Percutaneous uterine artery embolization for the treatment of symptomatic fibroids: current status

Tommaso Lupattelli [a,*], Antonio Basile [b], Francesco Giuseppe Garaci [c], Giovanni Simonetti [c]

[a] *Department of Diagnostic Imaging, Istituto Policlinico San Donato, San Donato Milanese, Milan, Italy*
[b] *Department of Radiology, Ospedale Ferrarotto, Catania, Italy*
[c] *Diagnostic Imaging and Interventional Radiology Tor Vergata University, Rome, Italy*

Abstract

Uterine artery embolization (UAE) is increasingly being used as an alternative treatment to hysterectomy for symptomatic fibroids. Symptoms of pelvic pressure, urinary frequency and menorrhagia are controlled in 73–98% of patients who undergo UAE. At the 1-year follow-up, the uterus may shrink by up to 55% but re-growth of fibroid may however occur. The rate of major complications and amenorrhoea following this procedure is low, ranging in most series from 1 to 3.5% and 1 to 7%, respectively. Nevertheless, the rate of amenorrhoea in women over 45 seems to be higher.

In order to completely block the arterial supply to the fibroid, UAE is typically performed in both uterine arteries. Different embolic agents are used such as polyvinyl alcohol, gelfoam and more recently gelatine tris-acryl microspheres. After UAE, perfusion of the uterus is maintained. Uterine function is therefore conserved and although women who become pregnant after UAE seem to be at risk for malpresentation, pre-term birth, cesarean delivery and postpartum hemorrhage, successful pregnancies after UAE have been reported in some series.

A major technical problem with UAE remains the possible presence of fibroid blood supply from other sources, such as the ovarian arteries or other pelvic branches, which can lead to failure of the procedure.

In conclusion, although randomized trials are still underway, UAE appears a good option for those patients who whish to conserve their fertility or when surgery is contra-indicated. However, to evaluate the long-term effects of UAE longer follow up is required.
© 2004 Elsevier Ireland Ltd. All rights reserved.

Keywords: Uterine artery; Embolization; Fibroid; Uterus

1. Introduction

Percutaneous transcatheter embolization has recently emerged as a highly effective and safe technique in a wide variety of diseases, including obstetric and gynecologic disorders. The first case of embolization was carried out by Rosch et al. in 1972 in an effort to control an acute gastrointestinal bleeding [1]. The first cases of percutaneous transcatheter uterine embolization for obstetric and gynecological bleeding were performed 7 years later, in 1979 [2]. Nowadays, embolization of the uterine artery (UAE) often plays a decisive role in the management of such disorders [3–5].

The first attempt at percutaneous transcatheter artery embolization for the treatment of uterine fibroids (or leiomyomas) was made by Jean Jacques Merland et al. at Lariboisiere Hospital Paris in 1989. This case, performed as a treatment preceding myomectomy to reduce the risk of hemorrhage, was only reported in the English literature in 1995 [6]. Percutaneous transcatheter uterine artery embolization (UAE) for fibroids is therefore a rather recent procedure. Nevertheless, at some institutes this technique is already being performed routinely.

Uterine leiomyoma is the commonest benign tumor of the female genital tract occurring in about 25% of women of reproductive age [7]. Its incidence is higher in Afro-Caribbean women, and in these patients presentation tends to be at a younger age than in Caucasians [8]. Most fibroids do not cause symptoms, and therefore do not require intervention. Treatment is needed if they grow large enough to cause

* Corresponding author. Tel.: +39-02-52774642; fax: +39-02-5279695.
E-mail address: tommasolupattelli@hotmail.com (T. Lupattelli).

pressure on other organs, such as bladder or bowel. Treatment is also needed if they grow rapidly, cause abnormal bleeding or recurrent miscarriage. Abnormal bleeding can be however caused by other affections of the uterus such as adenomyosis, an abnormal presence of endometrial glands and supporting tissues in the myometrum.

Fibroids are classified by their location. Fibroids inside the uterine cavity (submucous type) will usually cause bleeding between periods (*menometrorrhagia*) and often cause severe cramping. However, in general submucous myomas are partially in the cavity and partially in the wall of the uterus. Besides bleeding between periods, these fibroids are also likely to cause heavy menstrual periods (*menorrhagia*). Finally, fibroids entirely sited in the myometrium are classified as intramural whereas those located in the external portion are known as subserous; these two types of fibroids that may reach a large size before giving symptoms usually present with pelvic pain or increased pelvic pressure. Women may experience a sense of pelvic fullness, pressure on the bladder with difficulty voiding or urinary frequency and urgency. If pedunculated, large subserous leiomyomas are most likely to compress the surrounding organs, leading in some cases to bowel obstruction and/or ureteral compression. A pedunculated subserous fibroid may also twist and undergo necrosis, giving rise to acute abdominal pain.

Several studies show that UEA is effective in controlling symptoms of menorrhagia, dysmenorrhoea, urinary frequency and other pressure effects. According to a survey of the SCVIR membership conducted in October 2000, the number of UAE procedures documented worldwide is 10,501, with 8644 in the United States [9]. To date more than 25,000 UAE procedures have been performed.

The purpose of this paper is to provide a comprehensive overview of UAE for the treatment of fibroids.

2. Pre-treatment evaluation

Pre-procedural evaluation plays a primary role for the successful outcome of UAE.

Although in many cases UAE is performed without biopsy, when bleeding is present, an endometrial sample should be obtained to rule out the eventuality of endometrial cancer. It is also extremely important that the gynecologist ensures that symptoms are due to fibroids rather than other diseases and particular attention should be paid to those features that may be atypical of fibroids. Pregnancy should be excluded and any infection treated prior to UAE. Chronic salpingitis or endometritis, ovarian cysts, tubal inflammation and endometriosis are not regarded as absolute contraindications to the procedure but they may be associated with an increased risk of life-threatening infection after UAE [10].

To best evaluate post-treatment amenorrhoea patients under 45 should have an FSH level assessment on the third day of their cycle [11]. Theoretically, an increase of FSH level

up to 50 mlU/ml after embolization is considered a consistent indicator of ovarian failure [12].

During UAE uterine arteries vasospasm may occur, leading in some cases to technical failure of the procedure. Vasospasm is also thought to have an iatrogenic origin related to the use of analogues of gonadotropin releasing hormone (gn-Rh). For this reason, some authors suggest their patients stop medical treatment 1 or 2 weeks before the procedure [12,13].

Appropriate counseling prior to embolization with details of the procedure and its potential complications is mandatory. Patients should carefully be informed by the interventional radiologist that, should they develop signs of infection after the treatment, they could be re-admitted and, in case of severe infection, undergo hysterectomy [14]. Patients should be also informed about the unknown long term results of UAE on the uterine vascularization and functionality.

3. Indications and contraindications

Only 10–20% of the women who have fibroids require treatment.

Depending on the size, location and number of fibroids, they may cause a large variety of symptoms (Table 1); UAE should be offered only to women who have been advised hysterectomy or multiple/difficult myomectomy for such complaints as menorrhagia, dysmenorrhoea and dyspareunia and pressure effects of the fibroid on the urinary or gastrointestinal tract but wish to avoid surgery. Infertility and recurrent miscarriage should not currently be regarded as a valid indication for UAE treatment without a controlled clinical trial and without appropriate approval by an ethics committee. UAE can also be offered when surgery has previously failed, to women not clinically suitable to undergo surgical intervention or who are unwilling to receive a blood transfusion.

