fortune Journals

Research Article

JOURNAL OF RADIOLOGY AND CLINICAL IMAGING

ISSN: 2644-2809

Uterine Artery Embolization: A Growing Pillar of Gynecological Intervention

Sunil Balamurugan, Rahul Shah, Kurt Panganiban, Matthew Lehrack, Devendra K. Agrawal*

Abstract

Uterine Artery Embolization (UAE) is a minimally invasive procedure that has emerged as a transformative option for managing uterine leiomyomas (fibroids), postpartum hemorrhage, and other gynecological conditions. While traditional surgical interventions like hysterectomy and myomectomy remain standard, UAE offers a safer alternative for patients seeking uterine preservation or fertility maintenance. This article examines the efficacy, innovations, and challenges of UAE, with a focus on its expanding applications and implications for patient care. Existing research highlights high success rates of UAE, achieving significant symptom relief in over 90% of cases by occluding uterine arterial blood supply with embolic agents to induce localized ischemia and fibroid necrosis. Innovations in embolic materials, such as hydrophobic injectable liquids, and procedural techniques like transradial access have enhanced safety, reduced complications, and improved patient outcomes. The effectiveness of UAE in treating rarer conditions, including uterine arteriovenous malformations and adenomyosis, demonstrates its versatility. However, questions remain about its long-term reproductive impact, especially concerning fertility outcomes and pregnancy rates, as conflicting data suggest potential risks. This critical review addresses these gaps by synthesizing existing studies to assess comparative efficacy of UAE against surgical options, its safety profile, and its role in advancing minimally invasive gynecology. By exploring both well-established and emerging applications, this article underscores the importance of UAE in reducing morbidity, improving quality of life, and preserving reproductive potential. Further research is essential to refine patient selection criteria, optimize techniques, and better understand the long-term outcomes of the procedure, ensuring UAE continues to evolve as a valuable minimally invasive option within modern gynecological care.

Keywords: Cesarean Scar Pregnancy; Embolic agents; Fertility preservation; Gynecological intervention; Minimally invasive procedure; Myomectomy; Postpartum hemorrhage; Uterine artery embolization; Uterine Cancer; Uterine fibroids

Introduction

Arterial embolization is a minimally invasive, non-surgical procedure within the field of interventional radiology that targets diseased vasculature. This technique involves administering embolic agents via a transcatheter into the lumen of a blood vessel, leading to proximal occlusion and diminished downstream vessel flow. The process reduces arterial blood supply and lymphatic drainage, resulting in localized necrosis of the affected area, which prevents further neurovascular growth. These effects aid in better pain management, reduced tumor size, and decreased hemorrhage, showcasing the

Affiliation:
Department of Translational Research, College of Osteopathic Medicine of the Pacific, Western University of Health Sciences, Pomona, California 91766 USA

Corresponding author:
Devendra K. Agrawal, Professor and Director, Department of Translational Research, Western University of Health Sciences, 309 E. Second Street, Pomona, California 91766, USA

Citation: Sunil Balamurugan, Rahul Shah, Kurt Panganiban, Matthew Lehrack, Devendra K. Agrawal. Uterine Artery Embolization: A Growing Pillar of Gynecological Intervention. Journal of Radiology and Clinical Imaging. 8 (2025): 01-17.

Received: January 06, 2024
Accepted: January 28, 2024
Published: February 04, 2024

Balamurugan S, et al., J Radiol Clin Imaging 2025
DOI:10.26502/jrci.2809105

versatility of this procedure across a wide range of clinical applications [1,2].

The first documented case of embolization dates to 1904 when Robert Darwin occluded the carotid artery to reduce blood supply to the head and neck [3]. Early techniques employed steel pellets to deliberately block and redirect blood flow, eventually evolving to the use of gelatin pieces mixed with saline [4]. Modern advancements have introduced a broad spectrum of embolic materials, including metallic coils, liquid embolic agents, and shear-thinning biomolecules, which, coupled with X-ray guidance, enhance precision and minimize patient risks [5].

This paper specifically focuses on uterine artery embolization (UAE), a procedure targeting the uterine artery, which is in the gluteal region and branches from the internal iliac artery to supply blood to the uterus and placenta [6]. The first obstetric application of UAE was reported in 1979 when a woman experiencing severe vaginal bleeding following a prolonged childbirth underwent successful embolization of the uterine artery without complications [7].

Primary indications for UAE include uterine fibroids and postpartum hemorrhage [8]. However, contraindications such as chronic pelvic infections, previous pelvic radiation, refractory coagulopathy, use of GnRH hormone analogs, and renal impairment must be considered [9]. UAE provides a safe and minimally invasive alternative to traditional surgical interventions, such as hysterectomy and myomectomy, offering significant advantages in terms of reduced pain, improved quality of life, and faster recovery times. With its transformative impact on uterine condition management, UAE represents a pivotal advancement in gynecological care. A deeper understanding of its physiological mechanisms underscores its clinical value and broad applications.

Mechanism of Action

UAE primarily works by employing an interventional radiological technique to occlude the arterial blood supply to the uterus. This is achieved through the selective administration of embolic agents to the uterine arteries, inducing ischemic infarction in areas where uterine fibroids are present. The procedure significantly reduces uterine and fibroid volumes, which correlates with improved symptoms and overall quality of life for patients suffering from symptomatic uterine fibroids [10]. Embolic agents such as gelatin sponge particles and polyvinyl alcohol (PVA) particles are used to block the blood supply to the uterus by creating an upstream occlusion. These agents not only alleviate symptoms associated with uterine fibroids but also play a critical role in managing abnormal vascular structures, including pseudoaneurysms. By inducing infarction, the procedure facilitates necrosis of collateral vessels and vascular anomalies, leading to a reduction in mass and associated symptoms, including pelvic pain and heavy menstrual bleeding [11].

Further research emphasizes that the precise delivery of embolic agents improves the chances of success because controlled necrosis allows the preservation of healthy adjacent uterine tissue. Subramaniam et al. highlighted UAE as a well-established technique for conditions such as postpartum hemorrhage, demonstrating its minimally invasive nature compared to more invasive techniques traditionally used to manage such issues. This approach not only improves recovery times but also enhances patient comfort and overall outcomes [12].

The resultant occlusion of vessels decreases forward perfusion and nutrient supply to fibroid tissues, prompting a cascade of cellular events leading to apoptosis and tissue remodeling. Necrosis effectively removes fibroids and leads to uterine mass shrinkage, providing patients with symptomatic relief. Long-term studies have shown that UAE offers sustainable relief from symptoms, often eliminating the need for invasive surgical options such as hysterectomy [11].

In conclusion, UAE is a highly effective, minimally invasive approach for managing serious gynecological conditions. Through precise delivery and effective vessel occlusion, UAE provides significant symptom relief, improves quality of life, and reduces the risks associated with more invasive procedures. Understanding the mechanism behind UAE lays the foundation for identifying the patient groups and clinical scenarios best suited for this transformative procedure.

Populations: Indications and Contraindications

UAE is commonly performed in women of reproductive age, typically between their 30s and 50s, who suffer from symptomatic uterine fibroids. These fibroids often cause issues such as pelvic pain, heavy menstrual bleeding, and other related complications. The “ideal” candidate is a woman with no UAE contraindications, presenting with heavy menstrual bleeding or dysmenorrhea with intramural fibroids, premenopausal, and no desire for future pregnancy [13]. However, women still looking to conceive may view uterine artery embolization as a better alternative to other treatments, as it may still allow for possible conception. Fertility rates after uterine fibroid embolization have been approximated to be just under 40%, with possibly higher rates in younger mothers [14]. African American women are also associated with a higher likelihood of undergoing UAE due to the higher prevalence of fibroids within this demographic, as well as the fertility-preserving potential of the procedure [15]. Collaboration between interventional radiologists and obstetrician/gynecologists is imperative to allow for full assessment and evaluation of clinical care procedures [16].

Indications for UAE extend beyond symptomatic fibroids, addressing ailments such as abnormal uterine bleeding,

Balamurugan S, et al., J Radiol Clin Imaging 2025
DOI:10.26502/jrci.2809105

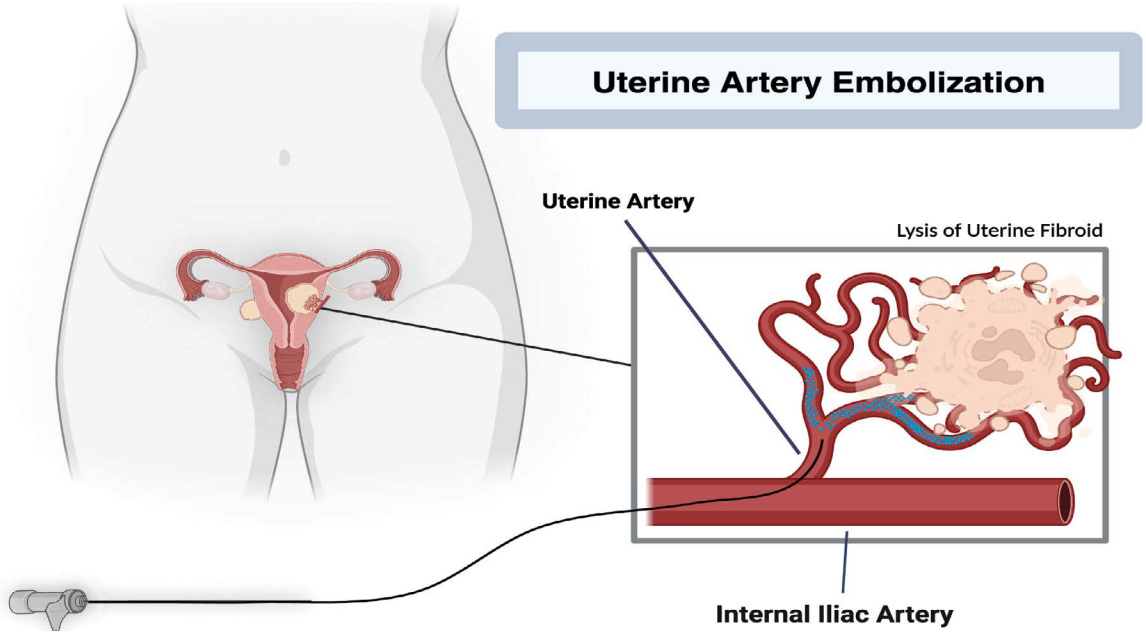

Figure 1: Anatomical representation of uterine artery embolization (UAE) for fibroid treatment. The zoomed-in panel provides a detailed view of the embolization process at the arteriole level, demonstrating the relationship between the uterine artery branching from the internal iliac artery and its supply to the fibroid tissue. The embolic agents (shown in blue) are delivered via catheter to occlude the vessels feeding the fibroid, leading to ischemic necrosis and subsequent lysis of the fibroid tissue. This minimally invasive approach effectively reduces blood supply to the fibroid while preserving normal uterine tissue perfusion through collateral circulation

