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REVIEW

Uterine Artery Embolization for Adenomyosis: A Review of Imaging, Techniques, Complications and Outcomes

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Abstract

Purpose of Review This review aims to provide a comprehensive summary of the literature regarding the use of uterine artery embolization (UAE) in the treatment of pure adenomyosis and to document indications, results and complications for symptomatic patients who have failed conservative treatment and wish to avoid hysterectomy.

Recent Findings There is growing evidence to support UAE as a safe and successful treatment for the treatment of symptomatic pure adenomyosis.

Summary Pure adenomyosis has historically been treated with conservative pharmacological treatments including non-steroidal anti-inflammatories, hormonal contraceptive medications, and intrauterine devices. When such treatments have failed, hysterectomy has served as a definitive treatment for patients with symptomatic adenomyosis. However, the use of UAE to treat symptomatic adenomyosis has gained attraction in recent years as a less invasive and uterine sparing procedure, which may prove to be a suitable alternative for patients wishing to avoid hysterectomy. With the low rate of major complications in accordance with the Society of Interventional Radiology (SIR) classification and good success rates, UAE should be proposed as an alternative for patients who have failed medical therapy.

Keywords Pure adenomyosis · Uterine artery embolization · Minimally invasive · Uterine-sparing · Menorrhagia · Abnormal uterine bleeding

Introduction

Adenomyosis is a benign disease of the uterus characterised by the invasion of the endometrium into the myometrium. The histological appearance is that of endometrial glands and stroma, surrounded by hypertrophic musculature [1]. This process can result in enlargement of the uterus and can be either diffuse or focal type which can direct treatment options [2].

Symptoms include menorrhagia, dysmenorrhoea, bulk symptoms, chronic pelvic pain, infertility, obstetric complications, pre-term and small for gestational age neonates as well as pre-eclampsia [3]. Patients with adenomyosis commonly also have concomitant leiomyoma which has a similar symptom profile and differentiating the cause of symptoms can be challenging [4].

The prevalence of symptomatic adenomyosis has been difficult to establish. Historically, the diagnosis of adenomyosis was based on histological analysis which has led to an overestimation of its true prevalence. The previously available literature had thus produced widely varying estimates of the prevalence of adenomyosis that ranged from 5–70% [4] and 8.8 -61.5% [5]. However, a more recent population-based study which took in consideration the increasing use of imaging modalities to diagnose adenomyosis has evaluated its prevalence at 0.8% [6]. Yu et al. also noted that the incidence was higher in black versus white women and highest in individuals aged 41 to 45 [6]. In patients diagnosed with adenomyosis the rates of co-occurrence with endometriosis and uterine fibroids were also reported at 18% and 47%, respectively.

Treatment options are based on symptoms and disease phenotype. First line therapy is medical management to control pain primarily with non-steroidal anti-inflammatory

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drug (NSAID) with the addition of a hormonal contraceptive pill or intra uterine device. The strongest evidence to date favours the use of levonorgestrel intra-uterine systems or dienogest in reducing pain, uterine volume, and abnormal uterine bleeding. Gonadotrophin releasing hormone analogues (GnRH-a) have also been proposed as second line treatment options with further evidence required to support its efficacy [7].

If these medical measures are insufficient in controlling symptoms, then more invasive options can be considered. Hysterectomy remains the definitive treatment in eliminating bulk and abnormal uterine bleeding. However, more and more, women are searching for minimally invasive options. Either due to the desire to become pregnant or to avoid the perioperative morbidity associated with hysterectomy, some patients may not be good surgical candidates.

As for minimally invasive, uterus preserving techniques, there are many options becoming available for clinicians and patients to choose. From the surgical techniques, adenomyomectomy, wedge resection and myometrial excision are available. These options are preferred for those seeking to preserve fertility, though no strong evidence favours any technique.

There are numerous endometrial ablative techniques including thermal balloon ablation, yttrium aluminium garnet (YAG) laser, rollerball ablation and radiofrequency. These methods have reported high failure rates and with a limitation of penetrance > 2.5 mm.

High intensity focused ultrasound (HIFU) has some promising potential. This involves magnetic resonance guided focused ultrasound to cause coagulative necrosis. This is particularly appealing as it is non-invasive and has a very low complications profile [2, 4, 8•].

In this article we will assess the current literature available to date on uterine artery embolization for the treatment of pure adenomyosis. Where available, we will show overall outcome of treatment as well as the rates of improvement in dysmenorrhea, abnormal uterine bleeding, and bulk symptoms. We will also establish complication rates according to the Society of Interventional Radiology SIR adverse event (AE) classification [9].

Indications

Uterine artery embolization is a recognized non surgical, minimally invasive technique employed in the management of symptomatic adenomyosis [10, 11]. Patients afflicted with adenomyosis commonly present with symptoms of abnormal uterine bleeding, dysmenorrhea, and chronic pelvic pain [12]. These symptoms are not pathognomonic of adenomyosis and are also present in patients with uterine leiomyomas.

