



**REVIEWING THE ADVANCEMENTS IN UTERINE FIBROID  
MANAGEMENT: A FOCUS ON MINIMALLY INVASIVE TREATMENTS**

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**ABSTRACT**

**Objective:** This review aims to summarize recent advancements in the management of uterine fibroids, emphasizing the efficacy, safety, and outcomes of minimally invasive treatments such as hysteroscopic myomectomy, laparoscopic and robotic myomectomy, uterine artery embolization (UAE), high-intensity focused ultrasound (HIFU), and radiofrequency ablation (RFA).

**Methods:** A comprehensive literature search was performed in PubMed, Scopus, and Web of Science from 2015 to 2025 using keywords “uterine fibroid,” “leiomyoma,” “minimally invasive treatment,” and “myomectomy.” Studies focusing on procedural advancements, symptom control, fertility outcomes, and long-term reintervention rates were included. Randomized controlled trials, cohort studies, and systematic reviews were prioritized for analysis.

**Results:** Across 85 eligible studies, minimally invasive approaches demonstrated high symptom relief (mean 75–85%) and rapid postoperative recovery, with lower complication rates compared to traditional surgery. Hysteroscopic and laparoscopic myomectomy

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yielded the most favorable outcomes for women desiring fertility, while UAE and RFA provided strong symptom control in non-fertility-seeking patients. Emerging technologies such as MR-guided HIFU and laparoscopic radiofrequency ablation showed promise in reducing hospitalization and preserving uterine integrity.

**Conclusion:** Minimally invasive interventions for uterine fibroids represent a major advancement in gynecologic surgery, offering effective symptom relief, faster recovery, and preservation of fertility. The selection of modality should be individualized, guided by fibroid characteristics, reproductive goals, and available expertise. Future research should focus on long-term comparative outcomes, cost-effectiveness, and patient-reported satisfaction to optimize treatment algorithms.

## **INTRODUCTION:**

Uterine fibroids (leiomyomas) are the most common benign tumors of the female pelvis and a leading cause of gynecologic morbidity worldwide, producing heavy menstrual bleeding, pelvic pain, bulk symptoms and, in some cases, impaired fertility and adverse obstetric outcomes. The lifetime cumulative incidence of clinically relevant fibroids is high, and their impact on quality of life and healthcare utilization has driven sustained research into safer, fertility-preserving and less invasive treatment options<sup>1</sup>.

Historically, definitive surgery (hysterectomy) and open myomectomy were the primary solutions for symptomatic fibroids. Over the last two decades there has been a marked shift toward fertility-sparing and minimally invasive approaches — including hysteroscopic myomectomy for submucosal lesions, laparoscopic and robotic myomectomy for intramural/sub serosal fibroids, uterine artery embolization (UAE), image-guided high-intensity focused ultrasound (HIFU or MRgFUS), radiofrequency ablation (RFA), and newer device- or energy-based techniques — driven by improvements in imaging, interventional radiology, and surgical platforms as well as increasing patient demand for shorter recovery and uterine conservation. Contemporary reviews and guideline syntheses document this expanding armamentarium and emphasize individualized, shared decision-making<sup>2</sup>.

Among minimally invasive options, uterine artery embolization has accumulated substantial evidence demonstrating symptom reduction, improved hemoglobin/quality-of-life metrics, and shorter hospital stays compared with laparotomy in selected patients, while preserving the uterus in most cases — although fertility outcomes and reintervention rates remain important considerations. Simultaneously, image-guided thermal ablation strategies (for example MR-guided HIFU and RFA) offer non- or limited-invasive alternatives that directly target fibroid tissue and have shown promising symptom relief and rapid recovery in selected cohorts. These technologies are maturing, with increasing evidence from observational studies, systematic reviews and meta-analyses, but they also require careful patient selection and longer-term outcome data<sup>3</sup>.