dysmenorrhea, pelvic pain, impaired urination, bowel dysfunction, infertility, and recurrent pregnancy loss [17]. A systematic review and meta-analysis on the effectiveness of UAE for adenomyosis demonstrated symptom improvements in 83% of patients [18]. While clinical outcomes are promising, more randomized controlled trials (RCTs) are needed to further solidify the efficacy of UAE for adenomyosis and establish it as a standard indication. The Quality of Life after Embolization vs. Hysterectomy in Adenomyosis (QUESTA) trial is one ongoing RCT that may provide valuable insights.

Similarly, UAE is indicated for uterine arteriovenous malformations (AVM) and cervical ectopic pregnancy [19-21]. UAE has also been shown to be a safe and effective procedure for managing emergencies such as primary postpartum hemorrhage, severe hemorrhage during pregnancy termination, and prophylactic use in cases of retained products of conception, abnormal placental implantation, or pregnancy termination [22].

For cesarean scar pregnancy (CSP), UAE has emerged as a minimally invasive option for managing this rare but potentially life-threatening condition characterized by implantation of the gestational sac within a cesarean scar. UAE is increasingly recognized for its ability to control bleeding while preserving uterine integrity, especially in early CSP, where timely intervention can prevent severe complications such as uterine rupture or hemorrhage [23, 24]. Studies highlight the efficacy of UAE in reducing hemorrhage risks and facilitating safer management of CSP without necessitating invasive surgical interventions [23]. Additionally, combining UAE with methotrexate injections has been shown to enhance the effectiveness of treatment in these cases [25].

When compared to traditional surgical strategies, such as laparoscopic excision or hysteroscopic resection, UAE offers a less invasive alternative with fewer complications. Surgical approaches often result in higher blood loss, longer recovery times, and potential fertility compromise, particularly in severe cases requiring hysterectomy [26, 27]. Aortic balloon occlusion (ABO) is another option explored in CSP management. Although ABO reduces bleeding during surgery, it is more invasive than UAE and carries risks such as complications from balloon placement and reduced perfusion to lower body regions [28]. UAE, by contrast, has demonstrated superior outcomes in minimizing bleeding and preserving uterine integrity, particularly in early CSP [29, 27].

Absolute contraindications for UAE include pregnancy and acute genital infection, as disruption to blood flow in these conditions could lead to worsening outcomes [30, 31]. Relative contraindications include malignancy, immunocompromised states, kidney dysfunction, blood clotting disorders, and allergic sensitivity to contrast dyes. Anatomical abnormalities, such as a common artery supplying the uterus and ovaries, are also considered relative contraindications, along with the presence of an intrauterine device (IUD). Subserosal or submucosal pedunculated

Balamurugan S, et al., J Radiol Clin Imaging 2025
DOI:10.26502/jrci.2809105

fibroids and the desire to maintain fertility further underscore the need for individualized clinical judgment [32]. Thorough history-taking and evaluation are critical to ensure the safety and efficacy of UAE in each case.

Careful assessment of the populations suitable for uterine artery embolization (UAE), along with a thorough understanding of its indications and contraindications, is essential for ensuring optimal clinical outcomes. UAE is most indicated for women with symptomatic uterine fibroids, adenomyosis, arteriovenous malformations, or other gynecological conditions associated with significant bleeding, pelvic pain, or infertility. Absolute contraindications, such as malignancy, pregnancy, and acute genital infections, must be ruled out, and relative contraindications, including anatomical anomalies or coexisting medical conditions, require careful evaluation. With these considerations in mind, the next step is to explore how UAE is performed, detailing the procedural techniques involved.

Stepwise Procedures in UAE

UAE begins with thorough pre-procedure planning. This includes a comprehensive patient assessment, administration of prophylactic antibiotics to reduce infection risk, and sedation to ensure patient comfort. Imaging studies, such as MRI or ultrasound, are employed to assess the size, number, and location of fibroids or hemorrhage sites. These studies aid in selecting appropriate embolic agents and guiding the procedure [33,34]. Access to the uterine arteries is typically achieved through the femoral artery, although transradial access is an alternative based on patient anatomy and clinician preference. Under fluoroscopic guidance, a catheter is navigated into the uterine arteries, and embolic agents—such as calibrated microspheres or polyvinyl alcohol (PVA) particles—are introduced to occlude blood supply to targeted areas [35-38]. The choice of embolic materials is based on their occlusive properties, durability, and compatibility with the vascular characteristics of fibroids or hemorrhage sites. Advanced imaging, including contrast-enhanced ultrasound and MRI, further enhances visualization during and after the procedure, ensuring precision and minimizing the risk of non-target embolization [39-41].

The inclusion of a superior hypogastric nerve block (SHNB) has greatly improved pain management during UAE. The superior hypogastric nerve plexus transmits pelvic pain signals, and SHNB blocks these signals, reducing pain during and after the procedure. This technique decreases reliance on narcotic analgesia, thereby minimizing associated side effects such as nausea and sedation [42,43]. Patients who undergo UAE with SHNB report lower pain scores and require less opioid use compared to those without the nerve block, leading to faster recovery and often same-day discharge [42]. Enhanced pain control not only improves the immediate procedural experience but also facilitates quicker recovery, enabling patients to resume normal activities sooner. In contrast, patients undergoing UAE without SHNB typically require higher doses of opioids, which can prolong recovery and increase pain management-related risks [43].

UAE can be performed using selective or non-selective embolization techniques, allowing for personalization based on patient needs. Selective embolization targets specific vessels, preserving healthy uterine tissue and making it ideal for patients desiring fertility preservation. Non-selective techniques, on the other hand, treat larger arterial branches and are often employed in urgent scenarios [44-46]. Both approaches show high success rates, with over 90% of cases achieving effective symptom relief [47-52].

The integration of SHNB exemplifies the evolving sophistication of UAE, complementing other advancements such as precision imaging and tailored embolic agents. Together, these innovations solidify UAE as a minimally invasive and effective treatment option. By offering significant benefits in pain management, faster recovery, and favorable fertility preservation, UAE continues to surpass traditional surgical alternatives. As advancements in UAE enhance patient outcomes, it remains critical to evaluate alternative treatments better suited for certain clinical scenarios or individual patient needs.

Alternative Treatments

While UAE is an effective treatment, other surgical or medical management options may be better alternatives based on the specific size and location of the fibroid, age of the woman, symptoms, access to treatment, and desire to maintain fertility. Each patient requires a comprehensive assessment to determine which treatment modality is best suited for their unique situation. At times, a combination of treatment modalities may even prove effective for a certain subset of patients. Pre-operative UAE has also been shown to be safely performed in both myomectomy and hysterectomy, potentially reducing intraoperative blood loss and improving outcomes for high-risk patients [53].

Gonadotropin-releasing hormone (GnRH) agonists provide menopausal-like effects by decreasing progesterone and estrogen production through desensitization of GnRH receptors, ultimately reducing the size and volume of fibroids. This approach is particularly beneficial for women approaching menopause, seeking symptom reduction, or requiring preoperative preparation [54, 55]. However, the effects are not sustained after cessation, with fibroid growth rebounding within six months. Side effects include vaginal dryness, hot flashes, muscle pain, mood swings, and vasomotor symptoms, necessitating hormonal "add-back" therapy with estrogen and/or progesterone to mitigate toxic effects [55].