Imaging

Pre-treatment Imaging Features

The main imaging modalities for assessment of adenomyosis are ultrasound (US) and magnetic resonance imaging (MRI). According to a recent meta-analysis, transvaginal US (including 2D and 3D) demonstrated overall aggregated sensitivity of 78% and specificity of 78% for adenomyosis, as compared to MRI which demonstrated similar sensitivity of 78% and higher specificity of 88% [13]. Transvaginal US is a highly accurate first line diagnostic imaging method for patients with suspected adenomyosis. The main diagnostic features of adenomyosis on US include signs of heterotopic glands (manifesting as echogenic nodules/striations, myometrial cysts, and cystic striations), signs of muscular hyperplasia (manifesting as decreased echogenicity and thickening of the inner myometrium, enlarged globular uterus and venetian blind shadowing) and signs of myometrial vascularity (manifesting as increased vascularity and penetrating vessels on doppler interrogation) [14] (Fig. 1). Although some US features overlap with MRI features (e.g., enlarged globular uterus) others are unique to US (e.g., venetian blind shadowing) (Fig. 1F). The presence of myometrial cysts is the most sensitive and specific US criterion [15] (Fig. 1G).

MRI is the second line imaging modality for diagnosing adenomyosis and may be preferred when there are additional concomitant pelvic pathologies, for example, coexisting leiomyomas and endometriosis, as well as a large uterine volume [16••]. In terms of MRI acquisition technique, the most important sequence is a T2-weighted 2D fast-spin-echo or turbo-spin echo sequence with a triplanar acquisition, or alternatively a T2 weighted 3D sequences, ideally with ≤ 3 mm thickness sections to optimize spatial resolution [16••]. The main MRI direct imaging feature of adenomyosis is the presence of small hyperintense myometrial foci which correlate with the presence of heterotopic endometrial glands in the myometrium An additional direct sign is the irregular endomyometrial junction with bands or finger-like striations of high signal endometrium extending into the myometrium on T2-weighted images [17]. The main MRI indirect sign of adenomyosis is localized or diffuse junctional zone JZ thickening. A threshold of 12 mm for diffuse JZ thickening is the most quoted diagnostic criterion for adenomyosis in the literature [17, 18] (Fig. 1A). However, using direct criteria in combination with JZ thickening improves the specificity of diagnosing adenomyosis [16••]. Adenomyosis can also manifest as a mass-like lesion, called adenomyoma, which is a focal consolidation of the ectopic glands within the