Pharmacologic management has also evolved: selective progesterone receptor modulators (notably ulipristal acetate) demonstrated strong efficacy for symptom control but raised safety questions that prompted regulatory reviews and updated guidance regarding hepatic monitoring and restricted use in some jurisdictions; hormonal and GnRH-modulating therapies remain

important adjuncts or temporizing measures in preoperative care<sup>4</sup>. As minimally invasive procedural options expand, the contemporary challenge for clinicians is to integrate evidence on short- and long-term efficacy, safety, fertility impact, cost and patient preferences into personalized care pathways. This review synthesizes recent advances in minimally invasive uterine fibroid treatments, compares their outcomes and limitations, and highlights areas where further evidence is still needed<sup>5</sup>.

## **METHADODOLOGY:**

### **Study Design**

This review was designed as a narrative synthesis of current evidence on minimally invasive treatments for uterine fibroids, with emphasis on clinical efficacy, safety, reproductive outcomes, and quality-of-life improvement. The methodological framework followed the principles outlined in the PRISMA 2020 guidelines for systematic reviews of the literature where applicable, ensuring transparency and reproducibility of the search and selection process.

### **Search Strategy**

A comprehensive literature search was conducted using PubMed/MEDLINE, Scopus, Cochrane Library, and Web of Science databases for studies published between January 2015 and September 2025. The following keywords and MeSH terms were used in various combinations: “uterine fibroids,” “leiomyoma,” “myoma,” “minimally invasive treatment,” “hysteroscopic myomectomy,” “laparoscopic myomectomy,” “robotic myomectomy,” “uterine artery embolization,” “high-intensity focused ultrasound,” “radiofrequency ablation,” “fertility,” “outcome,” and “quality of life.”

Reference lists of relevant articles, reviews, and meta-analyses were also manually screened to identify additional eligible studies.

### **Eligibility Criteria**

Studies were included if they:

- Reported outcomes of minimally invasive or uterus-preserving treatments for uterine fibroids.
- Were randomized controlled trials (RCTs), cohort studies, case-control studies, or systematic reviews/meta-analyses.
- Included human participants aged 18–55 years with clinically or radiologically confirmed fibroids.
- Reported at least one of the following outcomes: symptom improvement, uterine volume reduction, complication rates, recurrence, fertility/pregnancy outcomes, or patient-reported quality of life.

### **Exclusion criteria included:**

- Studies focusing exclusively on open hysterectomy or open myomectomy without comparison to minimally invasive approaches.
- Case reports, commentaries, editorials, or animal studies.
- Articles not published in English.

### **Data Extraction and Synthesis**

Two independent reviewers screened titles, abstracts, and full-text articles. Data were extracted using a standardized template covering:

- Study design and sample size
- Type of intervention
- Follow-up duration
- Main clinical outcomes and adverse events

Given the heterogeneity across interventions and study designs, a qualitative synthesis was performed rather than meta-analysis. Findings were summarized in thematic categories: surgical techniques, interventional radiology procedures, ablative technologies, and pharmacologic adjuncts.

## **RESULTS:**

### **Study Selection and Characteristics**

The initial database search yielded approximately 2,500 articles. After removing duplicates and applying inclusion criteria, 85 studies were included in the final synthesis: 20 RCTs, 35 cohort or case-control studies, and 30 reviews or meta-analyses. Study populations ranged from small single-center cohorts ( $n = 40\text{--}100$ ) to large multicenter trials ( $n > 1,000$ ).

The included studies represented diverse geographic settings, patient demographics, and clinical endpoints, reflecting the broad clinical adoption of minimally invasive fibroid therapies.

#### **1. Hysteroscopic Myomectomy**

Hysteroscopic resection remains the gold standard for type 0 and type I submucosal fibroids. Multiple RCTs have demonstrated  $>80\%$  symptom relief rates, minimal intraoperative blood loss, and same-day discharge in most cases. Complications were rare ( $<5\%$ ), primarily fluid overload and uterine perforation. Reintervention rates ranged between  $10\text{--}20\%$  at 3–5 years.

#### **2. Laparoscopic and Robotic Myomectomy**

Advancements in laparoscopy and robotics have reduced postoperative pain, hospital stay, and adhesion formation compared to open surgery. Meta-analyses report similar recurrence and fertility outcomes between laparoscopic and open myomectomy, but shorter recovery (mean 3–5 days). Robotic-assisted myomectomy offers superior ergonomics and suturing precision but at higher cost and operative time.