In contrast, GnRH antagonists competitively bind to GnRH receptors, leading to immediate suppression of

Balamurugan S, et al., J Radiol Clin Imaging 2025
DOI:10.26502/jrci.2809105

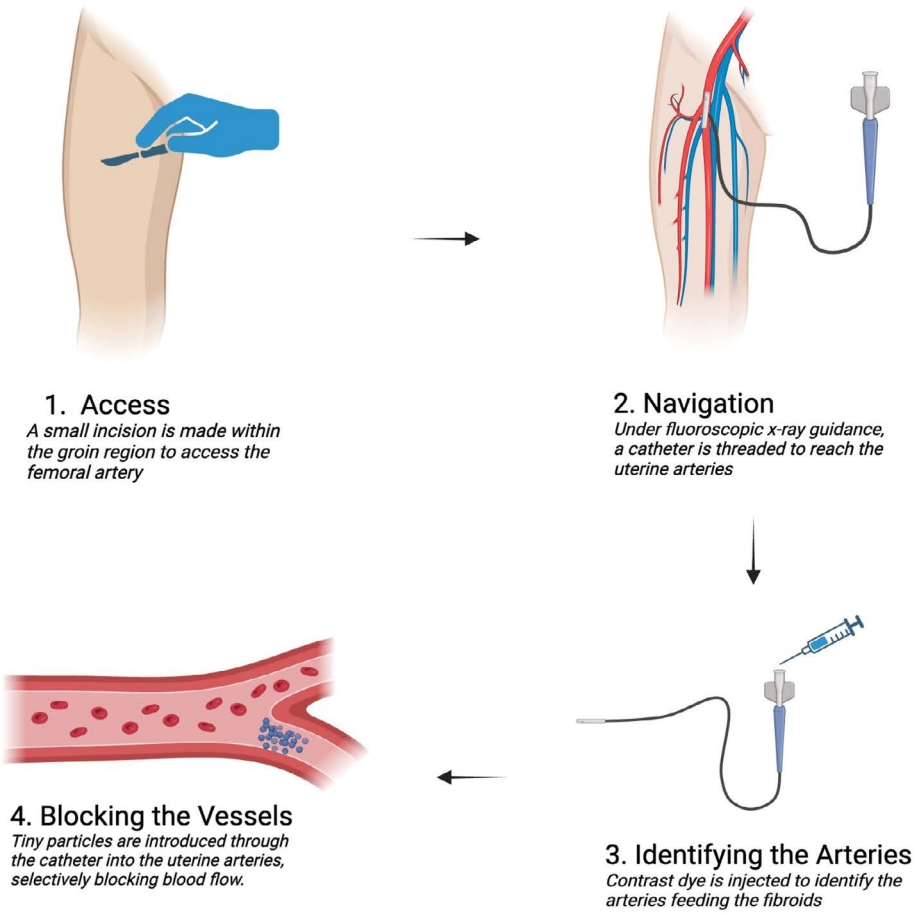

Figure 2: Step-by-step illustration of the uterine artery embolization (UAE) procedure. The procedure consists of four critical stages: (1) Access: Initial femoral artery access is achieved through a small incision in the groin region using sterile technique. (2) Navigation: Under real-time fluoroscopic guidance, a specialized catheter is advanced through the vascular system to reach the uterine arteries, typically proceeding from the femoral artery through the internal iliac artery. (3) Arteriography: Radiopaque contrast medium is injected to create an angiographic roadmap, enabling precise identification of the arteries supplying the fibroids. This step is crucial for targeting the embolic material and avoiding non-target embolization. (4) Embolization: Calibrated microspheres or other embolic agents are precisely delivered through the catheter to occlude the vessels feeding the fibroids, resulting in selective devascularization while preserving normal uterine tissue perfusion.

gonadotropins. Linzagolix, a GnRH antagonist, demonstrated significant reductions in heavy menstrual bleeding during phase 3 trials, without increasing osteoporosis risk [56]. However, dose-dependent adverse effects like hot flashes and endometrial hyperplasia have been observed, although "add-back" therapy substantially reduces these issues [56, 57]. Serum lipid increases noted with elagolix administration highlight the need for further research to evaluate potential contraindications [57].

The levonorgestrel intrauterine system (LNG-IUS), commonly used for contraception, thickens cervical mucus and suppresses endometrial growth, effectively reducing menstrual blood loss and possibly fibroid volume [58]. A systematic review highlighted its efficacy in reducing bleeding by 55.6%, though it was less effective for adenomyosis and endometrial hyperplasia [59].

Selective progesterone receptor modulators (SPRMs) inhibit cell proliferation and inflammation, offering another treatment avenue. By reducing inflammatory markers like TGF-β, IL-6, and IL-10, SPRMs promote fibroid symptom relief without significantly affecting vascularization [60]. Short-term SPRM treatment was less effective than GnRH agonists in reducing fibroid size but associated with fewer side effects like hot flashes [61, 62].

Non-hormonal treatments, such as tranexamic acid, inactivate plasminogen activators, preventing fibrinolysis and reducing menstrual blood loss without affecting fibroid size [63]. NSAIDs, which inhibit prostaglandin synthesis, offer pain relief and symptom control without altering fibroid dimensions [64].

Surgical treatments like UAE and myomectomy are frequently compared for their distinct advantages. UAE reduces symptoms such as heavy menstrual bleeding and pelvic pain in 85-90% of patients [65, 66]. It achieves a 10-15% recurrence rate within five years, with fewer complications, shorter recovery times, and lower major complication rates

Balamurugan S, et al., J Radiol Clin Imaging 2025
DOI:10.26502/jrci.2809105

(1-3%) than surgical alternatives [65-67]. However, minor complications like post-embolization syndrome occur in 30-50% of cases but are self-limiting [67].

Myomectomy, which removes fibroids while preserving the uterus, is ideal for fertility preservation. Symptom relief rates are comparable to UAE (80-90%), though recurrence rates are higher—up to 30% within five years for multiple fibroids [68, 69]. Minimally invasive techniques reduce recovery times but pose risks such as intraoperative hemorrhage, infection, and uterine rupture [70]. UAE and myomectomy differ in recovery times and fertility outcomes. UAE enables quicker recovery (one week), while myomectomy requires several weeks, depending on surgical complexity. Pregnancy rates of up to 59.5% have been reported following UAE [71, 72].

Hysterectomy is the most "radical" surgical approach for uterine fibroids and must be considered if symptoms become severe enough and other methods are not proving to be effective. Complete removal of the uterus will offer the most long-term relief for the patients but completely inhibits their childbearing potential. In an observational cohort study comparing hysterectomy, myomectomy, and UAE, similar symptom relief was found 1-year post-treatment, but more solidified improvements were observed for hysterectomy treatment groups every year thereafter [73]. However, as with any surgery, this comes with increased recovery times and postoperative risks of infection.

In cases of cesarean scar pregnancy (CSP), UAE has gained recognition as a minimally invasive alternative to surgical interventions and aortic balloon occlusion (ABO). UAE controls bleeding by selectively occluding uterine arteries supplying the gestational sac, preserving uterine integrity while achieving a success rate exceeding 85% in hemorrhage control [74, 75]. Compared to surgical approaches like laparoscopic excision or hysteroscopic resection, UAE reduces recovery times and complications [76]. While ABO effectively reduces intraoperative blood loss, its invasiveness and perfusion-related complications make UAE a preferred alternative [77, 78].

Surgical interventions for CSP, while effective, are associated with higher risks of significant blood loss, infection, and longer recovery times. Hysterectomy remains a last resort for severe CSP cases, particularly when fertility preservation is no longer a priority [79]. UAE, however, stands out as a promising alternative for managing CSP, offering shorter recovery times, lower complication rates, and the ability to preserve fertility, making it an integral component of comprehensive CSP management strategies [80, 81].

By integrating UAE and other treatments into a personalized approach, clinicians can address a range of conditions effectively while considering patient-specific factors like fertility preservation, recovery time, and symptom relief. The subsequent focus shifts to examining the efficacy and outcomes of UAE.

Table 1: Comparison of Treatments Strategies in Uterine Fibroids with advantages and disadvantages and clinical outcomes.

Treatment	Advantages	Disadvantages	Recovery Time	Impact on Fertility
UAE	Minimally invasive, symptom relief in >85% of cases, reduces heavy bleeding and fibroid size	Possible non-target embolization, rare complications, may require reintervention in some cases	~1 week	Preserves fertility; slightly lower pregnancy rates than myomectomy
GnRH Agonists	Reduces fibroid size and volume, effective preoperatively, beneficial for symptom management near menopause	Side effects include bone loss, hot flashes, and mood swings; rebound growth after cessation	Immediate symptom relief	Not suitable for long-term fertility preservation
GnRH Agonists	Rapid symptom relief, reduces heavy menstrual bleeding, dose-dependent efficacy	Risk of hot flashes, endometrial hyperplasia, and increased serum lipid levels without add-back therapy	Immediate symptom control	Limited impact on long-term fertility preservation
LNG-IUS	Reduces blood loss and possibly fibroid volume, effective for mild to moderate symptoms	Less effective in severe fibroid cases; device-specific risks such as expulsion or discomfort	Minimal recovery time needed	Fertility resumes immediately after removal
SPRMs	Reduces inflammation and fibroid size with fewer side effects than GnRH agonists	Limited by potential hepatotoxicity (e.g., ulipristal acetate); not approved for long-term use in all regions	Short-term recovery after treatment	Fertility preservation possible
Myomectomy	Removes fibroids while preserving the uterus, improves symptoms, higher quality of life post-treatment	Risk of surgical complications such as bleeding, infection, and uterine scarring	2–6 weeks, depending on approach	Preserves fertility
Hysterectomy	Definitive treatment with complete symptom resolution.	Major surgery with longer recovery, risk of infection, and complete loss of fertility	4–8 weeks	Eliminates fertility

GnRH, gonadotropin-releasing hormone; LNG-IUS, levonorgestrel intrauterine system; SPRMs, selective progesterone receptor modulators; UAE, uterine artery embolization

Citation: Sunil Balamurugan, Rahul Shah, Kurt Panganiban, Matthew Lehrack, Devendra K. Agrawal. Uterine Artery Embolization: A Growing Pillar of Gynecological Intervention. Journal of Radiology and Clinical Imaging. 8 (2025): 01-17.

Balamurugan S, et al., J Radiol Clin Imaging 2025
DOI:10.26502/jrci.2809105

Table 2: Comparison of Treatments in Cesarean Scar Pregnancy with advantages and disadvantages and clinical outcomes.

Treatment	Advantages	Disadvantages	Bleeding Control and Recovery Time	Impact on Fertility
UAE	Minimally invasive, preserves uterine integrity, high success rate (>85%) in managing CSP	Rare complications like non-target embolization; requires specialized expertise	Highly effective at controlling hemorrhage; typically outpatient procedure with ~1-week recovery	Preserves fertility
ABO	Reduces intraoperative blood loss effectively during surgery	Invasive; risks include complications from balloon placement and reduced lower body perfusion	Effective at minimizing bleeding during surgery; slightly longer recovery due to invasiveness	Fertility preservation depends on the extent of surgical involvement
Surgical Interventions	Directly resolves CSP; effective for severe or advanced cases	Higher risk of complications, significant blood loss, longer hospital stays, and infection risks	Provides direct bleeding control; recovery can take several weeks, depending on the surgical approach	Potentially compromises fertility, particularly with hysterectomy

ABO, aortic balloon occlusion; CSP, cesarean scar pregnancy; UAE, uterine artery embolization.