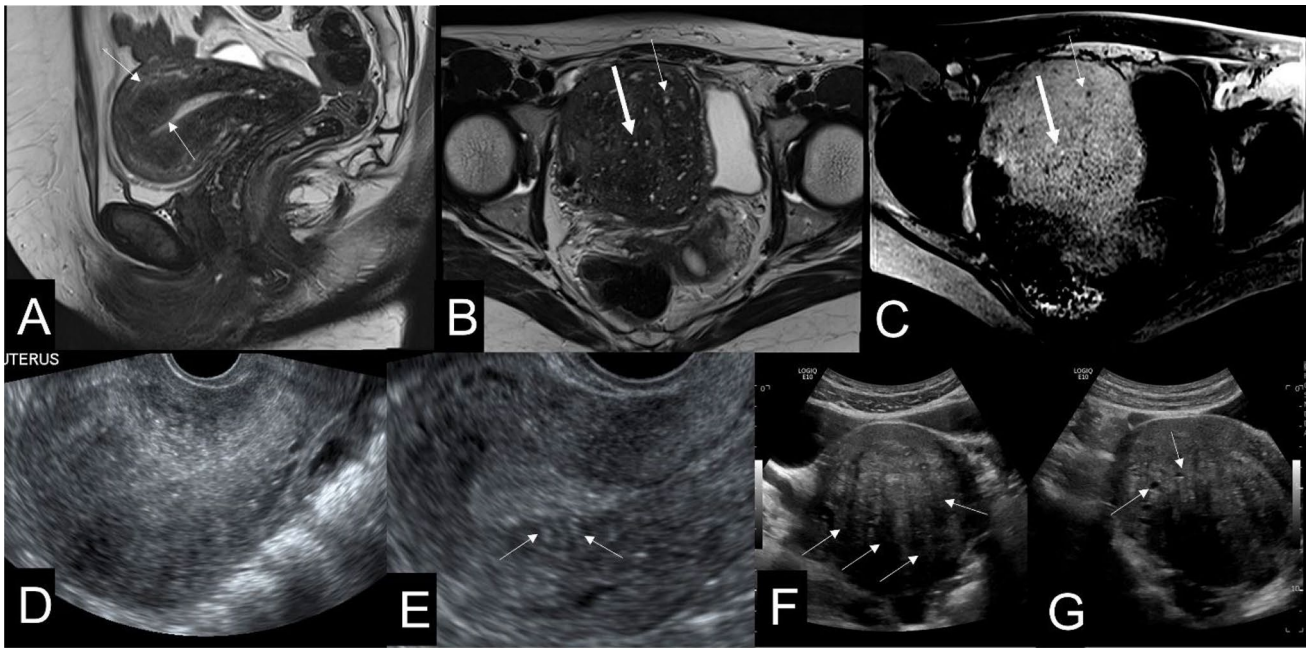

Fig. 1 Imaging characteristics of adenomyosis on MRI (A-C) and US (D-G). **A** Sagittal T2W sequence showing diffuse thickening of JZ (between arrows) measuring up to 17 mm in thickness (diffuse internal adenomyosis). **B** Axial T2W and **C** axial T1W pre-contrast sequence of another patient demonstrating hyperintense myometrial foci which can be of fluid signal (narrow arrows) or contain internal hemorrhagic signal (thick arrows). Patient also has concomitant bilateral ovarian endometriomas (not shown). US images of uterus in 3 different patients with adenomyosis showing **D** overall globular enlarged uterus with diffuse heterogeneous myometrium, **E** subendometrial echogenic striations, **F** venetian blind shadowing and **G** myometrial cysts

myometrium. Bazot and Daraï proposed 3 main imaging phenotypes of adenomyosis: internal adenomyosis (typically with myometrial hyperintense foci and JZ thickening) (Fig. 1A), adenomyoma (Fig. 2A–C), and external adenomyosis. The latter phenotype is controversial and is usually associated with endometriosis [17]. However, to date there is no universally accepted MRI classification system for adenomyosis and there is lack of standardization of terminology/definitions [16••].

Post-embolization Imaging Features

The most common post-uterine artery embolization (UAE) imaging appearance of adenomyosis are decreased uterine volume, decreased JZ thickness and development of areas of infarction [19, 20] (Fig. 2). A recent systematic review found that at the short-term (3 months) follow-up post embolization, patients with pure adenomyosis demonstrated more volume reduction than those with mixed adenomyosis/fibroids [19]. In fact, the average weighted absolute volume reduction was 56 cm^3 in the pure adenomyosis group versus 27 cm^3 in the combined group. Interestingly, at the midterm (6–12 months) follow-up, the further volume decrease between the two groups was no longer statistically significant. The volume loss then plateaued at the long-term follow-up beyond one year for the pure adenomyosis group (there was not enough data for the combined group). The JZ thickness, an important MRI diagnostic criterion for adenomyosis, also decreases post-embolization, with different studies reporting interval reduction ranging from 13.7% to 38% [20] (Fig. 2B). Both decreased uterine volume and JZ thickness reduction have been associated with post-treatment symptomatic improvement [10]. Finally, areas of devascularization of the adenomyotic tissue are often seen on post-embolization MRIs, with reported rates ranging from 44.2% to 82.5% [19]. The different subtypes of adenomyosis may also influence post-treatment infarction, as patients with focal adenomyosis were more likely to demonstrate areas of devascularization than those with diffuse adenomyosis [21, 22]. Post-embolization MRIs of patients with thicker JZ (> 20 mm) were also more likely to show areas of infarction [21]. However, the infarctions seen on short-term follow-up MRIs may not always persist and are often replaced by viable enhancing tissue at the long-term imaging follow-up (Fig. 2F).

Imaging characteristics have not only been used to assess treatment response, they also have the potential to help select patient populations more likely to benefit from UAE or help predict treatment response/failure. The predictors of treatment failures include thicker JZ at baseline imaging and lack of infarction on follow-up imaging [19]. For example, Smeets et al. reported that thicker JZ both at baseline imaging and at the short-term 3 months follow-up