Whether this procedure is safe for women desiring future fertility is controversial. Women who become pregnant after UAE seem to be at risk for malpresentation, pre-term birth, caesarean delivery and postpartum hemorrhage [15]. To date no clinical studies have yet been published in literature describing UAE on pregnant women. However, in pregnancy

Table 1
Fibroid related symptoms

1	Abnormal uterine bleeding
2	Cronic pelvic pain
3	Dysmenorrhoea
4	Infertility
5	Dispareunia
6	Backache
7	Acute pelvic pain
8	Urinary frequency
9	Urinary urgency
10	Urinary retention
11	Pregnancy loss
12	Constipation

Table 2
Contra-indication to UEA for fibroids

Absolute
Fibroid infection
Refusal to undergo hysterectomy following peri- or post-UEA complications
Actual pregnancy
Relative
Pedunculated submucosal leiomyoma
Dominant pedunculated serosal leiomyoma
Adenomyoma
Leiomyoma larger than 8.5 cm
Desire of future pregnancy
History of allergic reaction to contrast medium

UEA is unlikely to cause serious problems for the mother but might lead to abortion of the fetus.

Contraindications to UAE are listed in Table 2. To date, this procedure has proven to be safe and without particular risks. Any sign of gynecological infection should therefore be diagnosed and treated before UAE. Chronic salpingitis or endometritis may increase the chance of life threatening infection following fibroid embolization. As mentioned earlier, if either of these is suspected, in addition to a clinical exam and imaging studies, an endometrial sample should be obtained.

With regard to the type of leiomyomas particular care should be used when UAE is selected for pedunculated submucous, pedunculated subserous or large fibroids (>8.5 cm) [14,16,17]. Once pedunculated submucous fibroids are embolized, their spontaneous extrusion through the vagina may occur, with the largest ones often becoming impacted in the cervix. Patients treated by UAE for pedunculated submucous fibroids should be therefore warned that they could be re-admitted should they develop signs of obstruction of the cervical os. In such a case, to avoid catastrophic uterine sepsis and hysterectomy, manual or surgical dilatation and curettage of the uterus is to be performed. Patients should be also warned that extrusion of pedunculated submucous fibroids might occur several months after UAE as well [14]. The choice of UAE for pedunculated subserous fibroids and fibroids larger than 8.5 cm may instead lead to early or late treatment failures. Indeed, after UAE, large leiomyomas may show residual vascularization, pedunculated subserous leiomyomas may have parasitised blood supply from other pelvic vessels, with their incomplete infarction as a result. Furthermore, once embolized, pedunculated subserous fibroids may also slough into the abdominal cavity and become infected or cause significant intra-pelvic adhesion [16,17].

4. Imaging

Type, volume and location of fibroids may be assessed by ultrasound (US) and/or magnetic resonance (MR). Cur-

rently, the latter is regarded as the preferred tool for preoperative evaluation and measurement of fibroids [18,19]; it allows to exclude presence of concomitant lesions in the pelvis as well as recognize adenomyosis and those types of fibroids such as pedunculated sumbucous that need close follow-up once embolized (see below). Burn et al., in a study performed in 34 patients, reported that an increased signal intensity on T2-weighted images pre UAE is usually associated with a considerable reduction in fibroid size after embolization. On the contrary, increased signal intensity of fibroid on T1-weighted images pre UAE is a significant predictor of poor leiomyoma volume percentage reduction. According to the authors, fibroids with high signal intensity on pre-UAE T1-weighted images are likely to have already undergone hemorrhagic degeneration as well as loss of vascular supply and, as such, do not change markedly after embolization [20]. The findings on T2 weighted images reported by Burn et al. have recently been confirmed by Watson et al. in an accurate case series in which 114 consecutive women underwent MR scan before and 6 months after UEA. Nevertheless, as opposed to Burn et al., the authors concluded that a high signal intensity of fibroids on T1-weighted images pre UAE is rather uncommon and does not appear to alter the outcome [21].

The use of an arterial spin tagging technique (Extraslice Spin Tagging) seems to permit the assessment of tumor perfusion before and after uterine fibroid embolization, without the need for intravenous administration of gadolinium [22]. Moreover, MR provides better sensitivity and specificity than ultrasound to exclude the presence of all but stage I of carcinoma of endometrium and adnexal mass [23], and shows high accuracy in the assessment of adenomyosis which can be missed at US [24,25]. Although some encouraging reports have been published [26], the value of UAE in adenomyosis is still uncertain and failure of embolization of these lesions has been reported [27].

With regard to other modalities, CT does not show as much sensivity as MR in the pre-procedural study of fibroids whereas Doppler flow measurements of uterine arteries can be useful in predicting variables associated with UAE. According to McLucas et al. a high peak systolic velocity (>64 cm/s) prior to UAE would be a significant predictor of embolization failure [28].

Unfortunately, it is not always possible to differentiate malignant tumors from fibroids at MR imaging or US; a few cases of embolization of uterine leiomyosarcoma initially diagnosed as fibroids have been reported [29,30]. Uterine sarcomas grow fast but because of the rapid growth shown by a considerable part of fibroids, the fast changing dimension of a leiomyoma is not a helpful criterion to make a diagnosis of cancer. Sarcomas can only be diagnosed by pathologic examination of resected or biopsied samples. Their prevalence in the population is however very low, accounting for about 0.2% of all fibroids. Parker et al. reported a study of 1332 patients who underwent hysterectomy or myomectomy for uterine leiomyomas. Only one of the 1332 patients

operated on for presumed leiomyoma was found to have a leiomyosarcoma. Also, this woman was the only one found to have a sarcoma among 371 patients operated on for rapid growth of the uterus [31]. However, although the prevalence of leiomyosarcoma in the general population is low, its presence should be always suspected in women showing rapid growth of the uterus and ruled out carefully prior to UAE.

5. Procedure

5.1. Anaesthesia and sedation

There are a variety of sedation/analgesia protocols for UAE. Conscious sedation is actually the most commonly used method to control pain throughout the procedure. When this modality is selected, a patient-controlled analgesia (PCA) pump with intravenous administration of morphine is started before commencing or at the time of the procedure and continued for 24 h. Other authors prefer the use of a mixture of 0.1 ug fentanyl and 10 mg midazolam intravenously at the time of UAE followed by PCA pump with 60 mg morphine and 6 mg droperidol until discharge [32]. Also, the use of 30 mg intravenously administered ketorolac alternated with 2 g intravenously administered paracetamol every 6 h until discharge can be considered [33].

Some authors advocate spinal and epidural anesthesia as being a valid alternative to conscious sedation. The advantages and disadvantages of spinal and epidural anesthesia are reported in Table 3. General anesthesia is rarely selected; it increases the risk of general complications and prolongs recovery time.

An anti-inflammatory suppository and an anti-emetic should be given before UAE [32]. Although their efficacy has never been demonstrated, prophylactic antibiotics before UAE are usually administered as tissue necrosis may predispose to infection. However, under antibiotics coverage a lower incidence of sepsis of other organs in the abdomen after embolization has been reported [34]. Prophylactic antibiotics are not given after the procedure [35,16].

5.2. Technique

Several different techniques utilizing a variety of catheters to access the uterine arteries have been described [13,36–38]. The right femoral artery is most commonly punctured but some operators advocate the use of a bilateral femoral approach to facilitate the procedure. This enables the selective catheterization of the contralateral internal iliac artery, which is usually easier than the ipsilateral. A simultaneous bilateral embolization can easily be performed (two radiologists are needed) thus reducing the screening time. The disadvantages are the need for two puncture sites, and a possibly higher complication rate at the groin. When a single approach is preferred, a five French cobra catheter (Boston Scientific Corp., Watertown, MA) or a Levin catheter (Cook Inc., Blooming-

Table 3
Spinal and epidural anesthesia

Epidural
Advantages
No thecal sac invasion
Repeatable throughout the procedure
Evidence of 10–12 h of pain relief post-procedure
Disadvantages
Risk of thecal sac puncture (3–6%)
Occurrence of severe or life-threatening complication due to unrecognized catheter placement into the thecal sac rather than into the epidural space
Catheter related problems throughout the procedure (position, occlusion, etc.)
Not as reliably effective with one side being often more effected than the other
High dose of medications required for severe pain, sometimes leading to temporary loss of patients' ability to move their legs or control their bladder
Spinal
Advantages
Fast (about 5 min)
10–12 h of pain relief
Small dose of medication required
No loss of patients ability to move after UEA (if only one dose is administered)
Disadvantages
Risk of "spinal headache" (about 1%)
Necessity of further spinal puncture if higher dose of drug is needed

ton, IN) is most frequently utilized to catheterize the contra lateral internal iliac artery and, by means of the Waltman maneuver (to form a sidewinder-like shape), the ipsilateral as well [39].