Efficacy and Outcomes

The efficacy of UAE in treating various obstetric conditions has been well documented across multiple studies and it has been proven to be safe, effective, and minimally invasive for treating uterine arteriovenous malformations (AVMs), fibroids, and obstetric hemorrhage. Advantages of UAE over other treatment options include no general anesthesia, no surgical incision, and no blood loss or transfusion required, with a shorter recovery time in general [82].

The use of UAE in the treatment of arteriovenous malformations was found to have a technical success rate of 100% and a clinical success rate of 92% with a sample size of 225 patients in a prospective review [37]. The study also demonstrated that the 210 patients who were not lost to follow-up had no recurrence of bleeding by the 53-month mark. Of note, a total of 90 patients required re-embolization and there were 3 cases that required hysterectomy. However, the authors concluded that UAE is a safe, effective, minimally invasive method to treat uterine AVMs with long-term efficacy [37]. Other studies in the literature support the conclusion that bilateral UAE is an effective method to control bleeding uterine arteriovenous malformations, controlling hemorrhage, and preserving fertility [83].

The efficacy of UAE in the treatment of symptomatic uterine fibroids has been established as effective and safe, especially for those patients who like to preserve their uterus [82, 84]. According to a study from Kohi et al. in 2018, the expected outcomes following a UAE for the treatment of uterine fibroids are a 50 to 60% fibroid size reduction, 40 to 50% uterine size reduction, 88 to 92% reduction of bulk symptoms, greater than 90% elimination of abnormal uterine bleeding, and 80 to 90% patient satisfaction [85]. In a literature review from 2013, it is reported that a reduction in menorrhagia occurs in 80-93% of patients and the mean decrease in fibroid size varies from 50-78% [82]. The efficacy of UAE in treating various uterine fibroids is dependent on the size of the fibroid, and traditionally UAE has been most effective in treating fibroids <8 cm in diameter [86]. Today, it is widely accepted that UAE is the standard procedure for the treatment of uterine fibroids around the world [84].

Studies have shown that UAE is also an effective treatment option for addressing postpartum hemorrhage (PPH). In a literature review, it was concluded that UAE is a safe and effective method of controlling severe PPH in 90% to 95% of cases regardless of the cause for PPH. Compared to other treatment options such as hysterectomy, uterine or hypogastric artery ligation in treating PPH, UAE has been shown to have higher success rates (>90%) and is thus recommended to be the first choice in treatment for patients who are hemodynamically stable [87].

Other reports in the literature support the use of UAE as an effective method to control obstetric bleeding from non-uterine arteries [88, 89] and postpartum hemorrhage following myomectomy to avoid more invasive procedures such as a hysterectomy [90]. The application of UAE in patients with placenta accreta spectrum after abdominal aortic balloon occlusion has shown promising results in reducing hemorrhage and the need for extensive interventions like hysterectomy [11].

Overall, the cumulative evidence underscores the efficacy, safety, and minimally invasive nature of uterine artery embolization for a range of obstetric and gynecologic indications, including fibroids, uterine AVMs, and postpartum hemorrhage. Multiple studies report high technical and clinical success rates, substantial symptom relief, and meaningful reductions in fibroid size, all while preserving fertility in most cases. These findings affirm UAE as a robust alternative to more invasive treatments, offering advantages such as shorter recovery times, avoidance of major surgery, and the potential to retain uterine function. Having reviewed

Balamurugan S, et al., J Radiol Clin Imaging 2025
DOI:10.26502/jrci.2809105

the position of UAE among various treatment modalities, a thorough assessment of its safety and potential complications is crucial to assess its potential in the treatment landscape.

Safety and Complications

UAE is generally considered a safe and minimally invasive procedure for a range of gynecological conditions, including uterine fibroids, obstetric hemorrhages, and postpartum hemorrhage (PPH). While the procedure boasts a favorable safety profile, certain side effects and complications warrant attention to optimize patient outcomes and guide appropriate patient selection.

The most reported side effect post-UAE is pelvic pain, attributed to ischemia of the fibroid and transient ischemia to the myometrium. This pain typically resolves within 1-3 days and is effectively managed with pain relievers [91]. Another frequent complication is post-embolization syndrome, occurring in approximately 30-50% of patients, characterized by fever, malaise, nausea, and pain. While this syndrome is self-limiting, it can temporarily affect recovery and is managed with supportive care, including analgesics and antiemetics [12, 91].

In the context of PPH, UAE has demonstrated high efficacy in controlling severe bleeding, with success rates often exceeding 90-97% in cases involving uterine artery pseudoaneurysms, retained products of conception, or uterine atony [92]. However, complications unique to this scenario, such as uterine necrosis, occur in 1-5% of cases and emphasize the importance of careful monitoring when embolization is performed in emergent or complex settings [93-95]. Additionally, the risk of intrauterine infection or pelvic abscess is approximately 6-7%, though these complications are generally manageable with antibiotics [95].

Rare but serious complications associated with UAE include arterial dissections during catheterization, resulting in potentially fatal hemorrhage if not promptly treated [96]. Non-target embolization, which can damage adjacent organs, and complex sequelae such as gynecologic fistulas or ovarian thrombosis have also been documented, though they remain exceedingly rare (<1%) [97-99]. A unique case report noted severe hyperkalemia and acute kidney failure following UAE for a large fibroid, underscoring the importance of recognizing necrotic tissue as a potential source of complications [100].

Despite these risks, studies consistently show that UAE is associated with lower rates of major complications compared to surgical interventions like hysterectomy or myomectomy. Major adverse events occur in only 1-3% of cases, compared to 10-30% for surgical alternatives, making UAE a safer choice for many patients seeking fertility preservation or minimally invasive treatment options [91, 95].

By balancing safety of UAE with comprehensive patient selection, close monitoring, and post-procedure care, it remains an effective, fertility-sparing intervention for diverse gynecological and obstetric conditions. While it boasts high success rates and a favorable safety profile, clinicians must remain vigilant about potential complications, including post-embolization syndrome, uterine necrosis, and rare but serious events like arterial dissections and non-target embolization. These risks, although uncommon, highlight the importance of careful patient selection and thorough monitoring. Overall, UAE offers significant advantages over surgical alternatives, with lower rates of major complications and preserved fertility, making it a compelling choice for many patients. While these recognized safety considerations highlight the potential of UAE, additional drawbacks must also be weighed when selecting the most appropriate treatment strategy.

Drawbacks

Overall, there is a reported 14.4% reintervention rate in UAE over a 3–5-year period, and major complications can be expected in 5% of cases that are most common within the first month following procedure [85, 86]. In comparison of UAE to myomectomy, an alternative treatment for uterine fibroids, it has been reported that UAE is associated with a shorter hospital stay with fewer major interventions, but higher rates of minor complications and increased likelihood of surgical intervention within 2 to 5 years [85, 86]. Comparing UAE to hysterectomy, it has been established that UAE results in less bleeding, shorter hospital stay, and quicker resumption of work in the short term, with similar outcomes and quality of life in the long term [86]. With these comparisons, there are a handful of drawbacks for patients and clinicians to consider regarding treatment with UAE compared to other treatment options, some of which include infection, injury, fertility concerns, menstrual irregularities, uterine necrosis, and allergic reactions.

Active pelvic infection is widely understood to be a contraindication to UAE. The risk of infections following UAE procedures ranges from 0.9%-2.5% with infections arising through the hematogenous spread of vaginal flora via the cervical canal [101]. In the context of bilateral UAE following postpartum hemorrhage, there are case reports that suggest an increased likelihood of developing necrotizing myositis [81]. A recent study from 2020 found a 0.9% rate of postoperative uterine infection following UAE compared to a less than 4% rate of postoperative uterine infection following myomectomy [101]. Yet to mitigate this risk, prophylactic antibiotics are routinely administered to patients before the procedure and are a recommendation according to the 2018 guidelines on Antibiotic Prophylaxis during Vascular and IR procedures [101, 102].

One commonly reported complication is the vaginal expulsion of infarcted fibroids, where necrotic fibrinous tissue still attached to the myometrium is expelled. According to previous studies, fibroid expulsion after UAE was reported

Balamurugan S, et al., J Radiol Clin Imaging 2025
DOI:10.26502/jrci.2809105

in 5-15% of cases, with time periods ranging from days to years [103]. In one case report, fibroid expulsion 11 years following UAE presented as a small bowel obstruction that is thought to be due to the development of uteroenteric fistulas, requiring physicians to be aware of the potential for this complication [104]. These extremely rare presentations typically require hysterectomy and surgical intervention. In the setting of fibroid expulsion, this usually results in the need for further medical intervention to manage the fibroid and prevent additional injury [91].

Some of the most frequently reported drawbacks in the literature are fertility concerns following

UAE procedures. There is a large degree of uncertainty in the data surrounding fertility following UAE, with conflicting reports suggesting its effect on pregnancy and miscarriages [86, 105]. A systematic review comparing fertility outcomes in females undergoing UAE vs myomectomy found that those patients who underwent UAE exhibited lower rates of pregnancy and higher risks of miscarriage [106, 107]. A literature review in 2019 concluded that the true fertility rate following UAE is approximately 38.3% after comparing 5 studies with a total of 224 patients [14]. The data suggests that UAE may compromise reproductive outcomes, though the degree to this may be due to factors such as patient age, and the extent of fibroid involvement. It is currently recommended that counseling of women regarding fertility following UAE should be individualized [85].

Menstrual cycle disruption is another potential complication associated with UAE procedures. In an observational study involving 66 premenopausal women, 15% of participants failed to resume normal menstruation due to premature ovarian failure [108]. For certain women, this amenorrhea results in infertility, hormonal imbalances, and long-term consequences for reproductive health.