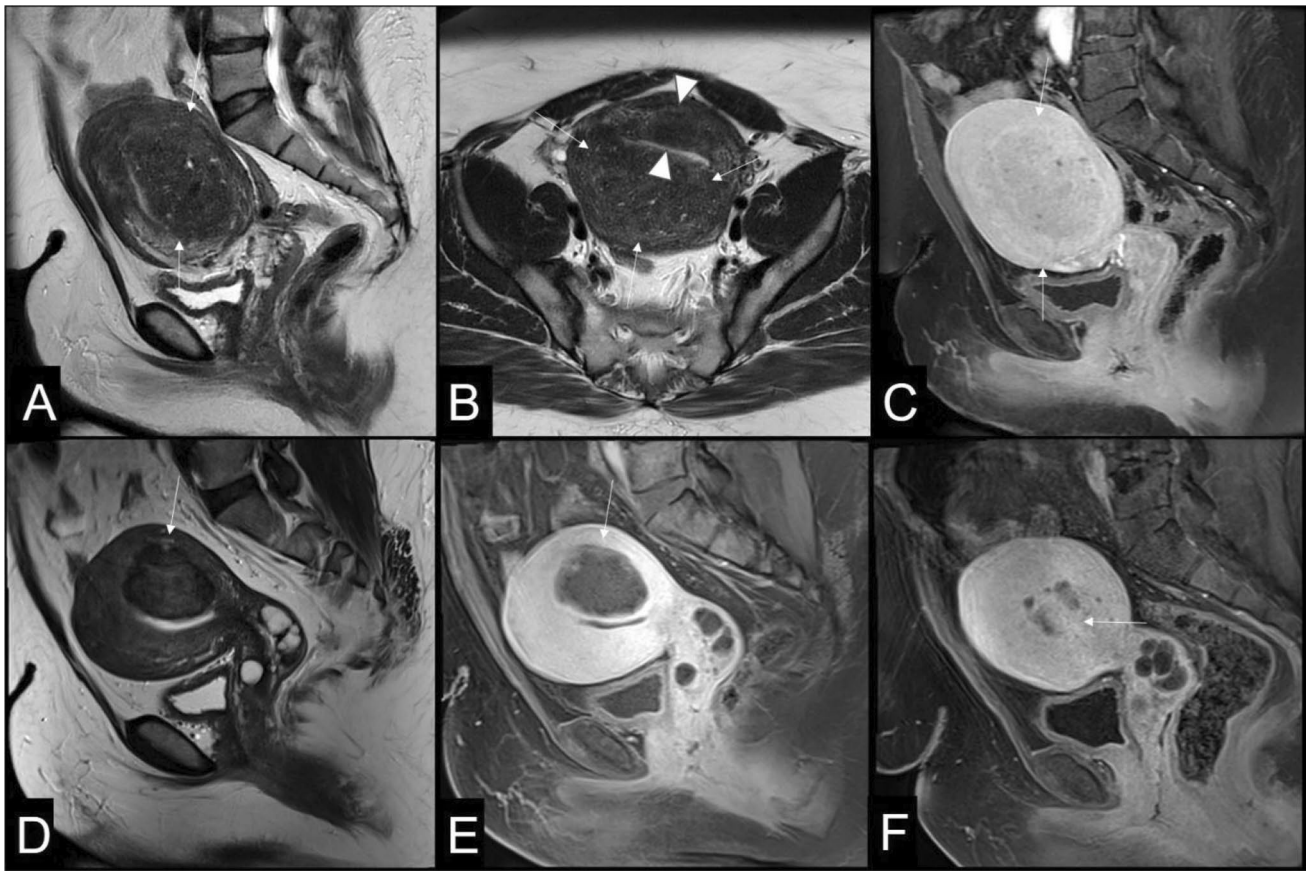

Fig. 2 Pre (**A**–**C**) and post embolization (**D**–**E**) imaging. 44-year-old woman with adenomyosis and symptoms of menorrhagia and dysmenorrhea, treated by uterine artery embolization. ***Pre-treatment images***: **A** Sagittal T2W and **B** axial T2W sequences images showing posterior uterine wall adenomyoma (between arrows) containing multiple T2 hyperintense foci. There was also focal JZ thickening anteriorly (between arrow heads) measuring up to 19 mm in thickness. **C** Post-contrast T1W sequence demonstrates complete enhancement and vascularisation of the adenomyoma. ***Post-treatment images:*** 5 months post-embolization, **D** sagittal T2W and **E** sagittal T1W post-contrast sequences demonstrate almost complete necrosis of the adenomyoma. Pre-treatment focal JZ thickening seen in B is no longer visualized post-treatment. Long-term follow up MRI at 3.5 years post-embolization demonstrates **F** revascularization of some portions of the adenomyoma. The patient's symptoms of menorrhagia and dysmenorrhea also recurred, and she underwent a second session of embolization shortly after

is associated with a higher likelihood of UAE treatment failure and hysterectomy [23]. Patients with initial baseline pre-treatment thicker JZ were also more likely to require additional therapy for symptomatic relief [24]. The degree of post-embolization adenomyosis necrosis can also help predict response, with Bae et al. suggesting a cut-off of less than 34.3% necrosis at the 3 months follow-up MRI as a predictor of midterm symptomatic recurrence [25]. In addition, dark T2 signal intensity of the adenomyotic tissue (defined as T2 signal similar to the rectus abdominis muscle by Kim et al.). was shown to be a favorable predictor for post-UAE necrosis, whereas heterogeneous T2 signal and T2 signal like that of the normal myometrium are poor prognostic factors [26]. In this study, all patients with dark T2 signal adenomyosis demonstrated complete necrosis post-embolization [22].

Technique

UAE is performed in a designated angiographic suite utilizing digital subtraction angiography. The procedure is commonly performed under conscious sedation via intravenous administration of midazolam and fentanyl. Epidural anesthesia can also be utilized following preprocedural assessment by an anesthesiologist [27]. Unilateral femoral artery or radial artery access is obtained under ultrasound guidance to allow the placement of a vascular sheath. A 4-or 5 Fr diagnostic catheter is used to catheterize and obtain angiographic images of the internal iliac artery, identify the uterine artery and any uterine ovarian anastomoses. Subselection of the uterine artery is performed using a high flow coaxial type microcatheter advanced distally into the vessel beyond the cervicovaginal branches.