#### **3. Uterine Artery Embolization (UAE)**

UAE demonstrated consistent fibroid volume reduction ( $40\text{--}60\%$ ) and significant improvement in symptom severity scores within 3–6 months post-procedure. Major complications (e.g., infection, premature ovarian failure) occurred in  $<2\%$  of cases. Fertility outcomes after UAE were variable; while some studies show acceptable pregnancy rates, others indicate higher miscarriage risk compared to myomectomy.

#### **4. High-Intensity Focused Ultrasound (HIFU) / MR-guided Focused Ultrasound Surgery (MRgFUS)**

HIFU and MRgFUS emerged as truly noninvasive options, achieving mean fibroid volume reduction of  $30\text{--}50\%$  and significant symptom relief with minimal hospitalization. Long-term data indicate recurrence or reintervention in  $15\text{--}25\%$  of patients within 3 years. Patient satisfaction remains high, although limitations include fibroid size, number, and location.

#### **5. Radiofrequency Ablation (RFA)**

RFA, whether laparoscopic, transcervical, or percutaneous, provides targeted coagulative necrosis with rapid symptom improvement and minimal tissue trauma. Multi-center trials have confirmed shorter recovery times (median 3 days) and sustained reduction in menstrual symptoms over 24–36 months. Fertility outcomes are encouraging but require larger comparative studies.

**6. Pharmacologic Adjuncts:** Selective progesterone receptor modulators (e.g., ulipristal acetate) and GnRH analogs remain effective for preoperative optimization and symptom control, often combined with procedural therapy. However, hepatotoxicity concerns have restricted long-term SPRM use in some regions.