Uterine necrosis following uterine artery embolization is a rare but serious complication that has been reported in the literature [81]. While the overall incidence of complications associated with uterine artery embolization is low, at around 1%, the incidence of uterine necrosis after UAE can be as high as 9.4% in patients with postpartum hemorrhage [81]. It is also more prevalent in patients with comorbidities such as diabetes [14].

Hypersensitivity reactions to the contrast used during UAE are rare but worth mentioning. These reactions range from mild, localized itching at the injection site, to systemic allergic reactions requiring intubation and hospitalization [109]. Though incredibly rare, the possibility of these reactions justifies the need for careful monitoring both during and after the procedure, especially for those patients with previous allergies.

While UAE offers significant benefits—such as shorter hospital stays and reduced perioperative morbidity—clinicians should be mindful of potential drawbacks. Reintervention rates, minor complications like infection or fibroid expulsion, and concerns surrounding fertility or menstrual disruption warrant thorough counseling and proactive management strategies. Rare but serious events, including uterine necrosis and hypersensitivity reactions, underscore the importance of careful patient selection, prophylactic measures, and vigilant post-procedural follow-up to optimize patient outcomes. Despite these complications, uterine artery embolization is generally regarded as safe, conservative, and minimally invasive in the treatment of uterine fibroids. It also is a promising option for future advancements in expanding its application and improving its efficacy.

Future Directions and Research

UAE has firmly established itself as a pivotal intervention for managing numerous gynecological conditions, yet ongoing advancements in technology continue to redefine its potential. Innovations in embolic materials, catheter techniques, imaging modalities, and adjunct therapies are paving the way for safer, more effective, and patient-centered approaches to this minimally invasive procedure. Concurrently, future research must address critical areas such as long-term reproductive outcomes, complication management, cost-effectiveness, and technological integration to ensure UAE evolves as a leading treatment option.

Building on traditional agents like polyvinyl alcohol (PVA) particles, emerging materials such as biodegradable microspheres, hydrophobic injectable liquids (e.g., PHIL), and drug-eluting beads (DEBs) are expanding therapeutic possibilities. Biodegradable microspheres offer controlled degradation, reducing ischemic complications while preserving uterine function [110, 111]. Hydrophobic injectable liquids like PHIL enable precise embolization with rapid solidification, minimizing non-target effects [111, 112]. Meanwhile, DEBs combine vessel occlusion with localized drug delivery, enhancing symptom relief and reducing fibroid size, particularly in complex or recurrent cases [113-115]. Despite these advances, challenges related to cost, clinician training, and validation of long-term outcomes require further exploration [110, 111].

Complementing advancements in embolic materials, refinements in catheter technology and vascular access hold significant promise. The transradial approach (TRA) is gaining traction as an alternative to the traditional transfemoral approach (TFA), offering shorter recovery times, reduced access-site complications, and lower radiation exposure [73, 116, 117]. Additionally, next generation microcatheters allow precise navigation of complex vascular anatomies, reducing the risk of non-target embolization [118, 119]. These technical advances are bolstered by innovative imaging solutions, such as contrast-enhanced ultrasound (CEUS) for real-time,

radiation-free guidance [39, 120], three-dimensional imaging for comprehensive uterine assessments [121], and MRI guidance for high-resolution targeting and post-procedural monitoring [122]. Collectively, these developments enhance procedural efficiency, safety, and outcomes [123, 124].

Expanding its therapeutic potential, UAE has shown promise as a minimally invasive treatment for uterine and cervical cancers, particularly as an adjunct to traditional therapies. By selectively occluding uterine arteries, UAE reduces blood flow to tumors, causing ischemia and shrinkage. This approach is particularly effective for hypervascular tumors and is performed under imaging guidance to minimize damage to surrounding healthy tissue [125, 126]. UAE has proven effective in controlling hemorrhage in uterine arteriovenous malformations associated with cancer and managing significant bleeding in advanced cervical cancer, often serving as a palliative measure [127, 128]. Moreover, its ability to reduce tumor vascularity can enhance the efficacy of chemotherapy and radiation, positioning UAE as a valuable component of multidisciplinary cancer care.

While UAE's safety and effectiveness are well-established, key knowledge gaps remain, particularly in its application to malignancies. The long-term effects on fertility, tumor recurrence, and overall survival require further investigation [126, 129]. Standardizing protocols for integrating UAE into cancer treatment pathways and refining patient selection criteria are critical steps toward optimizing its role in this context [128]. Furthermore, exploring the synergistic effects of UAE combined with systemic therapies and advancements in embolic materials could unlock additional therapeutic benefits [37, 125].

Future research must also address broader concerns, including the impact of UAE on reproductive outcomes. Although UAE generally preserves fertility and reduces symptoms like heavy menstrual bleeding and pelvic pain [45], some patients experience amenorrhea or cycle irregularities [130, 131]. Understanding how factors such as patient age, fibroid characteristics, and ovarian reserve influence these outcomes is essential, with anti-Müllerian hormone (AMH) levels serving as a key marker for ovarian function [11, 126, 132]. Promising pregnancy rates of approximately 59.5% have been observed [133], but further studies are needed to evaluate conception and miscarriage risks based on individual patient profiles [37, 129, 134, 135].

Complication management remains a vital research area. Although major complications, such as uterine necrosis (1–3%) and fistula formation (0.1–1%), are rare, improving patient selection through advanced imaging and comorbidity scoring could further mitigate these risks [136, 137]. Managing post-embolization syndrome, which affects 30–50% of patients, is also crucial to enhancing recovery and satisfaction [138]. Additionally, while shorter hospital stays in UAE confer economic advantages over surgical alternatives [128], studies examining long-term reintervention rates are needed to refine cost-effectiveness models [139-141].

Finally, emerging technologies like artificial intelligence (AI), virtual reality (VR), and telemedicine offer transformative potential for UAE. AI can streamline procedural planning and vascular mapping [142], VR provides advanced training tools for interventional radiologists [143], and telemedicine expands access to expert guidance for remote care [144]. Addressing challenges related to data security, infrastructure, and cost will be crucial for integrating these innovations into routine practice [145]. Although preliminary studies show substantial promise [146, 147], further validation is needed to ensure widespread clinical adoption.

UAE is ultimately poised to become an increasingly transformative intervention, with advancements in embolic materials, catheter technologies, imaging techniques, and adjunct therapies driving safer, more effective, and personalized treatments. Addressing key research gaps, such as long-term fertility outcomes, optimal patient selection, and integration with systemic therapies, will expand the role of UAE in managing gynecological conditions and malignancies. Innovations like artificial intelligence, virtual reality, and telemedicine promise to enhance procedural precision, clinician training, and patient access. As these developments converge, UAE is set to redefine minimally invasive gynecological care, offering improved outcomes, reduced complications, and greater accessibility for diverse patient populations.

Conclusion

In conclusion, uterine artery embolization (UAE) has emerged as a transformative and versatile procedure within interventional radiology and gynecology, redefining the management of a wide range of gynecological and obstetric conditions. By leveraging advancements in embolic materials, catheter technology, and imaging modalities, UAE offers patients a minimally invasive, fertility-preserving alternative to traditional surgical interventions. Its applications extend beyond fibroid management to include postpartum hemorrhage, adenomyosis, and even novel roles in cancer care, demonstrating its broad clinical utility. Compared to surgical options, UAE provides faster recovery times, reduced complications, and greater patient satisfaction, reinforcing its status as a safe and effective treatment choice.

However, challenges remain, particularly concerning long-term outcomes such as fertility preservation, recurrence rates, and the management of rare complications like uterine necrosis or post-embolization syndrome. These areas necessitate ongoing research to refine patient selection, optimize procedural techniques, and expand indications for UAE. The integration of innovative technologies such as

artificial intelligence for procedural planning, biodegradable embolic agents for targeted therapy, and advanced imaging techniques promises to further enhance the efficacy and safety of UAE.

As healthcare increasingly prioritizes personalized medicine, UAE exemplifies the potential of minimally invasive approaches to align treatment with individual patient needs. Through continued interdisciplinary collaboration and advancements in technology, UAE holds the potential to not only improve outcomes for patients but also set new benchmarks for gynecological care globally. Its trajectory as a preferred therapeutic option underscores the balance of clinical innovation and patient-centered care, paving the way for future breakthroughs in interventional radiology as well as gynecology.

Key Points

- Minimally Invasive Technique: UAE is a non-surgical procedure targeting vascular conditions with high precision, minimal recovery time, and preservation of uterine function.
- Diverse Indications: It is effectively used for symptomatic uterine fibroids, adenomyosis, postpartum hemorrhage, and uterine arteriovenous malformations.
- Advanced Embolic Materials: Innovations such as biodegradable microspheres and drug-eluting beads enhance procedural efficacy and reduce complications.
- Enhanced Imaging: Real-time guidance with advanced imaging modalities, including MRI and contrast-enhanced ultrasound, improves targeting accuracy.
- Fertility Considerations: UAE preserves fertility for many patients, though outcomes may vary based on factors like age and fibroid characteristics.
- Safety Profile: With lower rates of major complications compared to surgical interventions, UAE offers a favorable alternative for many patients.
- Complications Management: Common issues like post-embolization syndrome are manageable, but rare events such as uterine necrosis require vigilance.
- Comparative Outcomes: UAE achieves symptom relief and quality-of-life improvements comparable to or exceeding surgical options like myomectomy or hysterectomy.
- Emerging Applications: Potential use in cancer treatment and integration with adjunct therapies underscores the expanding therapeutic scope of UAE.
- Future Directions: Research into long-term outcomes, advanced materials, and integration with AI and telemedicine could further refine the role of UAE in clinical practice.