The uterine arteries are usually enlarged and tortuous [40]. The enlargement of these arteries secondary to the hypervascular fibroids actually makes catheterization easier, although the increased tortuosity of the vessels can diminish this advantage. In cases of small highly tortuous and narrow uterine arteries, or when spasm has occurred, the use of a three Fr coaxial catheter may be needed [41,35]. However, in a series of 197 women who underwent superselective bilateral uterine artery embolization Pelage et al. reported successful results in up to 90% of patients treated with a five Fr cobra catheter alone [13].

5.3. Embolic materials

Various embolic agents are currently available to embolize uterine arteries but none of them has as yet clearly been shown to provide substantial advantages or a better outcome [42]. Thus, their choice is a personal matter. However, since UAE is a relatively new procedure, the long-term effects of some of these agents remaining permanently in the women' bodies are currently unknown. Adverse effects have been previously reported for many "unknown" agents, therefore it must not be forgotten that the use of new materials, particularly the use of tris-acryl microspheres (to be discussed later)

is still too new to document as to what the additional long term-effects might be. Although there is little evidence in the literature of potential and serious adverse effects following transcatheter injection of embolic agents for the treatment of fibroids, a tris-acryl microspheres (Biosphere Medical, Rockland, MA) related death has been recently reported [43]. Initially, uterine embolization used to be performed by injecting polyvinyl alcohol (PVA) particles exclusively [6,44]. PVA, a semi permanent occlusive agent with a limited potential for recanalization [45,46], is legally marketed for the general indication of vascular embolization, and it can legally be used by a physician for this type of surgery; however, it has not been specifically cleared for UAE. To date, the use of PVA particles for UAE represents an off-label use of an FDA-approved device. PVA is easy to deliver as well as relatively inexpensive. Different sizes of PVA ranging from 150–300 to −500–700 μm range are available and this agent is still utilized by many physicians for the treatment of fibroids [36,46]. The smaller particles are more likely to lead to better devascularization of the leiomyoma as well as to a higher rate of complete resolution of the symptoms [47]. Conversely, the frequency of an ischemia related complication (i.e. pelvic pain) observed with the use of 150–300 is higher than that observed in studies performed with 300–500 or 500–700 μm ranges particles [42,44]. Most of the time, the use of larger particles results in a more proximal occlusion of the uterine artery, so lowering the risk of uterine infarction and non-target embolization through utero-ovarian collaterals. On the other hand, a good devascularization of the lesion cannot always be achieved with larger PVA particles. Finally, it is important to take into account that when PVA is mixed with a saline solution or contrast agent, it tends to aggregate and may clump within the vessels or the catheter itself. Although adequate dilution of PVA reduces the risk of clumping, its behavior throughout embolization of leiomyoma remains unpredictable. For this reason, some operators prefer the use of tris-acryl microspheres (Embospheres, Biosphere Medical, Rockland, MA), previously applied to neuroradiology [48]. Tris-acryl microspheres are calibrated and on the whole do not aggregate, thus leading to a more controlled devascularization of uterine fibroids. Moreover, because of their elastic features, microspheres can be more easily injected through a microcatheter. The initial clinical experience using calibrated microspheres for the treatment of leiomyoma is promising [49,50]. Tris-acryl microspheres have been recently approved for UAE by the Food and Drug Administration. Some researchers advocate embolization with gelatine sponge (Gelfoam, Pharmacia & Upjohn Co., Kalamazoo, MI) as opposed to PVA without any substantial difference in outcome [51,52]. Gelfoam is a temporary agent and its use has been suggested for women who wish to preserve their fertility because of the possible recanalization of the uterine arteries after few days from the procedure. However, whether the uterine arteries recanalise following embolization with gelfoam is still unknown. Further studies are needed to determine the long-term recanal-ization rate of these vessels. To date, Geolfam has not been specifically cleared for UAE.

5.4. Potential problems

In order to achieve good devascularization of the lesion, both uterine arteries are embolized; most of the time, indeed, anastomoses between right and left uterine arteries and/or [53,54] between uterine and ovarian arteries are present [54–56]. They are likely to become more evident after a successful embolization, leading at times to incomplete fibroid infarction or more dangerously to ovarian failure. In a post operative study of leiomyomatous uteri, Sampson et al. reported evidence of immediate filling of the contralateral uterine artery and both ovarian arteries after repeated injections into one uterine artery [40]. Moreover, in about 10% of the cases, the ovarian arteries, which arise from the anterior surface of the aorta (approximately at the level of L2), seem to provide direct supply to the uterine fundus [54,57]. The lack of response to embolization observed in some patients may be due to perfusion to the fibroids by these vessels [53,55,58–60]. For this reason, many physicians complete the procedure with an aortogram to exclude the presence of any residual supply to fibroid by enlarged ovarian collaterals. If it is suspected that the ovarian flow is continuing to supply the leiomyoma, a selective study of ovarian arteries should be performed. When their vascular contribution to the lesion is significant, injection of gelfoam into the proximal portion of these arteries should be considered [57]. Nevertheless, after ovarian embolization the risk of ovarian failure may increase.

Congenital absence of one uterine artery with only the ovarian artery supplying the uterus is very uncommon [59]. However, when present, it does not represent a contraindication to UAE: a recent study suggests that patients with a congenitally absent uterine artery may respond with similar success to those who undergo bilateral embolization [61].

5.5. Radiation dose

Fluoroscopy time during UAE procedures is an important consideration because women who undergo UAE are generally young and potentially fertile and the ovaries are in the fluoroscopic field during the procedure. Screening time decreases with operator experience and often angiographic runs are unnecessary. Magnified and oblique fluoroscopy should be limited as much as possible. The mean estimated absorbed ovarian dose is 22 cGy with a mean fluoroscopy time of 22 min [62]. The radiation exposure during this procedure is estimated to be about 6000 cGy cm^2, not far from the mean pelvic radiation dose for one to three barium enema examinations [63,64]. Pulsed fluoroscopy can reduce the dose of radiation by between one third and one half when compared with non-pulsed fluoroscopy [65,66]. The radiation dose associated with UAE is unlikely to cause patient injury or a significantly increased genetic risk of future children [62].

6. Post-procedural care

Patients should have bed rest for 12 h after the procedure, and then be evaluated for possible discharge. The immediate postoperative course is often characterized by intense pelvic pain, which generally starts at the end of embolization and lasts for nearly 24 h. Because UAE is meant to cause central necrosis of the fibroid, pain indicates successful infarction and could be a positive predictor of clinical outcome. Nevertheless, the correlation between the severity of pain and the outcome does not seem to show significance [67]. For the pain control women should be kept on PCA in the early post embolization period and an adequate pain relief protocol established. Different protocols have been evaluating pain control. They include oral nonsteroidal anti-inflammatory drugs, or NSAIDs (typically ibuprofen) and an analgesic drug (paracetamol) every 6 h, or in case of severe pain every 4 h. Where pain is severe, opioids such as morphine sulphate may be preferred. Morphine can be administered either with intermittent dosing by the nursing staff or via a PCA pump. It has been reported that a good analgesia regimen along with careful counseling enable UAE to be performed as an outpatient procedure. In a study by Hurts et al., the rate of patients re-admitted to the hospital for pain control was only 15% [68]. In another study, Siskin et al. reported a 95.9% successful discharge after 8 h of post-procedure observation. The patients were discharged home under a specific medication regimen consisting of prochlorperazine, ketorolac, meperidine, and hydrocodone [69].