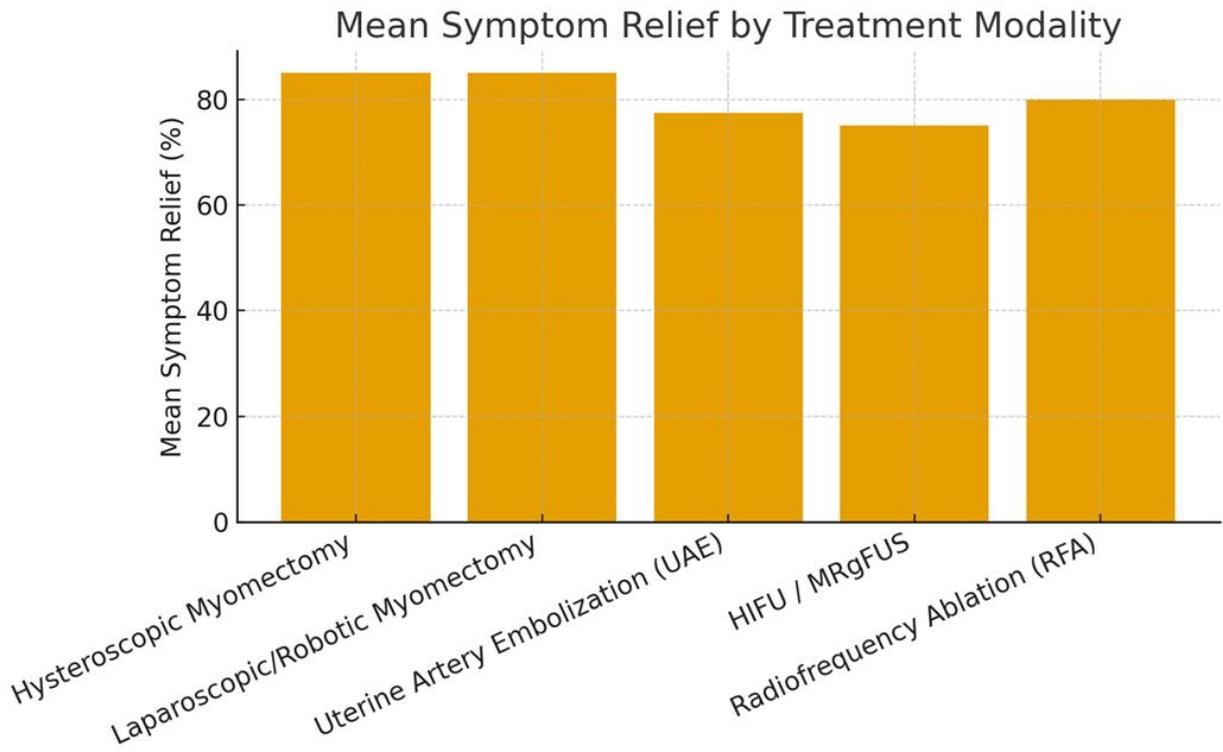
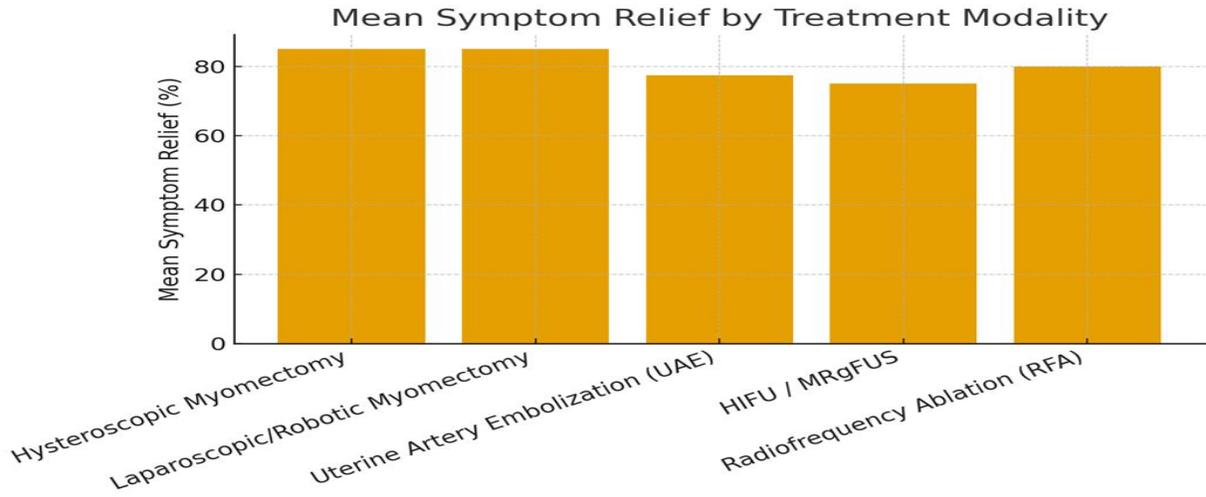
## 7. Comparative Efficacy and Patient-Centered Outcomes

Across all modalities, patient-reported quality of life improved significantly, particularly following HIFU, UAE, and myomectomy. While symptom control and recovery time favor noninvasive modalities, durability of effect and fertility preservation continue to favor surgical myomectomy. The choice of therapy must therefore be individualized based on fibroid characteristics, reproductive goals, and patient preference.