Funding

The research work of DKA is supported by the R25AI179582 and R01 HL147662 grants from the National Institutes of Health, USA. The contents of this article are solely the responsibility of the authors and do not necessarily represent the official views of the National Institutes of Health.

Competing Interests: All authors have read the manuscript and declare no conflict of interest. No writing assistance was utilized in the production of this manuscript.

Consent for Publication: All authors have read the manuscript and consented for publication.

References

1. Hu J, Albadawi H, Chong BW, et al. Advances in Biomaterials and Technologies for Vascular Embolization. Adv Mater 31 (2019): e1901071.
2. Bilbao JI, Martínez-Cuesta A, Urtasun F, et al. Complications of Embolization. Semin Intervent Radiol 23 (2006): 126-142.
3. Tadavarthy SM. Interventional Radiology 1 (1997).
4. Poursaid A, Jensen MM, Huo E, et al. Polymeric Materials for Embolic and Chemoembolic Applications. J Control Release 240 (2016):414-433.
5. Avery RK, Albadawi H, Akbari M, et al. An Injectable Shear-Thinning Biomaterial for Endovascular Embolization. Sci Transl Med 8 (2016): 365ra156.
6. Ostrowski P, Bonczar M, Michalczak M, et al. The Anatomy of the Uterine Artery: A Meta-Analysis With Implications for Gynecological Procedures. Clin Anat 36 (2023):457-464.
7. Heaston DK, Mineau DE, Brown BJ, et al. Transcatheter Arterial Embolization for Control of Persistent Massive Puerperal Hemorrhage After Bilateral Surgical Hypogastric Artery Ligation. AJR Am J Roentgenol 133 (1979): 152-154.
8. The American College of Obstetricians and Gynecologists. Uterine Artery Embolization (UAE).
9. Das CJ, Rathinam D, Manchanda S, et al. Endovascular Uterine Artery Interventions. Indian J Radiol Imaging 27 (2017): 488-495.
10. El-Sharkawy AM, Elsaeed HH, Kamel AH, et al., Comparison between the outcome of single versus multiple uterine fibroids after uterine artery embolization. Egypt J Radiol Nucl Med 51 (2020): 77.
11. Zhang K, Cheng S, Zhi Y, et al. Application of uterine artery embolization in patients with placenta accreta

spectrum after abdominal aortic balloon occlusion. Vascular and Endovascular Surgery 58 (2024): 498-504.

12. Subramaniam S, Nadarajan C, Aziz ME. Role of uterine artery embolization in pseudoaneurysm of uterine artery: A rare cause of secondary postpartum hemorrhage. Cureus 10 (2018): e2220.
13. Young M, Coffey W, Mikhail LN. Uterine Fibroid Embolization. StatPearls Publishing (2023).
14. Ludwig PE, Huff TJ, Shanahan MM, et al. Pregnancy success and outcomes after uterine fibroid embolization: updated review of published literature. Br J Radiol 93 (2020): 20190551.
15. Srinivas T, Lulseged B, Attari MM, et al. Patient characteristics associated with embolization versus hysterectomy for uterine fibroids: A systematic review and meta-analysis. J Am Coll Radiol 21 (2024): 729-739.
16. Spies JB. Current Role of Uterine Artery Embolization in the Management of Uterine Fibroids. Clin Obstet Gynecol 59 (2016): 93-102.
17. Stępniak A. Uterine artery embolization in the treatment of symptomatic fibroids - state of the art 2018. Prz Menopauzalny 17 (2018):141-143.
18. de Bruijn AM, Smink M, Lohle PNM, et al. Uterine Artery Embolization for the Treatment of Adenomyosis: A Systematic Review and Meta-Analysis. J Vasc Interv Radiol 28 (2017):1629-1642.e1.
19. Kim T, Shin JH, Kim J, et al., Management of bleeding uterine arteriovenous malformation with bilateral uterine artery embolization. Yonsei Med J 55 (2014):367-373.
20. Takeda K, Mackay J, Watts S. Successful Management of Cervical Ectopic Pregnancy with Bilateral Uterine Artery Embolization and Methotrexate. Case Rep Emerg Med (2018): 9593824.
21. Zakaria MA, Abdallah ME, Shavell VI, Berman JM, Diamond MP, Kmak DC. Conservative management of cervical ectopic pregnancy: utility of uterine artery embolization. Fertil Steril. 2011;95(3):872-876.
22. Vihtelic P, Skuk E, Suster NK, et al., Emergency and prophylactic uterine artery embolization in gynecology and obstetrics - a retrospective analysis. Radiol Oncol 58 (2024):397-405.
23. Kitami K, Koike W, Nakamura H, et al., Conservative endovascular and hysteroscopic management of a cesarean scar pregnancy in a woman with a previous history of uterine artery embolization. Clin Case Rep 7 (2019):524-528.
24. Morlando M, Buca D, Timor-Tritsch I, et al. Reproductive outcome after cesarean scar pregnancy: A systematic review and meta-analysis. Acta Obstet Gynecol Scan 99 (2020):1278-1289.
25. Sendy F, Ahmeed S, Obaid S, (2020). Cesarean scar pregnancy management: minimally invasive suction of the gestational sac content combined with local and intramuscular methotrexate injection. Ochsner Journal 20 (2020): 463-466.
26. Braud L, Knez J, Mavrelos D. Risk prediction of major haemorrhage with surgical treatment of live cesarean scar pregnancies. European Journal of Obstetrics & Gynecology and Reproductive Biology. 264 (2021): 224-231.
27. Ninama P, Mishra K, Parikh C, (2018). Cesarean scar pregnancy: a case of conservatively managed clinical rarity. Journal of South Asian Federation of Obstetrics and Gynaecology 10 (2018): 358-360.
28. Torky H. Cesarean scar ectopic pregnancy: A cause of failed first trimester surgical termination of pregnancy. JBRA Assist Reprod 24 (2020): 218-220.
29. Juárez M, Leal M, Coronel F, et al. Uterine artery embolization prior to hysterectomy as a prevention of the risk of hemorrhage. Rev Med Hosp Gen Mex 85 (2022): 219-223.
30. Deshmukh SP, Gonsalves CF, Rao R. Role of uterine artery embolization in the management of symptomatic uterine fibroids. Radiographics 32 (2012): E171-E194.
31. Juárez M, Leal M, Coronel F, et al. Uterine artery embolization prior to hysterectomy as a prevention of the risk of hemorrhage. Rev Med Hosp Gen Mex 85 (2022):219-223.
32. Carranza-Mamane B, Havelock J, Hemmings R, et al. The management of uterine fibroids in women with otherwise unexplained infertility. J Obstet Gynaecol Can 37 (2015): 277-285.
33. Kröncke T. An update on uterine artery embolization for uterine leiomyomata and adenomyosis of the uterus. Br J Radiol. 2023;96 (2023): 20220121.
34. Ra K, Weston M, Nougaret S, et al. European Society of Urogenital Radiology (ESUR) guidelines: MR imaging of leiomyomas. Eur Radiol 28 (2018): 3125-3137.
35. Rott G, Boecker F. The extremely rare vascular variant of a segmental duplicated uterine artery and its relevance for the interventionist and gynecologist: a case report. J Med Case Rep 10 (2016): 1092-1098.
36. Song J, Sathyanarayana S, Boone L, et al., A multi-disciplinary approach of a patient with extensive arterio-venous malformations undergoing a C-section. Open J Anesthesiol 3 (2013): 224-227.

37. Inampudi V. Efficacy of embolization in acquired uterine vascular malformations: An experience in tertiary care centre in India. Rev Bras Ginecol Obstet 45 (2023): 325-332.

38. Tilva H, Tayade S, Makhija N, et al., Uterine artery embolization and double-J stenting in a case of urinary retention due to a massive cervical fibroid: A case report. Cureus 14 (2022): e30163.

39. Jia, J, Mastrolonardo E, Soleman M. A novel use of contrast-enhanced ultrasound in uterine artery embolization. American Journal of Interventional Radiology, 4 (2020): 8.

40. Pan Y, Zhou X, Yang Z, et al. Retrospective cohort study of prophylactic intraoperative uterine artery embolization for abnormally invasive placenta. Int J Gynecol Obstet 137 (2017): 45-50.

41. Isono W, Tsuchiya A, Okamura A, et al. Unilateral uterine artery embolization and Bakri tamponade balloon insertion in the treatment of acute puerperal uterine inversion: A case report. J Med Case Rep 16 (2022): 109-115.

42. Park JY, Suh DS, Lee JH, et al. Pain control with superior hypogastric nerve block in uterine artery embolization: A prospective study. J Obstet Gynaecol Res 46 (2020):774-780.

43. Pereira MM, Horta AG, Silva JD, et al. Superior hypogastric nerve block in uterine artery embolization: Impact on pain and opioid use. Pain Med 21 (2020): 1420-1427.

44. Gao H, Li T, Fu D, Wei J. Uterine artery embolization, surgery, and high-intensity focused ultrasound in the treatment of uterine fibroids: A network meta-analysis. Quant Imaging Med Surg 11 (2021): 4125-4136.

45. Mishra V. Uterine artery embolization for acquired arteriovenous malformation in young patients with abnormal uterine bleeding: From diagnosis to management. J S Asian Fed Obstet Gynaecol 16 2024): 322-324.

46. Gollapudi R, Rammurty S. Selective uterine artery embolization: An effective treatment option for postpartum hemorrhage due to pseudoaneurysm of uterine artery. J S Asian Fed Obstet Gynaecol 9 (2017): 283-286.

47. Ahmad S. Peripheral arteriovenous malformation embolization using Squid. Case Rep Vasc Med (2023): 8858656.

48. LaRussa S, Berg R, Craig K, et al. Is there a role for combination, single-session selective transarterial embolization and microwave ablation for large renal masses? Cardiovasc Interv Radiol 43 (2020):1468-1473.

