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Advancements in Uterine Fibroid Management: Current Trends and Future Directions

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ABSTRACT

Uterine fibroids can disrupt daily life. Some women have heavy periods more than expected, and others feel constant lower abdominal pain. Many also face frustration when trying to conceive. Years ago, surgery was usually the first and often only option. But now - thanks to new advances - women have alternatives, choices that are less invasive and frequently easier to manage. Managing fibroids can involve several approaches. One that has gained attention is magnetic resonance imaging–high-intensity focused ultrasound (MR-HIFU). This procedure is (gentle and non-surgical), using advanced imaging together with concentrated ultrasound energy to concentrate directly on fibroid tissue and gradually shrink it. One treatment option is using oral GnRH antagonists together with hormone therapy (to help balance natural hormones). These medicines can make periods lighter and may help the fibroids get smaller. What makes them especially valuable is that they avoid the issue of bone loss - something that was common with (previous generations of treatment). For some women, however, the earliest steps - whether drug therapy or non-invasive methods - do not fully resolve symptoms. When that happens, the next stage may involve minimally invasive surgery. Approaches such as laparoscopic and robotic techniques are delicate in method, highly controlled, and more exact, offering meaningful advantages, especially for women who wish to protect their fertility and maintain future options.

Keywords: Uterine fibroids, leiomyoma, GnRH antagonists, relugolix, high-intensity focused ultrasound (HIFU)

1. INTRODUCTION

Most women (about 70–80%) develop uterine fibroids by age 50 (Baird et al., 2003). They are usually harmless but can still affect daily life (sometimes in noticeable ways). Many women have heavy or long periods, feel discomfort in the pelvis, and sometimes face difficulties with getting pregnant (Harding et al., 2008). Treating fibroids can be challenging, especially for women who wish to preserve their fertility. Treatment plans are tailored to each individual and take into account the size, number, and location of the fibroids (Pritts et al., 2009). For many years, surgical procedures were the mainstay of treatment - either removing the fibroids (myomectomy) or the entire uterus (hysterectomy). While these methods are

effective in relieving symptoms, they are invasive and, in the case of hysterectomy, result in permanent loss of fertility (Guo & Segars, 2012; Pritts et al., 2009).

Over time, the ways doctors treat fibroids have evolved a lot, and now they focus on preserving the uterus while providing care that truly adapts to each woman's situation (Al-Hendy et al., 2021). One of the most critical steps forward has been oral GnRH antagonists combined with add-back therapy (a small hormone dose to reduce unwanted side effects). These medications can help control heavy bleeding and shrink fibroids, and they do this without the bone loss associated with older treatments (Al-Hendy et al., 2021). Another treatment that is becoming more widely discussed is MR-HIFU, or high-intensity focused ultrasound guided by MRI. That (gentle, precise procedure) lets doctors target the fibroids directly, without cuts or incisions. Recovery is faster, but the treatment can be expensive and isn't available everywhere, so many women cannot access it (Anneveldt et al., 2021; Verpalen et al., 2019). Doctors increasingly use tools like artificial intelligence, radiomics, and advanced imaging to guide treatment decisions. Care is slowly becoming more individualized, focusing on each woman (and what works best for her situation). Over time, these advances are helping not only to treat fibroids but also to make daily life easier for women (reducing discomfort and improving overall quality of life) (Tinelli et al., 2025; Wen et al., 2024).

This review aims to summarize the latest developments in the treatment of uterine fibroids - from pharmacological and non-invasive methods to modern surgical approaches - while addressing current challenges and future opportunities, focusing on fertility preservation and improving patients' quality of life.

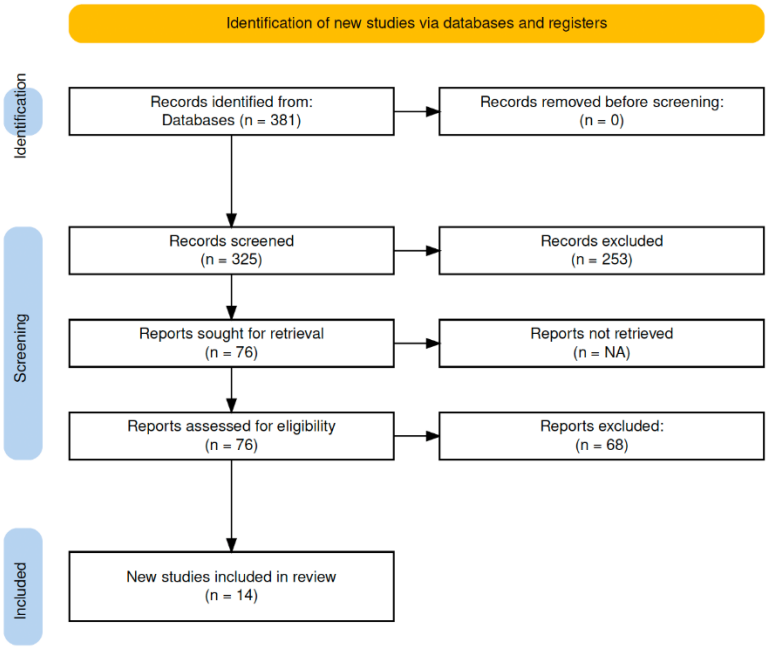

Figure 1 PRISMA Chart

2. REVIEW METHODS

We performed a structured literature review across databases like Scopus, Web of Science, Cochrane Library, and PubMed, including studies published from January 2015 to June 2025. Search terms included "uterine fibroids," "leiomyoma," "GnRH antagonists," "HIFU," and "radiomics". We included only human studies published in English that were peer-reviewed and explicitly focused on fibroid treatment. We excluded case reports, non-peer-reviewed work, and studies on malignant tumors.