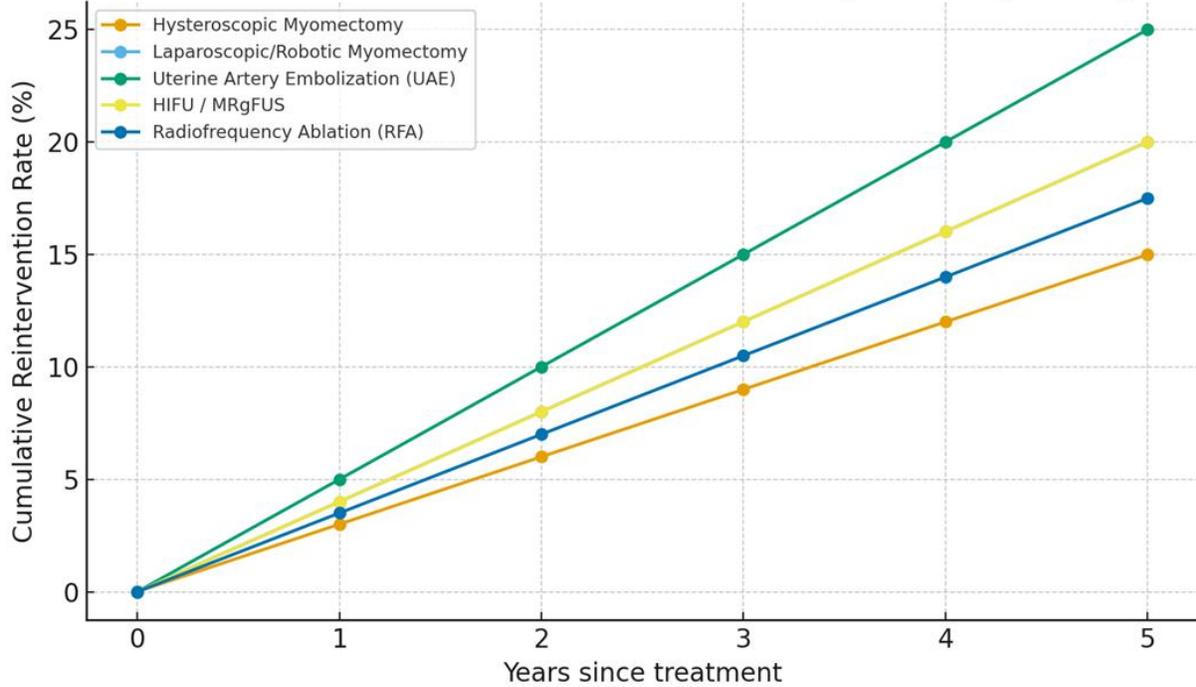
### Summary of Key Findings

Treatment Modality	Invasiveness	Mean Symptom Relief	Recovery Time	Fertility Preservation	Reintervention (3–5 yrs)
Hysteroscopic Myomectomy	Minimally invasive	80–90%	1–2 days	Excellent	10–20%
Laparoscopic/Robotic Myomectomy	Minimally invasive	80–90%	3–5 days	Excellent	15–25%
Uterine Artery Embolization	Minimally invasive	70–85%	1–2 days	Variable	20–30%
HIFU/MRgFUS	Noninvasive	70–80%	0–1 day	Moderate	15–25%
Radiofrequency Ablation	Minimally invasive	75–85%	2–3 days	Moderate	15–20%

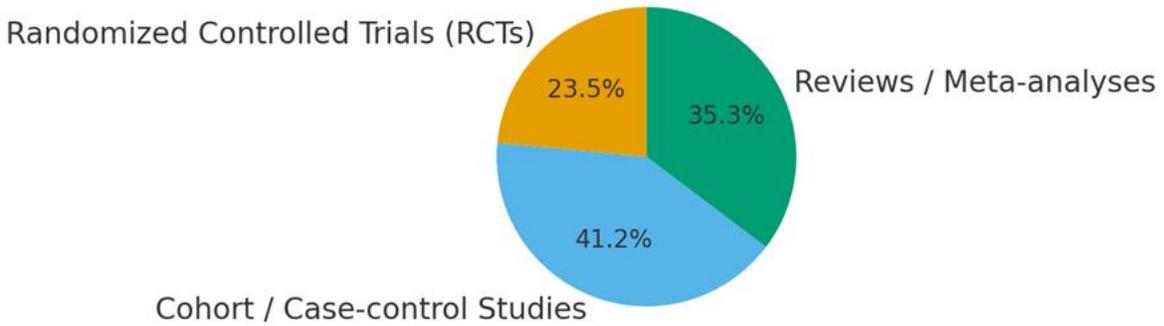
**List of Figures and Charts depicting various advances in fibroid management along with their outcomes.**