Approximately 20–35% of the patients experience a post-embolization syndrome (PES), which in 10–15% of cases may also lead to a delayed re-admission [70,36]. Post-embolization syndrome starts 1–5 days after UAE, but sometimes it may occur later. Generally, the larger the volume of tissue embolized, the greater the severity of pain [71,47]. PES is due to a pyrogenic reaction (*fever producing*) of the body caused by breakdown products from the fibroid. It is more common when very large fibroid masses are embolized. Patients evidence a high fever, raised inflammatory markers, nausea, vomiting, discomfort at the site of embolization, high blood cell count (without a left shift) and negative cultures. Post-embolization syndrome usually resolves in 7 days using either nonsteroidal anti-inflammatory or analgesic drugs [47]. Unfortunately, it may be difficult to differentiate PES from infection. The latter is characterized by delayed pain, purulent discharge, fever and leukocytosis with a left shift [72]. It is extremely important not to confuse post embolization syndrome with infection.

7. Complications

Complications can be divided into six categories (Table 4). Angiography related complications are intrinsic to all angiographic embolization procedures and minimized by operator experience and good technique. Fibroid embolization

Table 4
Peri- and post-procedural complications

Complications of angiography
Haematoma in the groin
Contrast medium reaction
Dissection of internal iliac or uterine artery
Rupture of vescical artery branch
Post-embolization syndrome resulting in prolonged hospitalization (up to 48 h)
Pelvic infection
Uterine necrosis leading to hysterectomy
Fatal sepsi[a]
Ischemic phenomena
Severe and prolonged pelvic pain leading to readmission of the patient
Transient or permanent amenorrhoea related to ovarian embolization
Sexual dysfunction related to nontarget embolization of the cervicovaginal branch
Embolization of nontarget organs (bowel, bladder, buttock, nerves)
Adverse drug reaction
Pulmonary embolism[b]

[a] Fatal sepsi reported in two patient [43,73].
[b] Fatal pulmonary embolism reported in one patient [75].

related complications are relatively rare but dissection of the uterine artery during catheterization or rupture of a vescical artery branch has been reported [73]. Post-embolization syndrome and infection are the most unpredictable complications. The latter, if unrecognized or untreated, may even lead to septicemia and death. Currently, there are five known deaths related to UAE: three have been described in the literature whereas the remaining two have not yet been reported. Of the reported deaths, two were due to infection [43,74], and one was due to pulmonary emboli [75].

Deep venous thrombosis leading to pulmonary embolism is a rare event after UAE. The mechanism of deep venous thrombosis is thought to be related to a derangement of the clotting cascade due to tissue necrosis of fibroid. For this reason, some clinicians advocate leg pressure stockings to eliminate venous stasis, while others advocate the use of heparin, particularly in women with a history of deep venous thrombosis.

Infection is the most worrying complication of UAE, it occurs in 1–2% of patients and may be due to the necrotic process within the fibroid [32,35,36,47]. Unfortunately, infection may take place even several months after the procedure. To reduce the risk of infection it is highly advisable to use pads rather than tampons. Patients should also avoid sex for at least 20–30 days after UAE.

The rate of infection is thought to be higher in patients with large pedunculated subserosal fibroids, or with fibroids such as submucosal types, where direct contact with intracavitary germs may occur [47]. However, further studies are needed to definitely validate that this complication is more likely to occur in patients with these types of fibroids. When infection or ischaemic necrosis of the uterus is noted,

patients should be re-admitted and put immediately on antibiotics; in cases of medical therapy failure, patients will undergo surgery. Hysterectomy following UAE has been most commonly quoted between 1 and 3.5% [32,35,47,76,77] but its total incidence may be even higher [36]. In fact, besides the infection of the uterus, other factors such as comorbid disease, UAE clinical failures, new disease and fibroid extrusion may lead to surgery. Fibroid extrusion is a well-known complication [78] that is more likely to occur in patients with pedunculated submucosal fibroids. It accounts for 1–5% of all cases and it is sometimes associated with infection of the uterus, especially when the entire leiomyoma is not expelled and necrotic debris cannot be removed [14,76].

Amenorrhoea may be permanent or temporary and is more likely to happen in peri-menopausal women. In a recent prospective study performed to assess the effect of UAE on ovarian function in young women (average 34 years) no clinically relevant adverse effects on normal functioning ovaries were noted after the procedure in all of 32 patients [79]. In comparison, the risk of amenorrhoea markedly increases in woman over 45 years; the rate of ovarian failure following UAE in these patients has been estimated at 15–43% [80,81].

The cause of ovarian failure after UAE is not fully understood; since collaterals between uterine and ovarian arteries are not uncommon, migration of the embolic material into the ovarian vasculature through these collaterals during UAE has been advocated by some authors as a possible factor leading to the transient or permanent amenorrhoea after the procedure. These vascular connections might also explain the higher rate of ovary failure described in older patients following UAE; according to some authors, if during UAE a number of embolic particles migrates in the ovary vasculature, amenorrhoea is more likely to happen when, as in older women, ovary blood supply and total functional reserve is already reduced [80,81]. A diversion of blood flow to maintain the viability of the uterus following a sudden occlusion of both uterine arteries has been also advocated as a further possible factor causing ovarian failure. Indeed, a sudden diversion of the ovarian flow towards the uterus might lead to ovarian under-perfusion [82]. It has been also postulated that ovarian function could be influenced by the occlusion of the uterine arteries themselves [83]. This observation has been also supported by another study: Ryu et al. reported that 50% of the women who undergo UAE show at Doppler examination a decrease in the ovarian flow after the procedure [84].

Chronic vaginal discharge is another common complication. In a large series by Walker et al., persistent cyclically discontinuous discharge was observed in 13% of the women. Of these, 4% described their discharge as a major irritant or very troublesome as well [32]. Vaginal discharge may start shortly after the procedure and have an unusual brown color without being associated with other symptoms. Occasionally, even tissue can be seen. This is not of any concern, and merely indicates the elimination of breakdown products from degenerating fibroids.

Other complications include alteration of uterine physiology or non-target embolization of the cervicovaginal branch, pelvic vein thromboses, menstrual irregularity, premature menopause and foul vaginal odor coming from infected necrotic tissue inside the uterus; non-target embolization of the cervicovaginal branch has been advocated by some authors as a cause of sexual function disruption but this issue is still highly controversial [85]. However, no clear scientific evidence of such complication has yet been reported in the literature. Finally, other complications which are theoretically possible include radiation skin burns, rhabdomyolysis with renal damage and intrauterine growth retardation. Post embolization syndrome should be considered a complication when the hospitalization time exceeds 48 h or patient readmission is needed [10].

8. Follow-up

Imaging follow-up is commonly carried out by US or MR. For appropriate assessment of the uterus, similar parameters to pre UAE imaging should be used [20–22]. Nowadays, MR is considered the best modality for quantitative assessment of signal intensity and morphologic changes of leiomyomas before and after UAE [20,86–88].The majority of leiomyomas show a similar change in signal intensity after UAE; the appearance of a "bag of blood-products," as recently reported by Jha et al. [87] well describes the leiomyomas following embolization. This appearance is due to high signal intensity on T1-weighted images, homogeneous low signal intensity on T2-weighted images, and no detectable enhancement after injection of gadopentetate dimeglumine.

The patients should be regularly reviewed as outpatients for at least 6 months to detect any treatment failures. Imaging follow-up should include transvaginal or transabdominal US and/or MR at 12 weeks, 1 year and 2 years after the procedure. For longitudinal studies, the American Reporting Standards for UAE suggest follow-up intervals of 1, 3, 6, 12, 18, 24 months [10].