On angiography, the vascular structure of adenomyosis is smaller than those seen in uterine fibroids [22]. The angiographic classification of adenomyosis is based on vascularity consisting of 3 levels. Level 1 lesions are the hypervascular subgroup where there is abundant peripheral and central blood. Level 2 lesions are characterised as the isovascular subgroup exhibiting peripheral blood flow but less blood flow on the centre of the lesions. Level 3 lesions are the hypovascular subgroup demonstrating mild staining with no blood flow at both the periphery and the centre of the lesions. Uterine artery supply can be equal or unequal, equal supply is derived from both uterine arteries whereas unequal supply is one uterine artery supplying more than 60% of the uterus [28].

A variety of embolic agents and particle sizes are utilized by interventional radiologists as follows: non spherical Polyvinyl alcohol (PVA) particles 355–500 µm and 500–700 µm diameter, Tris acryl microspheres 500–700 µm diameter and 700–900 µm diameter, hydrogel microspheres 500–900 µm diameter and Gelatin sponge particles [Table 1]. The use of smaller particles has also been reported in the treatment of adenomyosis and preserving the uterus based on the premise that 100 µm particles first block the smaller intra-adenomyosis vessels and larger 300 µm particles for proximal embolization [29••]. A recognized technique of embolization is the 1–2-3 protocol described by Kim et al. which entails the use of 150–250-µm particles and progressively increasing to 250–355-µm and then 355–500-µm particles to endpoint has also been quite popular [26]. The different techniques used in the literature are summarized in Table 1.

The end point of embolization is classified as stasis or near stasis along the ascending portion of the uterine artery [27]. Some interventional radiologists opt for stasis along the ascending uterine artery for 5 heartbeats [30] or 10 heartbeats [25, 31–34]. The stability of the end point is regularly assessed after 5 min and additional particles injected if the endpoint is not reached (Table 1) [12].

On completion of embolization of each uterine artery, an aortogram may be performed to identify any ovarian vessels supplying the uterus. Hemostasis at the puncture site is achieved by manual compression or vascular closure device.

Pain Management

Several modalities of pain management in patients undergoing UAE have been described. The Superior Hypogastric Nerve Block (SHGNB) has gained popularity allowing patients to be discharged on a same day basis and reducing the need of post procedural patient-controlled analgesia [35]. A prospective, randomized, double-blind, parallel clinical trial performed by Joongchul et al. demonstrated reduced requirements for pain control narcotics and antiemetics in patients undergoing SHNB with no major complications resulting from the procedure [36].

The Superior hypogastric plexus (SHP) is the part of the abdominopelvic sympathetic nervous system that provides a targeted intervention to sympathetic-mediated pain pathways of pelvic organs [37]. Following identification of the aortic bifurcation either via aortogram or use of a catheter, a 21/22-gauge needle is advanced to the anterior portion of the 5th vertebral body under ongoing fluoroscopic guidance. Once bony resistance is reached, using a connecting tube 2–5 ml of slightly dilute contrast is gently injected which typically reveals a characteristic triangular distribution of contrast with no vascular opacification. Needle position is confirmed in a lateral projection. The anaesthetic agents administered include Bupivacaine, Levobupivacaine or Ropivacaine.

After confirmation of a good position and extravascular location of the tip of the needle, injection is initiated. Before injection the needle is aspirated to confirm there is no blood. A preliminary test dose of about 3 cc of 0.5% Ropivacaine is then injected. If there is no change in heart rate or neurological status the remaining dose (total 60 mg Ropivacaine) is injected slowly with intermittent aspiration. During the entire injection, a slight forward tension is kept on the needle in order to avoid retraction into other structures including veins [37]. The typical onset of sensory block is within the first hour with duration of up to 12 h of injection [38].

The administration of intra-arterial preservative-free lidocaine directly into each uterine artery (1% 10 ml lidocaine (100 mg)) is another technique that is safe and effective in reducing post-procedural pain in the early hours and reducing opioid usage in the first 24 h post Uterine Artery Embolization [39].

Post Procedure

Postprocedural care includes hydration, nonsteroidal anti-inflammatories, antiemetics, and narcotics [40]. In many institutions, patients undergoing embolization are admitted to the hospital overnight [27]. Patients can also be discharged on a same day basis depending on the level of their pain and provided no hematoma has formed at the arterial access site following a period of observation. After discharge, pain is normally controlled by using nonsteroidal anti-inflammatory and analgesic therapy.