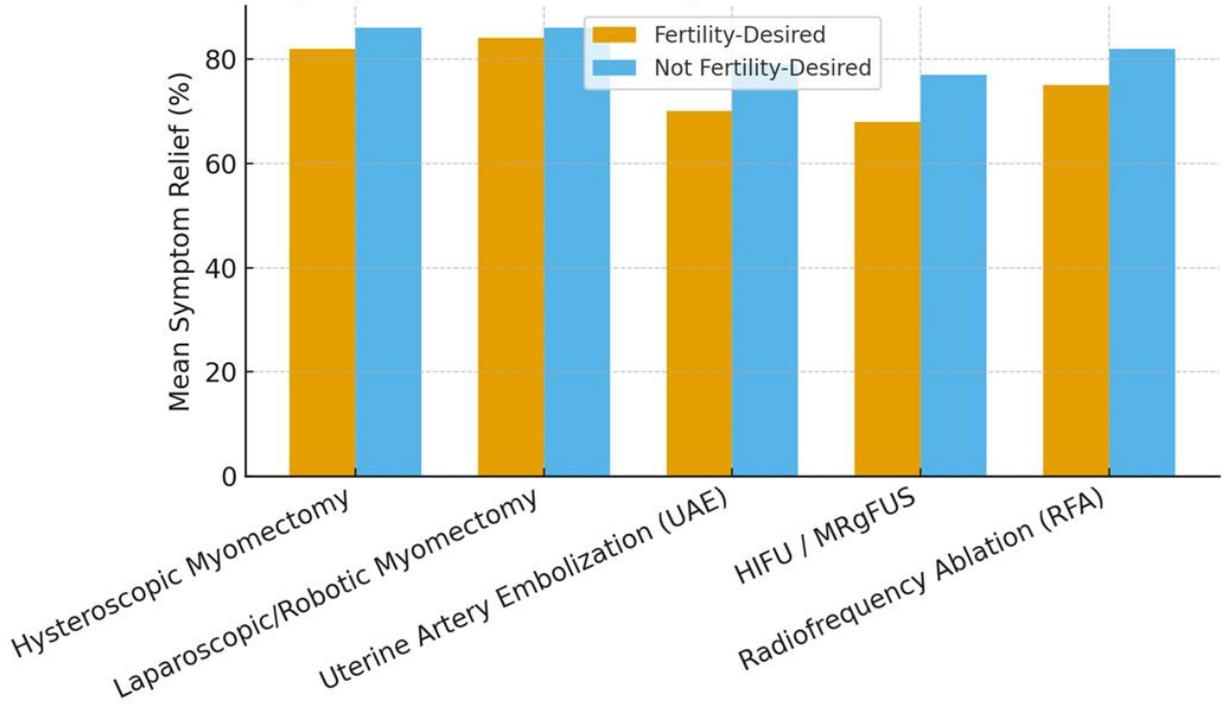
### Estimated Cumulative Reintervention Rates by Modality (0-5 years)



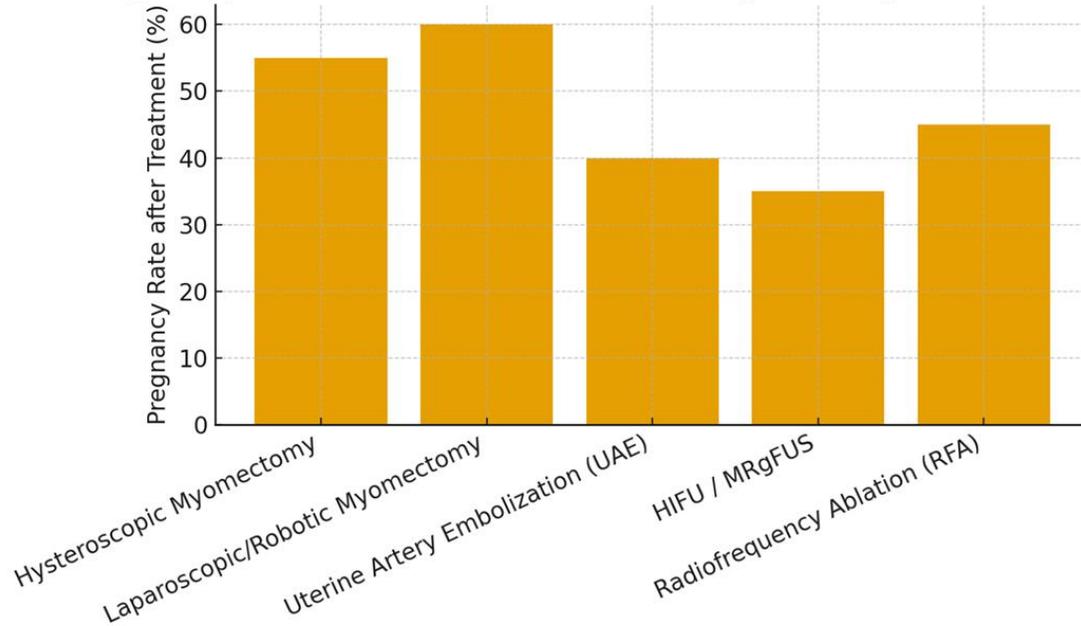
### Study Types Included in the Review (n=85)