49. Han Z, Du Y. Galenic dural arteriovenous fistula in neurofibromatosis type 1 treated with Onyx. Interv Neuroradiol 25 (2019): 692-696.

50. Mercado G, Delovino K, Carpela A. Arteriovenous malformation of the mandible in a young postpartum woman. Philipp J Otolaryngol Head Neck Surg 34 (2019): 52-55.

51. Miyayama S, Kikuchi Y, Yoshida M, et al. Outcomes of conventional transarterial chemoembolization for hepatocellular carcinoma ≥10 cm. Hepatol Res 49 (2019): 787-798.

52. Jullie A, Larissa C, Liziane L, et al. Uterine artery pseudoaneurysm after cesarean section treated with superselective embolization: A case report. Adv Ultrasound Diagn Ther 6 (2022): 210.

53. Kinariwala DJ. Pre-operative uterine artery embolization before hysterectomy or myomectomy: a single-center review of 53 patients. Clinical Imaging 101 (2023): 121-125.

54. Talaulikar VS, Belli AM, Manyonda I. GnRH Agonists: Do They Have a Place in the Modern Management of Fibroid Disease? Journal of Obstetrics and Gynecology India. 62 (2012): 506-510.

55. Madueke-Laveaux OS. GnRH analogs for the treatment of heavy menstrual bleeding associated with uterine fibroids. F S Reports 4 (2022): 46-50.

56. Donnez J, Taylor HS, Stewart EA, et al. Linzagolix with and without hormonal add-back therapy for the treatment of symptomatic uterine fibroids: two randomized, placebo-controlled, phase 3 trials 400 (2022): 896-907.

57. Schlaff WD. Elagolix for heavy menstrual bleeding in women with uterine fibroids. New England Journal of Medicine 382 (2020): 328-340.

58. Wrona W, Stępniak A, Czuczwar P. The role of levonorgestrel intrauterine systems in the treatment of symptomatic fibroids. Prz Menopauzalny 16 (2017): 129-132.

59. Atak Z. Levonorgestrel-releasing intrauterine device to treat abnormal uterine bleeding: not one treatment option fits all. Journal of the Turkish German Gynecological Association. 24 (2023): 246-251.

60. Szydłowska I. Markers of inflammation and vascular parameters in selective progesterone receptor modulator (Ulipristal Acetate)-treated uterine fibroids. Journal of Clinical Medicine 10 (2021): 3721.

61. Lee MJ. Uterine fibroid shrinkage after short-term use of selective progesterone receptor modulator or gonadotropin-releasing hormone agonist. Obstetrics &

Gynecology Science 60 (2017): 69-73.

62. Garnock-Jones K. P. Ulipristal Acetate: A Review in Symptomatic Uterine Fibroids. Drugs 77 (2017):1665-1675.

63. Peitsidis P. Tranexamic Acid (TXA) for the Hemostatic Treatment of Post-Partum Hemorrhage (PPH): What Key Points Have We Learnt After All These Years? Journal of Clinical Medicine 12 (2023): 6385.

64. Kashani BN, Centini G, Morelli SS, et al., Role of Medical Management for Uterine Leiomyomas. Best Pract Res Clin Obstet Gynaecol 34 (2016): 85-103.

65. Salama M. and Habib, M. Uterine artery embolization for symptomatic fibroids uterus in gaza. Mathews J Gynecol Obstet 7 (2023).

66. Daniels J, Middleton L, Cheed V, et al., Uterine artery embolisation versus myomectomy for premenopausal women with uterine fibroids wishing to avoid hysterectomy: the femme rct. Health Technology Assessment 26 (2022): 1-74.

67. Mitro, S. Long-term risk of reintervention after surgical leiomyoma treatment in an integrated health care system. Obstetrics and Gynecology (2024).

68. Aktürk, H. Comparison of recurrence and quality of life between myoma embolization and myomectomy. Cureus (2023).

69. Davis M, Soliman A, Castelli-Haley J, et al., Reintervention rates after myomectomy, endometrial ablation, and uterine artery embolization for patients with uterine fibroids. Journal of Women S Health. 27 (2018): 1204-1214.

70. Bahall, V. The hangman's tourniquet: a safe and practical approach for reducing blood loss during uterine myomectomy. Cureus. (2023).

71. Zanolli N, Bishop K, Kuller J, et al., Fibroids and fertility: a comparison of myomectomy and uterine artery embolization on fertility and reproductive outcomes. Obstetrical & Gynecological Survey 77 (2022): 485-494.

72. Gao H, Li T, Fu D, et al., Uterine artery embolization, surgery and high intensity focused ultrasound in the treatment of uterine fibroids: a network meta-analysis. Quantitative Imaging in Medicine and Surgery. 11 (2021): 4125-4136.

73. Chen R, & You J. Comparison of hysterectomy and uterine artery embolization in the treatment of symptomatic uterine fibroids: A protocol for systematic review and meta-analysis. Medicine. 101 (2022): e32440.

74. Anchan RM, Spies JB, Zhang S, et al. Long-term health-related quality of life and symptom severity following hysterectomy, myomectomy, or uterine artery embolization for the treatment of symptomatic uterine fibroids. Am J Obstet Gynecol 229 (2023): 275.e1-275.e17.

75. Brancazio S, Saramago I, Goodnight W, et al., Cesarean scar ectopic pregnancy: case report. Radiology Case Reports. 14 (2019): 354-359.

76. Gaur Y, Jain R, Gurjar S. Case report -cesarean scar ectopic pregnancy. Southeast Asian Journal of Case Report and Review. 9 (2023): 96-98.

77. Tang P, Li X, Li W, et al., The trend of the distribution of ectopic pregnancy sites and the clinical characteristics of caesarean scar pregnancy. Reprod Health 19 (2022):182.

78. Salvi P. Medical management of cesarean scar ectopic pregnancy: a unique approach. Cureus (2024).

79. Ninama P, Mishra K, Parikh C. Cesarean scar pregnancy: a case of conservatively managed clinical rarity. Journal of South Asian Federation of Obstetrics and Gynaecology 10 (2018): 358-360.

80. More V. Cesarean scar pregnancy: a new challenge for obstetricians. Journal of South Asian Federation of Obstetrics and Gynaecology 15 (2023): 338-340.

81. Li K. Dai Q. Differential diagnosis of cesarean scar pregnancies and other pregnancies implanted in the lower uterus by ultrasound parameters. Biomed Research International (2020): 1-7.

82. Firouznia K, Ghanaati H, Jalali AH, Shakiba M. Uterine artery embolization for treatment of symptomatic fibroids: a review of the evidence. Iran Red Crescent Med J. 2013;15(12) :e16699.

83. Kim T, Shin JH, Kim J, et al., (2014). Management of Bleeding Uterine Arteriovenous Malformation with Bilateral Uterine Artery Embolization. Yonsei Med J, 55 (2014): 367-373.

84. Mogahed, M., Mona, Darwish, J., & Soliman, H. (2017). Epidural Anesthesia vs General Anesthesia in Uterine Artery Embolization. Journal of Anesthesia & Clinical Research 8 (2017).

85. Kohi M, Spies J. Updates on uterine artery embolization. Seminars in Interventional Radiology 35 (2018): 048–055.

86. van Overhagen, H, Reekers JA. Uterine Artery Embolization for Symptomatic Leiomyomata. Cardiovascular and Interventional Radiology 38 (2015): 536–542.

87. Singhal A, Singh A, Raghunandan C, et al., Uterine artery embolization: exploring new dimensions in obstetric emergencies. Oman Med J 29 (2014):217-219.

Balamurugan S, et al., J Radiol Clin Imaging 2025
DOI:10.26502/jrci.2809105

88. Agrawal S, Thakur R, Sonker S. Study of uterine artery embolization: A newer modality in secondary PPH. International Journal of Reproduction, Contraception, Obstetrics and Gynecology 7 (2018): 452.

89. Kim JE, So YH, Kim BJ, Kim SM, Choi YH, Sung CK. Postpartum hemorrhage from non-uterine arteries: clinical importance of their detection and the results of selective embolization. Acta Radiol. 2018;59(8):932-938.

90. Wan AY, Shin JH, Yoon HK, et al. Post-operative hemorrhage after myomectomy: safety and efficacy of transcatheter uterine artery embolization. Korean J Radiol 15 (2014): 356-363.

91. Memtsa M, Homer H. Complications associated with uterine artery embolisation for fibroids. Obstet Gynecol Int. (2012):290542.

92. Iwahata Y, Tamura M, Yamada T, et al., Three-dimensional computed tomography is effective in diagnosing uterine arterial pseudoaneurysm, a cause of secondary postpartum hemorrhage: A case report. SAGE Open Medical Case Reports 9 (2021).

93. Shaikh, Najma, Shaikh, Maria, Shaikh, Farhana, et al., Role of the Uterine Artery Ligation (UAL) In Control of Postpartum Hemorrhage. Annals of PIMS-Shaheed Zulfiqar Ali Bhutto Medical University. 17 (2021): 184-187.

94. Fouad A, Bouab M, Youssouf N, et al., Uterine necrosis simulating a textiloma: A case report. Int J Surg Case Rep 91 (2022): 106754.

95. Mahmood I, Abdelrahman H, Hakim S, et al. A multidisciplinary approach to rescue a full-term pregnant and her fetus after blunt abdominal trauma: A case report and literature review. J Surg Case Rep 12 (2022): rjac559.

96. Schirf BE, Vogelzang RL, Chrisman HB. Complications of uterine fibroid embolization. Semin Intervent Radiol. 23 (2006):143-149.

97. Oguz, Yuksel, Eldem, et al., Uterine Arteriovenous Malformation. Gynecology Obstetrics & Reproductive Medicine. 25 (2018): 1.