Methods

A comprehensive search was performed in the bibliographic databases Ovid and PubMed to identify all relevant studies. Search terms included controlled MeSH terms as well as free text terms. The terms “uterine artery embolization,” “embolization”, “uterine artery embolisation” were used in combination with the term “adenomyosis”.

Table 1 UAE Techniques and outcomes

Author, year	Design	n	UAE Technique	Follow-up (months)	Primary Outcome	Secondary Outcome
Chen et al., 2002[a]	Prospective cohort	19	GFP	16	Symptom improvement, HRQOL	Uterine volume
Toh et al., 2003[a]	Retrospective cohort	12	400–600 μm PVA	10.9	Symptom improvement	Uterine volume
Kim et al., 2004	Retrospective cohort	43	250–710 μm PVA	3.5	Symptom improvement	Uterine volume, infarction
Pelage et al., 2005	Prospective cohort	10	355–500 μm PVA, 500–900 μm TGM	24	Symptom improvement	Uterine volume
Chen et al., 2006[a]	Prospective cohort	117	199–200 μm GFP, 300–500 μm PVA, 500–700 μm KMG	50	Symptom improvement	NA
Kim et al., 2007	Prospective cohort	54	250–355 μm, 355–500 μm, 500–710 μm PVA	58.8	Symptom improvement	Uterine volume, infarction
Lohle et al., 2007	Prospective cohort	15	500–700 μm, 700–900 μm TGM	17	Symptom improvement	Uterine volume, infarction
Zeng et al., 2007[a]	Prospective cohort	23	PLE	9	Symptom improvement	Uterine volume
Duan et al., 2008[a]	Prospective cohort	23	500–700 μm KMG	60	Symptom improvement	Uterine volume
Kim et al., 2011	Prospective cohort	21	1, 2, 3 protocol[a]	14	Symptom improvement	Uterine volume, infarction
Froeling et al., 2012	Prospective cohort	19	355–900 μm TGM	40	Symptom improvement, UFS-QOL	NA
Lee et al., 2012	Retrospective cohort	92	PVA, GFP	3	Imaging	Symptom improvement
Smeets et al., 2012	Prospective cohort	18	500–700 μm TGM	65	Symptom improvement, UFS-QOL	Uterine volume, JZ thickness, infarction
Yao et al., 2013[a]	Prospective cohort	15	300–500 μm PVA, 500–700 μm TGM	24	Symptom improvement	Uterine volume
Bae et al., 2015	Retrospective cohort	50	1, 2, 3 protocol	48	Symptom improvement	Uterine volume
Nijenhuis et al., 2015	Prospective cohort	14	500–900 μm hydrogel microspheres	37	Symptom improvement, UFS-QOL	Uterine volume
Park et al. 2015[a]	Prospective cohort	25	1, 2, 3 protocol	3	Uterine volume	NA
Yao et al., 2015[a]	Prospective cohort	45	Lipiodol, 350–700 μm KMG	29.6	Symptom improvement	Uterine volume
Wang et al., 2016	Prospective cohort	115	500–700 μm TGM	12	Symptom improvement	Uterine volume, infarction
Zhou et al., 2016	Retrospective cohort	252	355–500 μm, 500–610 μm PVA	60	Symptom Improvement	Blood supply relation to UAE success
de Brujin et al., 2017—follow-up to Nijenhuis et al., 2015	Prospective cohort	14	500–900 μm hydrogel microspheres	88.8	Symptom improvement, UFS-QOL	Uterine volume
Soeda et al., 2018	Prospective cohort	14	Gelatin sponge	42	Symptom improvement	Uterine volume, UAE Performance by OBGYN
Zheng et al., 2019	Retrospective cohort	68	500–700 μm TGM	40.6	Symptom improvement	Uterine Volume, JZ reduction, Adenomyosis necrosis, Ca 125 levels
Alrashidi et al., 2020	Retrospective cohort	14	355-500 μm(n = 11), 500-700 μm(n = 3) PVA	12	Symptom improvement, UFS-QOL	Uterine Volume, JZ reduction
Wang et al., 2020	Retrospective cohort	147	PVA, size not specified	15	Symptom improvement	Incidence of Asherman Syndrome, vascularity type

Table 1 (continued)

Author, year	Design	n	UAE Technique	Follow-up (months)	Primary Outcome	Secondary Outcome
Guo et al., 2021	Retrospective cohort	59	500-700 µm, 700-900 µm TGM	12	Symptom improvement	Endometritis as a predictive value for UAE success in adenomyosis
Guo et al., 2021	Retrospective cohort	73	500-700 µm, 700-900 µm TGM	12	Symptom improvement	Uterine volume, JZ thickness, adenomyosis morphology, T1W1 and T2W1 characteristics
Yuan et al., 2021	Retrospective cohort	19	100, 300 µm PVA	42	Symptom improvement, UFS-QOL	Uterine volume, JZ reduction
Kim et al., 2021	Retrospective cohort	163	Gelatin sponge,150-350um sponge particles, 350–560 um, 560-710um sponge particles	12.3	Symptom improvement	Uterine volume, infarction