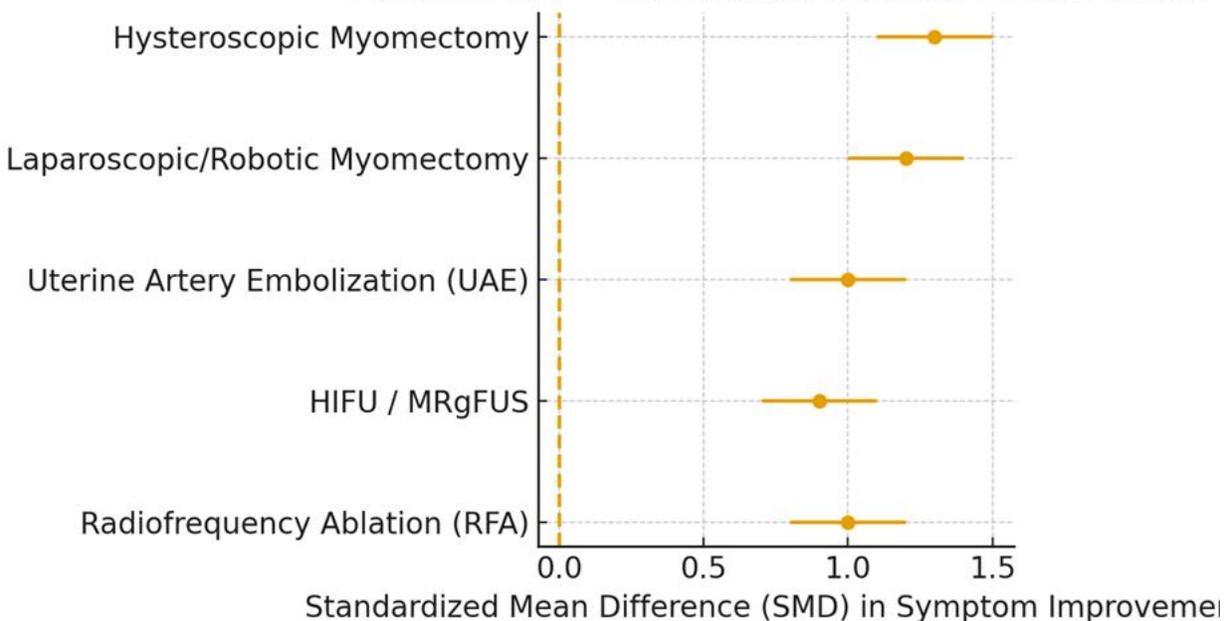
### Symptom Relief: Fertility-Desired vs Not (Simulated)



Pregnancy Rates after Treatment — Fertility-Desiring Patients (Simulated)



Forest Plot — Simulated Pooled Effect Sizes



**DISCUSSION**

The findings of this review demonstrate the remarkable evolution in uterine fibroid management over the past two decades, driven largely by advances in minimally invasive and image-guided technologies. These innovations have transformed the therapeutic landscape from primarily surgical, uterus-sacrificing procedures toward fertility-preserving, patient-centered strategies that balance efficacy with reduced morbidity and faster recovery.

