the region of hemorrhage is performed. Hemostasis can be achieved with embolization of the regional arteries, including the source of hemorrhage, even without actual demonstration of the bleeding artery[9,10]. The most accurate demonstration of the flow distribution of transcatheterally infused material is obtained with combined angiography C-arm and CT equipment. Unfortunately, such machines are not universally available. Therefore, the interventional radiologist needs to judge the vascular anatomy and the distribution of the embolic material mainly on the basis of the simple two-dimensional angiography radiographs in frontal or oblique projections.

Embolic material

Practical embolic materials are summarized in Table 1. Gelatine particles are the most commonly used embolic material in embolization for postpartum hemorrhage as they are expected to dissolve in several weeks' time, leading to recanalization of the embolized artery. However, these are not free from embolic complications[2,11]. Other advantages of gelatine particles include that they are economical and easily available. Where the particle form of gelatine is unavailable, gelatine plate or sponge could be cut into particles or grated. Despite the popular usage of gelatine particles, there is no evidence to contraindicate the use of permanent embolic material, such as polyvinyl alcohol (PVA) particles (Figure 4).

Table 1 Embolic materials

Materials	*Duration of effect*	*Approximate size*	*Mechanism of effect*	*Advantages*	*Disadvantages*
Particles					
Gelatin sponge (cut)	temporary	1–5 mm	blockage of blood vessel, inflammatory occlusion (partly)	economic, safe	cutting is time-consuming, proximal embolization due to particle size
Gelatin sponge (grated)	temporary	0.3–5 mm	blockage of blood vessel, inflammatory occlusion (partly)	economic, safe, easy to make	effect could be short-lived, proximal embolization could occur
Polyvinyl alcohol (PVA)	permanent	100–700 μm	blockage of blood vessel, inflammatory occlusion (partly)	readily available	could be expensive, proximal embolization could occur
Autologous blood clot	temporary	1–5 mm	blockage of blood vessel, inflammatory occlusion (partly)	available by adding thrombin *in vitro*	duration of effect is unreliable
Autologous blood clot (degenerate)	permanent	< 1 mm to 5 mm	blockage of blood vessel, inflammatory occlusion (partly)	available by heating or exposing to alcohol or its derivatives	
Liquid					
Alcohol	permanent		destruction of blood vessel by ablating the intima, producing degenerate thrombi	economic and ultra-potent	painful, unwanted vessels could be affected
Ethanolamine oleate	permanent		similar to alcohol but milder effect	similar to alcohol but milder effect; the effect could be stabilized when combined with gelatin sponge	similar to alcohol but milder effect
Glues such as cyanoacrylate	permanent		blockage of blood vessel	readily available, stable	requires expertise in the use of material; adherence of the delivery catheter could occur

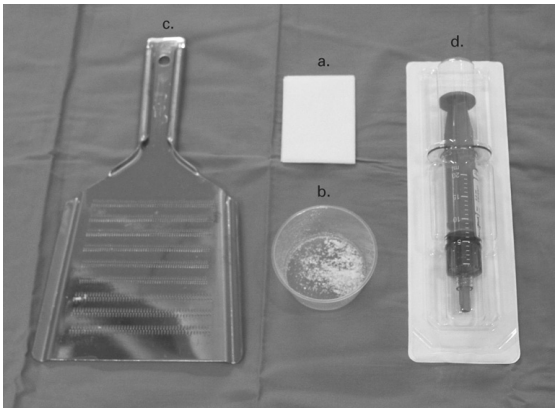

Figure 4 Embolization materials. (a) Gelatin sponge; (b) grater for gelatine sponge; (c) grated gelatine sponge; and (d) polyvinyl alcohol (PVA) particles in a bottle syringe

Embolic material should not be infused into the inferior gluteal artery for the reason described above. In spite of this, there are reports where infusion of gelatine particles into the inferior gluteal trunk either did not result in sciatic nerve symptoms[3] or only in a minority of instances[2]. It is assumed that the amount of embolic material infused is the key factor as to whether sciatica presents or not. Even if superselective catheterization is achieved, care needs to be taken to minimize overflow of embolic material. As embolization of a branch approaches completion, some overflow is usually unavoidable. Particular caution is necessary when liquid embolic material is used, such as cyanoacrylate, alcohol and its derivatives.

COMPLICATIONS

The reported frequency of complications is small. The causes of complications include:

(1) *Technical errors* These include hematoma at the puncture site (groin)[12] and vascular injury[13]. Allergic reactions to iodine contrast and nephrotoxicity are also possible.