GFP gelatin sponge pledgets, *HRQOL* health-related quality of life, *JZ* junctional zone, *KMG* sodium alginate microspheres, *n* number of patients, *NA* not applicable, *PLE* Lipidol, *PVA* polyvinyl alcohol, *T1W1* T1-weighted, *T2W1* T2-weighted, *TGM* trisacryl gelatin microspheres, *UAE* Uterine Artery Embolization, *UFS-QOL* uterine fibroid symptom and quality of life

[a]1, 2, 3 protocol = 150–250 µm / 250–355 µm / 355–500 µm PVA until stasis

In total 25 papers described the use of UAE for the treatment of adenomyosis or combined groups with adenomyosis and leiomyoma. Publications with data on pure adenomyosis were considered for outcome and adverse event analysis. Publications with fewer than 10 cases of pure adenomyosis were excluded. Publications with duplication of the patient cohort were also excluded, keeping the more recent article with longer follow-up for review.

All analysis involved descriptive statistics performed with Microsoft Excel (Microsoft Corporation, 2018). Ethical committee approval was not required.

Results

Outcomes Of the 25 publications analysed, 17 had experience of 10 or more cases of embolization for pure adenomyosis alone. This left a cumulative total of 1,081 patients with a mean follow-up time of 27.3 (3–58.8) months. Overall improvement was stated as an outcome measure in 10 publications with 220 patients, from 299 (73.58%) seeing an overall improvement. Dysmenorrhea improvement was documented in 7 publications, with 487 of 682 (71.41%) women seeing improvement. Abnormal uterine bleeding or menorrhagia was documented to have improved in 532 women, from 712 (74.72%) in 8 publications. Only two centres with treatment of pure adenomyosis had recorded improvement of bulk symptoms with 30 out of 44 (68.18%) women seeing an improvement. Results are summarized in Table 2.

The need for additional interventions were recorded in 8 publications yielding 464 patients in whom 3 (0.65%) required repeat UAE and 26 (5.6%) underwent hysterectomy (Table 2). Where stated the median time to hysterectomy was 17.5 months following UAE.

Zeng et al. [34] was the only publication identified to evaluate outcome measures in patients where complete necrosis was achieved vs. incomplete necrosis in pure adenomyosis cohorts. They found a statistically significant difference in dysmenorrhea and abnormal uterine bleeding improvement; 94.7% vs. 50% and 96.2% vs. 57.1% respectively.

Complications

Fourteen publications stated complications in pure adenomyosis patients only providing 970 patients for analysis (Table 2). The overall major complication rate (category C-F from the SIR classification) was 3.5% with 69.7% (n = 23) of major complications resulting from premature ovarian failure or permanent amenorrhea. Of the other major complications, there were 5 class C adverse events; 2 cases of endometritis requiring antibiotics and 3 cases of UTI requiring antibiotics. There were 4 class D adverse events; 2 cases of femoral pseudoaneurysms requiring thrombin injections and 2 cases of severe endometritis requiring hysterectomy. There was one recorded death (class F) as result of PE. The authors do no not elaborate further as to the events surrounding the event.

Table 2 Results and complications

Author, year	n	Improved Overall	Follow-up (months)	Dysmenorrhea Improvement	AUB Improvement	Bulk Symptoms Improvement	SIR complications	Additional Interventions
Kim et al., 2004	43	40 (93)	3.5	40/42 (95.2)	38/40 (95)	25/32 (78.1)	Class A: 1 permanent amenorrhea, no treatment	NA
Pelage et al., 2005	10	5 (5)	24	NA	5/9 (55.6)	3/6 (50)	Class A: 2 cases of mild vaginal discharge, resolved spontaneously Class A: 4 cases of persistent cramping, resolved spontaneously Class A: 1 case of longstanding pain, no treatment Class B: 1 myometrial ischemia leading to severe pain treated with oral analgesics	Hysterectomy: 5 (3.9, 9, 13, 25, 27 months)
Kitamura et al., 2006	7	6 (85.7)	12	NA	NA	NA	No complications reported	NA
Kim et al., 2007	54	31 (57.4)	58.8	27/42 (64.3)	NA	27/34 (79.4)	No complications reported	Hysterectomy: 5
Lohle et al., 2007	15	12 (80)	15	NA	NA	NA	Class A: 8 cases of transient amenorrhea, resolved spontaneously	Hysterectomy: 2
Bratby and Walker, 2009	5	3 (60)	24	NA	NA	NA	No complications reported	Hysterectomy: 2 (2, 8 months)
Kim et al., 2011	21	15 (71.4)	14	13/15 (86.7)	15/15 (100)	NA	Class A: 1 transient amenorrhea, resolved spontaneously	NA
Froeling et al., 2012	11	6 (54.5)	40	NA	NA	NA	No complications reported	Hysterectomy: 5 (6, 9, 24,44, 69 months)
Lee et al., 2012	92	77 (83.6)	3	NA	NA	NA	No complications reported	NA
Bae et al., 2015	50	38 (76.0)	48	NA	NA	NA	Class A: 1 case of transient amenorrhea, resolved spontaneously Class D: 1 femoral pseudoaneurysm treated with thrombin injection	Hysterectomy: 1 (18 months)