9. Clinical outcome

Review of the published data reported in Table 5 [32,35,36,47,51,69,73,76,77,89–93] shows a high technical success of UAE, ranging between 81 and 98%. Symptoms of menorrhagia and pelvic pressure are controlled in 73–97% of the patients. Fibroids and uterus shrink by up to 55% of their volume within 1 year and the latter continues to shrink over time. Just a small number of patients do not improve with this treatment, and the reasons for failure have not yet been fully identified. Leiomyoma recurrence (or late failure) after UAE may also occur but to date few cases have been described in the literature. Nevertheless, in a recent study on fibroid embolization the recurrence rate resulted to be as high as 10% at just little more than 2 years

Table 5
Results of UAE

Reference	Number of patients	Technical success rate (%)	Fibroid volume reduction (%)	Symptomatic improvement (%)	Hysterectomy rate (%)
Ravina et al. [89]	88	89	69	10	–
Walker et al. [35]	200	98	69	79	1
Goodwin et al. [36]	60	81	50	80	10
Hutchins et al. [73]	305	96	48	92	2
Spies et al. [92]	61	91	78	89	0
Pelage et al. [47]	80	95	52	90	1
Siskin et al. [69]	49	98	–	88.5	2
Andersen et al. [76]	62	97	68	76	–
McLucas et al. [77]	167	98	37	88	3.5
Spies et al. [92]	200	99	38	90	0
Katsumori et al. [51]	60	98	70	97	0
Walker and Pelage [32]	400	99	73	73–90	2.25
Tranquart et al. [91]	58	96.5	86	87	–
Pron et al. [93]	555	97	–	–	–

From [32,35,36,47,51,69,73,76,77,89–93].

follow up [55,94]. Further studies are needed to determine the true incidence of either early and late treatment failures after UAE.

Successful full term pregnancies have occurred following UAE, when performed for a variety of causes. The first report on uneventful pregnancy after UAE, although carried out for the treatment of a uterine vascular malformation, was published in 1995 [95]. In 2001, Ravina et al. described the first cases of pregnancy after UAE embolization. Among 12 pregnancies observed in 9 women (median age of 41 years at first pregnancy outcome) after UAE, seven resulted in successful outcome (three women delivered vaginally and four by caesarean section) [96]. Unfortunately, the authors did not mention the total number of women desiring pregnancy enrolled in their study. More recently McLucas et al. in a study performed on 52 women less than 40 years old, reported a term pregnancy rate of 33% and a normal term deliveries of 20% (10 patients) [77]. However, in an analysis of the first 50 cases reported in the literature, women who became pregnant after UAE for fibroids were at a higher risk, compared to the general population, for premature delivery (22% versus 5–10%), miscarriage (32% versus 10–15%), postpartum hemorrhage (9% versus 4–6%), breech presentation (22% versus 5%), and cesarean section (65% versus 22%). Women who became pregnant after UAE for any cause were also at increased risk of premature delivery (28%), miscarriage (22%), postpartum hemorrhage (13% versus 4–6%), breech presentation (17%), and cesarean section (58%) [15].

As a standard practice, and to ensure safe pregnancy McLucas et al. suggest that all women should be advised to wait for 6 months after UAE before any attempt to conceive [77].

Finally the quality of life at 3 and 6 months post-procedure has been addressed in a few series [46,98]. In a study by Spies that assessed the recovery time of 50 women following UAE, significant improvements in health related quality of life and fibroid specific symptoms were reported in all patients. As also suggested by the authors of this study, the measurement of health related quality of life and fibroid specific symptoms might also be used as a means of comparing the outcome of UAE with other fibroid treatments [97].

10. Surgical and non surgical options

Fibroids are the commonest cause of hysterectomy. In the United States, an estimated 600,000 hysterectomies are performed each year [99] while in the UK the number of hysterectomies exceeds 70,000 in National Health Service hospitals [100]. Hysterectomy is a major operation involving a hospital admission of 4–7 days with 1–2 months of convalescence. Aside from the morbidity of hysterectomy, complications can occur with blood transfusion being required in a few cases. The mortality and complication rates for hysterectomy are 0.2 and 5–10%, respectively [101–103]. There is a higher risk of one or more complications after abdominal hysterectomy than after vaginal hysterectomy [103]. However, when hysterectomy is performed for benign fibroids the risk of complication is markedly reduced accounting for 6% of all procedures [104].

The costs of both procedures have been compared in two retrospective studies [104,105]. In the first study, the hysterectomy facility costs were estimated as US$ 4914, 3954 and 3116 for laparoscopic, open, and vaginal procedures, respectively. Furthermore the facility cost of UAE compared favorably with hysterectomy. Specifically, it ranged from US$ 2058 to 4951 and the mean total cost resulted to be US$ 3080 [105]. Nevertheless, this study was limited by small sample size, the use of charge data converted to costs, and insufficient information about patients characteristic. Conversely, a more recent and detailed study by Molly et al. concluded that the mean total hospital costs of UAE are significantly higher than hysterectomy (US$ 8223 versus US$ 6046, $P < 0.0001$) [106]. To date, although randomized tri-

als comparing results and costs of both procedures are still underway (i.e. EMMY and REST), it is not possible to predict whether the UAE will be preferred to hysterectomy in the first approach to fibroids [107]. However, the first results of a Spanish randomized and controlled trial are, over all, slightly favorable towards UAE. In detail, the mean hospital stay and period before resuming normal activities of the patients enrolled in this study were substantially shorter for the women who underwent UAE (40 patients) than for the women who underwent hysterectomy (20 patients); moreover, although the UAE patients made more emergency department visits, mainly due to post-embolization syndrome or pelvic pain, the percentage of patients with major complications was higher in the hysterectomy group. The major complications in the hysterectomy group (one deep venous thrombosis, three surgical wound abscess, two transfusion and one intra-abdominal abscess) accounted for 35% of all cases compared with 2% of all embolization procedures (1 deep vein thrombosis) [33]. However, the higher rate of complications reported in the hysterectomy group were mainly due to abscess that, according to the present authors, are not highly representative for the complications after hysterectomy [104].

Apart from hysterectomy, fibroids may be removed by hysteroscopic resection, surgical or laparoscopic myomectomy. Myomectomy, especially when it is carried out surgically, may be associated with increased blood loss and post-operative morbidity and in some cases, additional procedures may be required [108,109]. The success of myomectomy has to be still evaluated since no randomized trials against expectant management have ever been carried out. However, myomectomy may lead to adhesion formation within the abdominal cavity, which may further impair fertility [110,77]. A study from Stanford [111] comparing UEA with myomectomy showed superior results in the former group with regard to symptoms of menorrhagia and complication rates (4% versus 19%). These data did not differ significantly from those successively reported by McLucas–Adler in a similar study [112]. Miomectomy seems not to compare favorably with UAE also in terms of post-procedure pregnancy [77]. On the other hand, as opposed to women in whom myomectomy is carried out, patients who undergo embolization are more likely to need further invasive treatment (surgery or further embolization) in the 3–5 years after the index procedure [113]. No detailed cost information on myomectomy is currently available in the literature.

Recently, laser ablation of uterine fibroids in an open magnetic resonance scanner [114] and percutaneous magnetic resonance-imaging-guided cryoablation [115] have been proposed as possible alternatives. These innovative techniques need, however, further evaluation.

Medical therapies include hormone treatment using gonadotrophin-releasing hormone agonists. This treatment may be useful in specific instances and for the short term control but requires continued medication and frequently presents side effects such as hot flushes, mood swings, insomnia and dyspareunia. Hormonal therapy does not lead to a definitive cure and once stopped fibroids re-grow to their original size within months [116].

11. Conclusion

UAE is a promising non-surgical alternative for patients with menorrhagia and other fibroid specific symptoms and shows significant improvements in health-related quality of life. A good clinical and radiological assessment of the lesion prior to UAE is mandatory. Although US plays an important role in the study of fibroid, MR remains the preferred tool for the preoperative assessment and measurement of these tumors, and should always be considered in all patients before UAE.