(2) *Post-embolic ischemia* Infarct and necrosis of the uterus requiring hysterectomy[11], as well as the cervix and upper vagina[2] and bladder[11] have been reported. A decision between surgical and conservative management needs to be made in each case.

(3) *Sciatica* This is described above.

(4) *Infection* Intra-pelvic abscess formation[14,15], post-embolic pyrexia and pain/tenderness in the pelvis are frequently observed, all of which can be managed with anti-inflammatories and antibiotics.

(5) *Coagulopathy* Difficult hemostasis at the groin may be a result of coagulopathy.

(6) *Acute intra-arterial thrombosis of the lower limb* This may be due to limited arterial flow in the lower limb following arterial puncture and catheter maneuver; thrombosis and occlusion of the lower limb artery may occur[2]. The risk is increased when balloon occlusion is performed for a long period.

(7) *Ischemia of the lower limb* This is described above.

(8) *Radiation* The biological effect of radiation has been studied from the data of measured absorption doses of the skin and estimated doses to the ovaries in a series of 20 cases of uterine artery embolization[16]. In this study, fluoroscopy was performed up to a maximum of 52.5 min with a mean of 21.9 min, resulting in a maximum skin dose of 304 cGy (mean 162 cGy). The estimated maximum ovarian dose was 65 cGy (mean 22.3 cGy). These figures were greater than the doses of other image examinations of the pelvis such as hysterosalpingography (0.04–0.55 cGy), recanalization of the Fallopian tube (0.2–2.75 cGy), computed tomography of the body trunk (0.1–1.9 cGy); on the other hand, they were smaller than the dose in radiotherapy for intrapelvic Hodgkin's lymphoma (263–3500 cGy). On the basis of the known risks of pelvic irradiation for Hodgkin disease, the dose associated with uterine artery embolization is unlikely to result in acute or long-term radiation injury to the patient or to a measurable increase in the genetic risk to the patient's future children. In embolization for postpartum hemorrhage, there may be cases where longer fluoroscopy time is required than uterine artery only embolization; however, it would be still in the similar region to that of uterine artery

embolization, and, therefore, the injury from irradiation in embolization is unlikely.

(9) *Fertility* A 35-month follow-up survey on six patients, who underwent uterine artery embolization with polyvinyl alcohol (PVA) particles for therapy of fibromyomata and wished subsequent conception, confirmed eight pregnancies in five patients (83%), seven births including five transvaginal and two Cesarean deliveries, and an abortion due to the patient's request for termination[17]. The authors of this study concluded that uterine embolization with PVA particles did not affect fertility. In embolization for postpartum hemorrhage, although the non-uterine artery branches could be embolized and the embolic material could be others than PVA, the effect on fertility is unlikely.

LOGISTICS

Postpartum hemorrhage is essentially an emergency situation, which may arise at any time. The incidence of truly intractable hemorrhage is small, and, in the majority of cases, there is time during which the obstetricians perform the first line of treatment, including transfusion, and wait for preparation by the interventional radiology team. However, urgent intervention is requested in the minority of cases. This could cause a strain in the management of staff in the interventional radiology department. It could also be a reason why embolization has not been widely recognized or discussed among the obstetricians and radiologists as the choice of treatment, despite a number of successful reports both in postpartum and post-Cesarean cases[8–10,12–15,18–27]. Nevertheless, the safety, feasibility and low complication rate of embolization cannot be emphasized enough. The idea of offering embolization is simply kinder to the patient compared to hysterectomy or other surgical intervention. The ability to offer embolization would require an obstetric department which is well aware of the implications of embolization in postpartum uterine hemorrhage. Such a change in thinking will invariably necessitate a proactive protocol providing easy access for the obstetricians to an emergency appointment with the interventional radiology team. Such a protocol should be established with input from both the obstetricians and interventional radiologists. It would include a list of the resources required, including the personnel involved, the equipment, the consumables and the setting. It should also make consideration for out-of-hours emergency work and the case load. Therefore, the protocol will depend on the requirements and resources of each specific department.

CONCLUSION

Though embolization has had a relatively short life of practice, it is a highly feasible, safe and beneficial procedure, as it may preclude an indication for further laparotomy and hysterectomy. Therefore, embolization should be the choice of treatment prior to surgical intervention, anywhere in the world, when the first line of conservative treatment fails.

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