Table 2 (continued)

Author, year	n	Improved Overall	Follow-up (months)	Dysmenorrhea Improvement	AUB Improvement	Bulk Symptoms Improvement	SIR complications	Additional Interventions
Nijenhuis et al., 2015	14	12 (85.7)	37	NA	NA	NA	Class A: 2 cases of transient amenorrhea, resolved spontaneously Class C: 1 case of endometritis treated with antibiotics Class D: 1 false aneurysm of femoral artery treated with thrombin injection Class D: 1 case of endometritis treated with curettage Class E: 4 cases of permanent amenorrhea, no treatments	Repeat UAE: 3 (6, 7, 14 months) Hysterectomy: 1 (17 months)
Wang et al., 2016	115	108 (93.9)	12	108/115 (93.9,64 complete; 44 partial)	NA	NA	No complications reported	None
Zhou et al., 2016	252	NA	12	145/196 (74)	161/227 (70.9)	NA	Class E: 7 ovarian failures, no treatment Class F: 1 death due to PE	NA
	195	NA	60	107/152(70.4%)	117/17 0(68.8)	NA		NA
Zheng et al., 2018	46 CN	NA	12	94.70%	96.20%	NA	No complications reported	NA
	22 IN	NA	12	50%	57.10%	NA		
Alrashidi et al., 2020	14	NA	12	NA	NA	NA	Class E: 10 cases of permanent amenorrhea, no treatment	None
Wang et al., 2020	147	NA	15	76.87%	85.53%	NA	Class A: 25 cases of transient or permanent amenorrhea, no treatment Class C: 1 case of endometritis treated with antibiotics Class D: 2 cases of endometritis treated with hysterectomy Class E: 2 cases of ovarian failure	Hysterectomy: 4
Guo et al., 2021	59	NA	12	49/57 (86)	42/50(84)	NA	No complications reported	NA

Table 2 (continued)

Author, year	n	Improved Overall	Follow-up (months)	Dysmenorrhea Improvement	AUB Improvement	Bulk Symptoms Improvement	SIR complications	Additional Interventions
Kim et al., 2021	163	79.40%	12.3	Significant improvement for N = 95	Significant for N = 102	NA	Class A: 10 cases of transient amenorrhea, resolved spontaneously Class A: 2 cases of permanent amenorrhea (age 47 and 50), no treatment Class B: 2 cases of urinary retention, resolved with conservative treatment Class C: 3 cases of UTI, resolved with medication	Hysterectomy: 3

n (%)
CN Complete Necrosis, *IN* Incomplete Necrosis, *n* number of patients

The minor complication (class A–B) rate was 6.08% (n = 59). The overwhelming majority was due to transient or perimenopausal amenorrhea (n = 49). Two ladies experienced mild vaginal discharge resolving spontaneously. Persistent cramping pain resolving eventually without intervention or admission was seen in 5 cases. There was 1 case of myometrial ischemia requiring further oral analgesia. And finally, 2 cases of urinary retention which were resolved with conservative treatment. The different reported complications are summarized in Table 2.

Fertility

Uterine Artery Embolization has gained recognition as a uterus sparing minimally invasive treatment option for adenomyosis. There is a lack of data on the use of UAE for the sole purpose of improving fertility since medical management remains the first line treatment option. Many of the studies performed excluded women desiring preservation of fertility and UAE was often performed in women with mixed adenomyosis and fibroids. In a study by Kim et al. [31], a 30-year-old woman with complete necrosis of focal adenomyosis who desired future pregnancy, succeeded in becoming pregnant twenty-four months after UAE. Liang et al. [41] also documented two patients who unintentionally became pregnant, however, there were multiple complications along the course of pregnancies. There is therefore an overall need for larger studies for more conclusive results for patients wishing to preserve fertility.

Conclusion

Adenomyosis is a benign disease of the uterus manifesting clinically as menorrhagia, dysmenorrhea, abnormal uterine bleeding, and chronic pelvic pain. For patients where best medical therapy has failed to control symptoms and wish to avoid hysterectomy, UAE has been established as a minimally invasive, uterus sparing technique for patients afflicted with this disease. This comprehensive literature review has demonstrated a 73.58% improvement in patients' overall symptoms with a 71.41% and 74.72% improvement of symptoms of dysmenorrhea and abnormal uterine bleeding/menorrhagia, respectively. The overall major complication rate of UAE (SIR category C-F) was found to be 3.6%, primarily permanent amenorrhea with a minor complication rate (SIR category A-B) of 6.08%.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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