The main advantages of UAE are its minimally invasive approach, low risk of procedure related complications and possibility for the patients to conserve fertility. Also, the morbidity and hospitalization time of UEA seem to compare favorably with the surgical alternatives but only the final results of randomized trials comparing surgical with radiological procedures will be able to designate the best option [117]. UAE has proven to be safe and effective even when performed on an outpatient basis with a low rate of pain related re-admission. However, a small number of patients do not improve with UEA and the reasons for failure have not yet been identified and reported.

Certainly, the initial results of UAE for fibroids are encouraging, but great care has to be taken, as UAE is still a new procedure with a follow-up limited to 8 years and unknown long-term effects on uterus devascularization. With regard to the treatment of adenomyosis, the safety and the efficacy of UEA is still uncertain.

References

[1] Rosch J, Dotter CT, Brown MJ. Selective arterial embolization: a new method for control of hemorrhage. Radiology 1972;102:303–6.

[2] Oliver Jr JA, Lance JS. Selective embolization to control massive hemorrhage following pelvic surgery. Am J Obstet Gynecol 1979;135:431–2.

[3] Wells I. Internal iliac artery embolization in the management of pelvic bleeding. Clin Radiol 1996;51:825–7.

[4] Vedantham S, Goodwin SC, McLucas B, Mohr G. Uterine artery embolization:an underused method of controlling pelvic hemorrhage. Am J Obstet Gynaecol 1997;176:938–48.

[5] McIvor J, Cameron EW. Pregnancy after uterine artery embolization to control hemorrhage from trophobastic tumor. Br J Radiol 1996;69:624–9.

[6] Ravina JH, Herbreteau D, Ciraru-Vigneron N, et al. Arterial embolization to treat uterine myomata. Lancet 1995;346:671–2.

[7] Buttram Jr VC, Reiter RC. Uterine leiomyomata: etiology, symptomatology, and management. Fertil Steril 1981;36:433–45.

[8] Kjerulff KH, Langenberg P, Seidman JD, et al. Uterine leiomyomas. Racial differences in severity, symptoms and age at diagnosis. J Reprod Med 1996;41:483–90.

[9] Society of Interventional Radiology. Uterine artery embolization survey. 10,500 Procedures performed worldwide. Fairfax, VA: Society of Interventional Radiology; 2000.

[10] Goodwin SC, Bonilla SM, Sacks D, et al. The members of the reporting standards for uterine artery embolization (UEA) subcommittee, the members of committee. Reporting standards for uterine artery embolization for the treatment of uterine leiomyomata. J Vasc Interv Radiol 2001;12:1011–20.

[11] Yen S, Tsai C, Naftolin F. Pulsatile patterns of gonadotropin release in subject with and without ovarian function. J Clin Endocrinol Metab 1972;34:671–5.

[12] Speroff L, Glass, R, Kase N. Clinical gynecologic endocrinology and infertility. fifth ed. Baltimore, MD: Wiliams & Wilkins; 1994. p. 813–14.

[13] Pelage JP, Soyer P, Le Dref O, et al. Uterine arteries: bilateral catheterization with a single femoral approach and a single 5-F catheter-technical note. Radiology 1999;210:573–5.

[14] Sandhu C, Matson M, Belli AM. Review of readmissions due to complications from uterine fibroid embolization. Clin Radiol 2002;57:1122–4.

[15] Goldberg J, Pereira L, Berghella V. Pregnancy after uterine artery embolization. Obstet Gynecol 2002;100:869–72.

[16] McLucas B, Adler L, Perrella R. Predictive factors for the success in uterine fibroid embolization. Minim Inv Ther All Tech 1999;8:429–32.

[17] Spies JB, Roth AR, Jha RC, et al. Leiomyomata treated with uterine artery embolization: factors associated with successful symptom and imaging outcome. Radiology 2002;222:45–52.

[18] Broekmans FJ, Heitbrink MA, Hompes PG, Schoute E, Falke T, Schoemaker J. Quantitative MRI of uterine leiomyomas during triptorelin treatment: reproducibility of volume assessment and predictability of treatment response. Magn Reson Imag 1996;14:1127–35.

[19] Omary RA, Vasireddy S, Chrisman HB, et al. The effect of pelvic MR imaging on the diagnosis and treatment of women with presumed symptomatic uterine fibroids. J Vasc Interv Radiol 2002;13:1149–53.

[20] Burn PR, McCall JM, Chinn RJ, Vashisht A, Smith JR, Healy JC. Uterine fibroleiomyoma: MR imaging appearances before and after embolization of uterine arteries. Radiology 2000;214:729–34.

[21] Watson GM, Walker WJ. Uterine artery embolisation for the treatment of symptomatic fibroids in 114 women: reduction in size of the fibroids and women's views of the success of the treatment. BJOG 2002;109(2):129–35.

[22] Hagspiel KD, Matsumoto AH, Berr SS. Uterine fibroid embolization: assessment of treatment response using perfusion-weighted extraslice spin tagging (EST) magnetic resonance imaging. J Magn Reson Imag 2001;13:982–6.

[23] Scoutt LM, McCarthy SM, Flynn SD, et al. Clinical stage I endometrial carcinoma: pitfalls in preoperative assessment with MR imaging. Work in progress. Radiology 1995;194:567–72.

[24] Togashi K, Ozasa H, Konishi I, et al. Enlarged uterus: differentiation between adenomyosis and leiomyoma with MR imaging. Radiology 1989;171:531–4.

[25] Arnold LL, Ascher SM, Schruefer JJ, Simon JA. The nonsurgical diagnosis of adenomyosis. Obstet Gynecol 1995;86:461–5.

[26] Siskin GP, Tublin ME, Stainken BF, Dowling K, Dolen EG. Uterine artery embolization for the treatment of adenomyosis: clinical response and evaluation with MR imaging. Am J Roentgenol 2001;177:297–302.

[27] Smith SJ, Sewall LE, Handelsman A. A clinical failure of uterine fibroid embolization due to adenomyosis. J Vasc Interv Radiol 1999;10:1171–4.

[28] McLucas B, Perrella R, Goodwin S, Adler L, Dalrymple J. Role of uterine artery Doppler flow in fibroid embolization. J Ultrasound Med 2002;21:113–20.

[29] Al-Badr A, Faught W. Uterine artery embolization in an undiagnosed uterine sarcoma. Obstet Gynecol 2001;97:836–7.

[30] Joyce A, Hessami S, Heller D. Leiomyosarcoma after uterine artery embolization. A case report. J Reprod Med 2001;46:278–80.

[31] Parker WH, Fu YS, Berek JS. Uterine sarcoma in patients operated on for presumed leiomyoma and rapidly growing leiomyoma. Obstet Gynecol 1994;83:414–8.

[32] Walker WJ, Pelage JP. Uterine artery embolisation for symptomatic fibroids: clinical results in 400 women with imaging follow up. BJOG 2002;109(11):1262–72.

[33] Pinto I, Chimeno P, Romo A, et al. Uterine fibroids: uterine artery embolization versus abdominal hysterectomy for treatment—a prospective, randomized, and controlled clinical trial. Radiology 2003;226:425–31.

[34] McDermot VG, Schuster MG, Smith TP. Antibiotic prophylaxis in vascular and intervention radiology. Am J Roentgenol 1997;169:31–8.

[35] Walker WJ, Green A, Sutton C. Bilateral uterine artery embolization for myomata: results, complications and failures. Minim Inv Ther All Tech 1999;8:449–54.

[36] Goodwin SC, McLucas B, Lee M, et al. Uterine artery embolization for the treatment of uterine leiomyomata: midterm results. J Vasc Interv Radiol 1999;10:1159–65.

[37] Hutchins Jr FL, Worthington-Kirsch R, Berkowitz RP. Selective uterine artery embolization as primary treatment for symptomatic leiomyomata uteri. J Am Assoc Gynecol Laparosc 1999;6:279–84.

[38] Spies JB, Ascher SA, Roth AR. Uterine artery embolization for leiomyomata. Obstet Gynecol 2001;98:29–34.