98. Vendittelli F. Gynecological fistulas after UAE: A review of 10 cases. Fugaru I, Fogaing C, Aldhaheri S, Weibel H, Fahmy N. Complex Gynecologic Fistulas Presenting 10 Years After Uterine Artery Embolization. Obstet Gynecol 141 (2015): 375-378.

99. Tanaka K, Koizumi T, Higa T, et al. Hyperkalemia and acute kidney failure associated with preoperative uterine artery embolization for a large uterine fibroid: a case report. J Med Case Reports 306 (2016).

100. Lukies M, Clements W. Current Strategies for Prevention of Infection After Uterine Artery Embolisation. Cardiovasc Intervent Radiol 45 (2022): 911-917.

101. Zarrinpar A, Kerlan RK. A guide to antibiotics for the interventional radiologist. Semin Intervent Radiol 22 (2005): 69-79.

102. Memon S I, Acharya N S, Potdar J. Spontaneous Expulsion of a Huge Cervical Fibroid After Uterine Artery Embolization Done as a Lifesaving Procedure for Acute Severe Abnormal Uterine Bleeding. Cureus 14 (2022): e30163.

103. Roberson JL, Krumeich LN, Darwich NF, et al. Fibroid expulsion: a unique presentation of mechanical small bowel obstruction 11 years after uterine artery embolization: a case report. J Med Case Reports 356 (2021).

104. Cope AG, Young RJ, Stewart EA. Non-extirpative Treatments for Uterine Myomas: Measuring Success. J Minim Invasive Gynecol 28 (2021): 442-452.e4

105. Karlsen K, Hrobjartsson A, Korsholm M, Fertility after uterine artery embolization of fibroids: a systematic review. Arch Gynecol Obstet 297 (2018): 13-25

106. Keung JJ, Spies JB, Caridi TM. Uterine artery embolization: A review of current concepts. Best Pract Res Clin Obstet Gynaecol 46 (2018): 66-73.

107. 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 11 (2000): 699-703.

108. Demello AB. Uterine artery embolization. AORN J 73 (2001): 790-814.

109. Doucet J, Kiri L, O'Connell K, et al., Advances in degradable embolic microspheres: A state-of-the-art review. Journal of Functional Biomaterials 9 (2018): 14.

110. Zhou T, Chen S, Wan H, et al., Safety and efficacy of drug-eluting bead transarterial chemoembolization with Callispheres® microsphere for hepatocellular carcinoma with portal vein tumor thrombus: A preliminary study. Journal of Cancer, 12 (2021): 4522-4529.

111. Garg T, Shrigiriwar A, Habibollahi P. Intraarterial therapies for the management of hepatocellular carcinoma. Cancers, 14 (2022): 3351.

112. Cui W. Drug-eluting beads bronchial arterial chemoembolization in advanced and standard treatment-refractory/ineligible NSCLC (2024).

113. Zhao Y, Liu S, Qin H, et al., Efficacy and safety of Callispheres drug-eluting beads for bronchial arterial chemoembolization for refractory non-small-cell lung cancer and its impact on quality of life: A multicenter prospective study. Frontiers in Oncology 13 (2023).

114. Bie Z, Li Y, Li B. The efficacy of drug-eluting beads bronchial arterial chemoembolization loaded with gemcitabine for treatment of non-small cell lung cancer. Thoracic Cancer, 10 (2019): 1770-1778.

115. Barros G, Bass D, Osbun J, et al., Left transradial access for cerebral angiography. Journal of Neurointerventional Surgery, 12 (2019): 427-430.

116. Khanna O, Sweid A, Mouchtouris N, et al., Radial artery catheterization for neuroendovascular procedures. Stroke, 50 (2019): 2587-2590.

117. Dawoud M, Alaa D, Elzanaty M, (2023). Efficacy and safety of the transradial approach (TRA) versus transfemoral approach (TFA) in uterine artery embolization (UAE) for the management of uterine fibroids: A systematic review and meta-analysis. Evidence Based Women's Health Journal, 13 (2023), 87-93.

118. Khandelwal P, Majmundar N, Rodríguez G, et al., Dual-center study comparing transradial and transfemoral approaches for flow diversion treatment of intracranial aneurysms. Brain Circulation 7 (2021): 65-70.

119. Samancı C, Özköse B, Ustabaşıoğlu F, et al., The diagnostic value of superb microvascular imaging in prediction of uterine artery embolization treatment response in uterine leiomyomas. Journal of Ultrasound in Medicine 40 (2021): 2607-2615.

120. Wang C, Xia J, Wen-hua C, et al., Value of Dyna CT in guiding embolization during transarterial uterine artery embolization of fibroids. Experimental and Therapeutic Medicine, 20 (2020): 1353-1358.

121. Lee W, Kim M, Han K. Potential benefit of GnRH-agonist treatment before uterine artery embolization for large fibroids: MRI prediction of fibroid volume reduction. Acta Radiologica 63 (2021): 1425-1432.

122. Nocum D, Robinson J, Liang E, et al., The factors contributing to the total radiation exposure of patients during uterine artery embolisation. Journal of Medical Radiation Sciences, 66 (2019): 200-211.

123. Soliman K, Almutairi A, AlHarbi M. Analysis of factors affecting air kerma area product obtained during uterine artery embolization procedures using logistic regression. Indian Journal of Radiology and Imaging 31 (2021): 265-269.

124. Khan S, Saud S, Khan I, et al., Acquired uterine arteriovenous malformation following dilatation and curettage treated with bilateral uterine artery embolization: a case report. Cureus (2019).

125. Zhang G, Li J, Tang J, et al., Role of collateral embolization in addition to uterine artery embolization followed by hysteroscopic curettage for the management of cesarean scar pregnancy. BMC Pregnancy and Childbirth 19 (2019).

126. Shetty G, Kamath G, Srinivasan P. Transvaginal ultrasound-guided direct thrombin injection for the treatment of intramyometrial pseudoaneurysm in a young female with uterine hemorrhage after failed uterine artery embolization. Journal of Clinical Ultrasound. 49 (2020): 385-389.

127. Hirides P, Michalis K, Athanasios T, et al., Huge intravaginal pedunculated fibroid embolization and resectoscopy—a case report and review of literature. Surgical Science. 10 (2019): 222-228.

128. Mukherjee A, Bhattacharyya B, Chakrabarty R, Dakshit D. Uterine artery embolization: different indications and outcome. J Evid Based Med Healthc 6 (2019): 2198-2202.

129. Lubna, K. Uterine AV malformation and treatment-related fertility outcome. Medical Journal of Clinical Trials & Case Studies, 3 (2019).

130. Moynihan H, Richardson J, Loveridge K. Fertility-preserving management of uterine arteriovenous malformation in a 16-year-old female. Cureus (2021).

131. Dziadek O, Bhalwal A, Papanna R, et al., Cervical ectopic pregnancy. Obstetrics Gynecology and Reproductive Sciences, 5 (2021): 01-03.

132. Goyal, N., Agrawal, M., & Eleti, M. Expulsion of infarcted myoma following ultrasound-guided uterine artery embolization: A fertility-preserving approach. Cureus (2022).

133. Lin B, Zhang Y, Hu Y, et al., Retrospective analysis of the effect of lidocaine combined with methylprednisolone on pain control after uterine artery embolization. Frontiers in Surgery 9 (2022).

134. Javed A, Chander R, Hoodbhoy Z. Uterine Arteriovenous Malformations after Suction Evacuation of Missed Miscarriage. J Coll Physicians Surg Pak 28 (2018): S33-S34.

135. Ruiz-Labarta J, Recarte M, Leyte M. Uterine artery embolization of uterine arteriovenous malformation: A systematic review of success rate, complications, and posterior pregnancy outcomes. Journal of Personalized Medicine, 12 (2022): 1098.

136. Khayrutdinov E, Vorontsov I, Arablinski, A, (2021). A randomized comparison of transradial and transfemoral access in uterine artery embolization. Diagnostic and Interventional Radiology 27 (2021): 59-64.

137. Chen W, Zhang Z, Li, X. Delayed surgical and non-surgical treatment of placental remnants: No difference was found in the clinical efficacy and long-term

pregnancy outcomes. Therapeutics and Clinical Risk Management, 14 (2018): 1205-1212.

138. Babiker M. Uterine artery pseudoaneurysm: A case report. Journal of Diagnostic Medical Sonography, 36 (2020): 273-276.

139. Wang Y, Sun L, Si Y, Clinical efficacy analysis of different therapeutic methods in patients with cesarean scar pregnancy (2019).

140. DiGiacinto D, Bagley JE, Gildon B, Cantrell G. Postpartum Pseudoaneurysm After Cesarean Delivery. Journal of Diagnostic Medical Sonography. 2019;35(2):136-140.

141. Al–shami S, Mamun A, Ahmed E, et al., Artificial intelligent towards hotels' competitive advantage. An exploratory study from the UAE. Foresight, 24 (2021): 625-636

142. Khalil M, Prinsloo P, Slade S. In the nexus of integrity and surveillance: Proctoring (re)considered. Journal of Computer Assisted Learning, 38 (2022): 1589-1602.

143. Martin J, Hulsberg P, Soule E, et al., Welcome to the new era: A completely wireless interventional procedure. Cureus. (2018).

144. Gelany S, Mosbeh M, Ibrahim E, et al., Placenta accreta spectrum (PAS) disorders: Incidence, risk factors and outcomes of different management strategies in a tertiary referral hospital in Minia, Egypt: A prospective study. BMC Pregnancy and Childbirth, 19 (2019).

145. Elmokadem A, Abdel-Wahab R, El-Zayadi A, et al., Uterine artery embolization and methotrexate infusion as sole management for cesarean scar and cervical ectopic pregnancies: A single-center experience and literature review. Canadian Association of Radiologists Journal, 70 (2019): 307-316.

146. Jeon G, Kim,Y. Uterine artery embolization for postpartum hemorrhage with placenta accreta spectrum. Acta Radiologica 64 (2023): 2321-2326.