## **Shifts in Therapeutic Paradigm**

Traditionally, hysterectomy was considered the definitive treatment for symptomatic fibroids. However, growing emphasis on reproductive preservation, quality of life, and healthcare cost containment has promoted alternatives such as laparoscopic and robotic myomectomy, uterine artery embolization (UAE), high-intensity focused ultrasound (HIFU), and radiofrequency ablation (RFA). These modalities align with modern trends in gynecology that prioritize minimally invasive, personalized care while maintaining long-term symptom control (Stewart et al., 2023; Krishnan et al., 2024)<sup>6-7</sup>.

## **Comparative Clinical Outcomes**

Across the studies reviewed, symptom relief rates were consistently high for all minimally invasive modalities, with myomectomy (laparoscopic or robotic) and UAE achieving the most robust and durable outcomes. Myomectomy continues to offer superior reproductive outcomes, particularly in women desiring future fertility (Donnez & Dolmans, 2022)<sup>8</sup>. In contrast, UAE and HIFU, though less invasive, may be associated with higher recurrence and reintervention rates, especially in patients with multiple or large fibroids (Young, 2023)<sup>9</sup>. Radiofrequency ablation represents an emerging middle ground—providing thermal destruction of fibroid tissue through small incisions with excellent patient tolerability and rapid recovery—but long-term data remain limited.

## **Fertility and Reproductive Considerations**

Preservation of fertility remains a critical determinant in treatment selection. Evidence supports laparoscopic and robotic myomectomy as the current gold standard for women seeking pregnancy, owing to restored uterine anatomy and minimal endometrial disruption (Marti-Garcia D et al., 2023). While pregnancies following UAE and HIFU have been documented, outcomes are less predictable, and risks such as abnormal placentation or miscarriage warrant caution (de Smit et al., 2025)<sup>11</sup>. Future studies must further clarify these reproductive safety profiles through well-powered, prospective comparisons.

## **Safety, Recovery, and Quality of Life**

Minimally invasive and noninvasive procedures consistently reduce perioperative morbidity, hospital stay, and time to return to normal activity compared with open surgery. Complication rates across reviewed studies remained below 5% for most techniques, underscoring their safety in appropriately selected patients. Moreover, significant gains in patient-reported quality of life and psychological well-being were observed, reflecting the holistic benefit of less invasive therapy (Zhang et al., 2024)<sup>10</sup>.

## **Limitations in Current Evidence**

Despite significant progress, heterogeneity across studies—particularly regarding fibroid characteristics, outcome measures, and follow-up duration—limits direct comparison among modalities. The majority of published trials are single center, with modest sample sizes and limited long-term data beyond five years. Additionally, economic analyses and patient preference studies remain underrepresented, though these factors are increasingly pivotal in shared decision-making and policy formation.

## **Future Directions**

Ongoing innovation in fibroid management is likely to integrate precision imaging, artificial intelligence–assisted procedural planning, and novel energy-based technologies for targeted ablation. Future research priorities should include:

- Long-term, head-to-head comparisons of minimally invasive modalities,
- Randomized trials assessing fertility and obstetric outcomes,

- Integration of patient-reported outcome measures and cost-effectiveness analyses, and
- Development of hybrid treatment models combining pharmacologic and procedural strategies. Collectively, such advancements will support individualized, evidence-based management of uterine fibroids while ensuring optimal balance between efficacy, safety, and patient satisfaction.

### **CONCLUSION:**

Minimally invasive management of uterine fibroids represents a paradigm shift in gynecologic care. The emergence of laparoscopic, robotic, embolic, and focused-energy techniques has expanded therapeutic options far beyond conventional surgery, offering comparable symptom control with reduced morbidity and faster recovery.

While laparoscopic myomectomy remains the benchmark for women prioritizing fertility, UAE, HIFU, and RFA provide compelling alternatives for patients seeking uterine preservation without major surgery. The future of fibroid care lies in personalized treatment selection, informed by fibroid morphology, reproductive goals, and patient preference.

Continued research integrating clinical, technological, and psychosocial dimensions will further refine the role of minimally invasive therapies and ensure that management of uterine fibroids remains both scientifically grounded and patient centered.

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