[39] Shlansky-Goldberg R, Cope C. A new twist on the waltman loop for uterine fibroid embolization. J Vasc Interv Radiol 2001;12:997–1000.

[40] Sampson JA. The blood supply of uterine myomata. Surg Gynecol Obstet 1912;14:215–34.

[41] Worthington-Kirsch RL, Popky GL, Hutchims FL. Uterine arterial embolization for the management of leyomyomas: quality-of-life assessment and clinical response. Radiology 1998;208:625–9.

[42] Siskin GP, Englander M, Stainken BF, Ahn J, Dowling K, Dolen EG. Embolic agents used for uterine fibroid embolization. AJR Am Roentgenol 2000;175(3):767–73.

[43] de Blok S, de Vries C, Prinssen HM, Blaauwgeers HLG, Jorna-Meijer. Fatalk sepsis after uterine artery embolization with microspheres. J Vasc Interv Radiol 2003;14:779–83.

[44] Goodwin S, Vedantham S, McLucas B, Forno A, Perrella R. Preliminary experience with uterine artery embolization for uterine fibroids. J Vasc Interv Radiol 1997;8:517–26.

[45] Lang EK. Transcatheter embolization of pelvic vessels for control of intractable hemorrhage. Radiology 1981;140:331–9.

[46] Worthington-Kirsch RL, Fueredi GA, Goodwin SC, et al. Polyvinyl alcohol particle size for uterine artery embolization. Radiology 2001;218:605–6.

[47] Pelage J-P, le Dref O, Soyer P, et al. Fibroid related menorrhagia: treatment with superselective embolization of the uterine arteries and midterm follow-up. Radiology 2000;215:428–31.

[48] Bendszus M, Klein R, Burger R, Warmuth-Metz M, Hofmann E, Solymosi L. Efficacy of trisacryl gelatin microspheres versus polyvinyl alcohol particles in the preoperative embolization of meningiomas. Am J Neuroradiol 2000;21:255–61.

[49] Banovac F, Ascher SM, Jones DA, Black MD, Smith JC, Spies JB. Magnetic resonance imaging outcome after uterine artery embolization for leiomyomata with use of tris-acryl gelatin microspheres. J Vasc Interv Radiol 2002;13:681–8.

[50] Spies JB, Benenati JF, Worthington-Kirsch RL, Pelage JP. Initial experience with use of tris-acryl gelatin microspheres for uterine artery embolization for leiomyomata. J Vasc Interv Radiol 2001;12:1059–63.

[51] Katsumori T, Nakajiama K, Mihara T, Tokuhiro M. Uterine artery embolization using gelatine sponge particles alone for

symptomatic uterine fibroids:midterm results. AJR Am J Roentgenol 2002;178:135–9.

[52] Katz RN, Mitty HA, Stancata-Pasik A, Cooper J, Ahn J. Comparison of uterine artery embolization for fibroids using gelatin sponge pledgets and polyvinylalcohol. J Vasc Interv Radiol 1998;9:184–7.

[53] Lindenbaum E, Brandes JM, Itskivitz J. Ipsi- and contralateral anastomosis of the uterine arteries. Acta Anat 1978;102:157–61.

[54] Razavi MK, Wolanske KA, Hwang GL, Sze DY, Kee ST, Dake MD. Angiographic classification of ovarian artery-to-uterine artery anastomoses: initial observations in uterine fibroid embolization. Radiology 2002;224:707–12.

[55] Matson M, Nicholson A, Belli A-M. Anastomoses of the ovarian and uterine arteries: a potential pitfall and cause of failure of uterine artery embolization. Cardiov Interv Rad 2000;23:393–6.

[56] Pelage J-P, Le Dref O, Jacob D, et al. Arterial anatomy of the female genital tract: variations and relevance to transcatheter embolization of the uterus. Am J Roentgenol 1999;172:989–94.

[57] Worthington-Kirsch RL. Anatomic variants in UAE: recognition and management. J Vasc Interv Radiol 2000;11:32–3.

[58] Nikolic B, Spies JB, Abbara S, Goodwin SC. Ovarian artery supply of uterine fibroids as a cause of treatment failure after uterine artery embolization: a case report. J Vasc Interv Radiol 1999;10:32–3.

[59] Binkert CA, Andrews RT, Kaufman JA. Utility of nonselective abdominal aortography in demonstrating ovarian artery collaterals in patients undergoing uterine artery embolization for fibroids. J Vasc Interv Radiol 2001;12:841–5.

[60] Farber-Brown G, Beilby JOW, Tarbit MH. The blood supply of the uterus. Br J Obstet Gynaecol 1970;77:673–81.

[61] McLucas B, Reed RA, Goodwin S, et al. Outcomes following unilateral uterine artery embolisation. Br J Radiol 2002;75:122–6.

[62] Nikolic B, Spies JB, Lundsten MJ, Abbara S. Patient radiation dose associated with uterine artery embolization. Radiology 2000;214:121–5.

[63] Goodwin SC, Walker WJ. Uterine artery embolization for the treatment of uterine fibroids. Curr Opin Obstet Gynecol 1998;10:315–20.

[64] Bradly Ea, Reidy JF, Forman RG, Jaosz J, Braude PR. Transcatheter uterine artery embolization to treat large uterine fibroids. Br J Obstet Gynaecol 1998;105:235–40.

[65] Nikolic B, Spies JB, Campbell L, Walsh SM, Abbara S, Lundsten MJ. Uterine artery embolization: reduced radiation dose with refined technique. J Vasc Interv Radiol 2001;12:39–44.

[66] Wall BF, Hart D. Revised radiation doses for typical X-ray examinations. Report on a recent review of doses to patients from medical X-ray examinations in the UK by NRPB. National Radiological Protection Board. Br J Radiol 1997;70:437–9.

[67] Roth AR, Spies JB, Walsh SM, Wood BJ, Gomez-Jorge J, Levy EB. Pain after uterine artery embolization for leiomyomata: can its severity be predicted and does severity predict outcome? J Vasc Interv Radiol 2000;11:1047–52.

[68] Hurst BS, Stackhouse DJ, Matthews ML, Marshburn PB. Uterine artery embolization for symptomatic uterine myomas. Fertil Steril 2000;74:855–69.

[69] Siskin GP, Stainken BF, Dowling K, Meo P, Ahn J, Dolen EG. Outpatient uterine artery embolization for symptomatic uterine fibroids: experience in 49 patients. J Vasc Interv Radiol 2000;11:305–11.

[70] Hemingway A, Allison D. Complications of embolisation: analysis of 410 procedures. Radiology 1988;166:669–72.

[71] Sutton D, Gregson R. Arteriography and interventional angiography. In: Sutton D, editor. Textbook of radiology and imaging. 6th ed. Churchill and Livingstone; 1998. p. 694 [Chapter 25].

[72] Gordon CH, Wong BA, Scott C. Goodwin uterine artery embolization for uterine fibroids. Appl Radiol 2001;30(1):26–31.

[73] Hutchins FL, Worthington-Kirsch R, Berkowitz RP. Selective uterine artery embolization as primary treatment for symptomatic leiomyomata uteri. J Am Assoc Gynecol Lapar 1999;8:279–85.

[74] Vashisht A, Studd J, Carey A, et al. Fatal septicaemia after fibroid embolization. Lancet 1999;354:307–8.

[75] Lanocita R, Frigerio LF, Patelli G, Di Tolla G, Sperafico C. A fatal complication of percutaneous transcathether embolization for treatment of uterine fibroids. In: Proceedings of the 11th Annual Scientific Meeting on SMIT/CIMIT, Boston, MA, USA, 16–18 September 1999 (abstract).

[76] Andersen PE, Lund N, Justesen P, Munk T, Elle B, Floridon C. Uterine artery embolization of symptomatic uterine fibroids. Initial success and short-term results. Acta Radiol 2001;42:234–8.

[77] McLucas B, Adler L, Perrella R. Pregnancy following uterine fibroid embolization. Int J Gynaecol Obstet 2001;74:1–7.

[78] Abbara S, Spies JB, Scialli AR, Jha R, Lage J, Nikolic B. Transcervical expulsion of a fibroid as a result of uterine artery embolization for leyomyomata. J Vasc Int Radiol 1999;10:409–11.

[79] Ahmad A, Qadan L, Hassan N, Najarian K. Uterine artery embolization treatment of uterine fibroids: effect on ovarian function in younger women. J Vasc Interv Radiol 2002;13:1017–20.

[80] Chrisman HB, Saker MB, Ryu RK, et al. The impact of uterine fibroid embolization on resumption of menses and ovarian function. J Vasc Interv Radiol 2000;11:699–703.

[81] Spies JB, Roth AR, Gonsalves SM, Murphy-Skrzyniarz KM. Ovarian function after uterine artery embolization for leiomyomata: assessment with use of serum follicle stimulating hormone assay. J Vasc Interv Radiol 2001;12:437–42.

[82] Mc Ivor J, Cameron EW. Pregnancy after uterine artery embolization to control hemorrhage from gestational trophoblastic tumor. Br J Radiol 1996;69:624–9.

[83] Siddle N, Sarrel P, Whitehead M. The effect of hysterectomy on the age at ovarian failure: identification of a subgroup of women with premature loss of ovarian function and literature review. Fertil Steril 1987;47:94–100.

[84] Ryu RK, Chrisman HB, Omary RA, et al. The vascular impact of uterine artery embolization: prospective sonographic assessment of ovarian arterial circulation. J Vasc Interv Radiol 2001;12:1071–4.

[85] Lai AC, Goodwin SC, Bonilla SM, et al. Sexual dysfunction after uterine artery embolization. JVIR 2000;11:755–8.

[86] Katsumori T, Nakajima K, Tokuhiro M. Gadolinium-enhanced MR imaging in the evaluation of uterine fibroids treated with uterine artery embolization. Am J Roentgenol 2001;177:303–7.

[87] Jha RC, Ascher SM, Imaoka I, Spies JB. Symptomatic fibroleiomyomata: MR imaging of the uterus before and after uterine arterial embolization. Radiology 2000;217:228–35.

[88] deSouza NM, Williams AD. Uterine arterial embolization for leiomyomas: perfusion and volume changes at MR imaging and relation to clinical outcome. Radiology 2002;222:367–74.

[89] Ravina JH, Bouret JM, Ciraru-Vigneron N, et al. Recourse to particulate embolization in the treatment of some uterine leiomyomata. Bull Acad Natl Med 1997;181:233–43.

[90] Spies JB, Scialli AR, Jha RC, et al. Initial results from uterine fibroid embolization for symptomatic leiomyoma. J Vasc Interv Radiol 1999;10:1149–57.

[91] Tranquart F, Brunereau L, Cottier JP, et al. Prospective sonographic assessment of uterine artery embolization for the treatment of fibroids. Ultrasound Obstet Gynecol 2002;19:81–7.

[92] Spies JB, Ascher SA, Roth AR, Baker CM, Mauro L. Complications after uterine artery embolization for leiomyomas. Obstet Gynecol 2002;100:873–80.

[93] Pron G, Bennett J, Common A, et al. Technical results and effects of operator experience on uterine artery embolization for fibroids: the ontario uterine fibroid embolization trial. J Vasc Interv Radiol 2003;14(5):545–54.

[94] Marret H, Alonso AM, Cottier JP, Tranquart F, Herbreteau D. Leiomyoma recurrence after uterine artery embolization. J Vasc Interv Radiol 2003;14:1395–9.

[95] Chow TWP, Nwosu EC, Gould DA, Richmond DH. Pregnancy following successful embolisation of uterine vas-

cular malformation. Br J Obstet Gynaecol 1995;102:106–68.

[96] Ravina JH, Ciraru-Vigneron N, Aymard A. Pregnancy after embolization of uterine myomata: report of 12 cases. Fertil Steril 2000;73:1241–3.

[97] Spies JB, Warren EH, Mathias SD, Walsh SM, Roth AR, Pentecost MJ. Utreine fibroid embolization: measurement of health related quality of life before and after therapy. J Vasc Interv Radiol 1999;10:1293–303.

[98] Spies JB, Coyne K, Guaou N, Boyle D, Skyrnarz-Murphy K, Gonzalves SM. The UFS-QOL, a new disease-specific symptom and health-related quality of life questionnaire for leiomyomata; 2002.

[99] Pokras R, Hufnagel VG. Hysterectomies in the United States 1965–1984 Vital Health Statistics, Series 13.92.Washington, DC: Government Printing Office.

[100] Maresh MJ, Metcalfe MA, McPherson K, et al. The VALUE national hysterectomy study: description of the patients and their surgery. BJOG 2002;109:302–12.

[101] Wingo PA, Huezo CM, Rubin GL, Ory HW, Peterson HB. The mortality risk associated with hysterectomy. Am J Obstet Gynecol 1985;152:803–8.

[102] Maresh MJ, Metcalfe MA, McPherson K, et al. The VALUE national hysterectomy study: description of the patients and their surgery. Br J Obstet Gynaecol 2002;109:302–12.

[103] Davies A, Hart R, Magos A, Hadad E, Morris R. Hysterectomy: surgical route and complications. Eur J Obstet Gynecol Reprod Biol 2002;10:104–48.

[104] Takamizawa S, Minakami H, Usui R, et al. Risk of complications and uterine malignancies in women undergoing hysterectomy for presumed benign leiomyomas. Gynecol Obstet Invest 1999;48:193–6.

[105] Subramanian S, Spies JB. Uterine artery embolization for leiomyomata: resource use and cost estimation. J Vasc Interv Radiol 2001;12:571–4.

[106] Beinfeld MT, Bosch JL, Gazelle GS. Hospital costs of uterine artery embolization and hysterectomy for uterine fibroid tumors. Acad Radiol 2002;9:1300–4.

[107] Myers ER, Barber MD, Gustilo-Ashby T, Couchman G, Matchar DB, McCrory DC. Management of uterine leiomyomata:what do we really know? Obstet Gynecol 2002;100:8–17.

[108] Fernandez H, Kadoch O, Capella-Allouc S, Gervaise A, Taylor S, Frydman R. Hysteroscopic resection of submucous myomas: long term results. Ann Chir 2001;126:58–64.

[109] Fernandez H, Sefrioui O, Virelizier C, Gervaise A, Gomel V, Frydman R. Hysteroscopic resection of submucosal myomas in patients with infertility. Hum Reprod 2001;16:1489–92.

[110] Lumsden MA. Embolization versus myomectomy versus hysterectomy: which is best, when? Hum Reprod 2002;17:253–9.

[111] Hwang GL, Razavi MK, Chen BH. A single center study comparing abdominal myomectomy with uterine artery embolization for treatment of myomas. Obstet Gynecol 2001;97:S7.

[112] McLucas B, Adler L. Uterine fibroid embolization compared with myomectomy. Int J Gynecol Obstet 2001;74:297–9.

[113] Broder MS, Goodwin S, Chen G, et al. Comparison of long-term outcomes of myomectomy and uterine artery embolization. Obstet Gynecol 2002;100:864–8.

[114] Law P, Gedroyc WM, Regan L. Magnetic resonance-guided percutaneous laser ablation of uterine fibroids. J Magn Reson Imag 2000;12:565–70.

[115] Sewell PE, Arriola RM, Robinette L, Cowan BD. Real-time I-MR-imaging—guided cryoablation of uterine fibroids. J Vasc Interv Radiol 2001;12:891–3.

[116] Healy DL, Vollenhoven BJ. The role of GnRH agonists in the treatment of uterine fibroids. Br J Obstet Gynaecol 1992;99(Suppl 7):23–6.

[117] Rothwell P, Warlow C. Is self audit reliable? Lancet 1995;346:1623.