The screening process followed the PRISMA guidelines (Figure 1). Our goal was not just to gather the most technical studies, but those that were the most relevant and impactful. To ensure we captured all appropriate studies, we also checked the reference lists of key articles (looking for any research that database searches might have missed). We focused particularly on papers that were widely cited or (frequently) highlighted in other authoritative reviews.

3. RESULTS & DISCUSSION

Pharmacological Treatment

In recent years, oral GnRH antagonists - particularly when combined with estradiol and norethisterone acetate (so-called add-back therapy) – have significantly transformed the conservative treatment of uterine fibroids. The results from clinical trials (LIBERTY 1 and 2) have been auspicious. In fact, over 70% of patients (specifically 73.4% in LIBERTY 1) saw at least a 50% reduction in heavy menstrual bleeding after only 24 weeks of treatment. That's a significant improvement for many women, a real relief from symptoms that can be (painful, exhausting, and disruptive) to daily life (Al-Hendy et al., 2021). Importantly, this therapy does not cause bone mineral density loss (T-scores stayed within the normal range even after 12 months), a significant drawback of older treatments using GnRH agonists. Long-term studies, like LIBERTY EXTEND, are now underway to look at the safety and effectiveness of continuing treatment for more than two years, including its impact on (quality of life, daily well-being, and the risk of fibroid recurrence).

Non-Invasive and Minimally Invasive Methods

More and more women are looking at MR-HIFU (Magnetic Resonance-guided High-Intensity Focused Ultrasound) to treat fibroids without surgery. The method uses focused ultrasound waves guided by MRI to heat and shrink fibroid tissue. Doctors can target the fibroids directly, without cutting or making incisions. It is a (gentle, careful, minimally invasive) option, giving women more choices when deciding how to manage their fibroids. Studies across multiple centers show that MR-HIFU can shrink fibroids by about 30–40%, and many women notice improvements in quality of life that last for months, sometimes up to a year (Verpalen et al., 2019). Still, there are limits. The procedure needs special equipment, like the ExAblate 2100 system, trained staff, and suitable patient anatomy. For example, fibroids cannot be too deep or close to the sacrum. Each session can also take a long time - usually three to four hours (Tonguc et al., 2022). Despite these challenges, MR-HIFU offers a [targeted, precise, non-surgical] way for women to treat fibroids, helping them avoid traditional surgery while improving daily life.

Radiomics and Artificial Intelligence

The development of advanced imaging and medical data analysis has led to growing interest in using radiomics and artificial intelligence (AI) in planning fibroid treatment. Recent studies suggest that a detailed analysis of MRI images can help doctors predict how well a patient might respond to HIFU, particularly by looking at the fibroid's non-perfused volume ratio (NPVR). AI is becoming an essential part of fibroid care, helping doctors in ways that were not possible before. Predictive models using T2-weighted images show encouraging results, with area under the curve (AUC) values over 0.85—one model even reached 0.879 - showing their potential usefulness in real-world clinical practice. But AI is not limited to predictions. It is also used for (mapping fibroid tissue automatically on T1- and T2-weighted scans), planning treatments like determining the correct energy dose for MR-HIFU, and even estimating the risk of fibroid recurrence. AI is helping make the treatment process smoother, more precise, and less dependent on the experience of a single doctor. Gradually, it supports care that is (careful, consistent, and reliable), giving patients outcomes that are more predictable and a treatment journey that is easier to follow (and simpler to manage) (Li et al., 2023; Wen et al., 2024; Zhou et al., 2023).

Surgical Innovations

These days, a lot of women are choosing minimally invasive surgery - things like laparoscopy or robotic procedures. It just makes recovery easier. Smoother. Gentler. Getting back to everyday life sooner is a big deal for many women. These surgeries often give (faster healing, fewer complications, and a gentler recovery). Laparoscopy usually takes about three days to bounce back from. Open surgery? Five to seven. The difference is noticeable. Minimally invasive surgery is safer, easier to manage, and in many cases (more patient-friendly) (Chen et al., 2024). Robotic systems, such as the da Vinci Xi, take this further. The 3D HD imaging helps surgeons see clearly and reach fibroids that are deep or difficult to remove safely. And yet, it's not just about precision - this approach can also be constructive for women who want to have children later. Studies have found (positive, encouraging) results after robotic myomectomy. Lots of women get pregnant naturally within six to twelve months, and there's no extra risk of uterine rupture. Altogether, it shows that minimally invasive surgery can treat fibroids effectively while protecting fertility, supporting reproductive health, and helping women plan their families (Sinha et al., 2024). Table 1 shows a comparison of different treatment options.

Table 1. Overview of treatment options for uterine fibroids: description, advantages, limitations, and outcomes.

Treatment	Description	Advantages	Limitations	Outcomes
Oral GnRH Antagonists + Add-back	medication reducing bleeding and fibroid size.	Effective; no bone loss.	Long-term safety under study.	More than 70% of patients experienced at least a 50% reduction in bleeding.
MR-HIFU	MRI-guided focused ultrasound destroying fibroids.	Non-invasive; quick recovery.	Expensive; lengthy procedure.	30–40% fibroid volume reduction
AI and Radiomics	Imaging and AI to predict treatment response,	Personalized; improves planning,	Needs advanced tools,	High accuracy in predicting treatment.
Minimally Invasive Surgery	Laparoscopic or robotic fibroid removal	Faster recovery; fertility-friendly	Surgical risks	Short hospital stay; good reproductive outcomes

Clinical Implications and Future Directions

Fibroid treatment has improved dramatically in the past few years. Doctors now use newer medications, better imaging, and less invasive surgeries to help women recover faster [and at the same time keep the uterus intact and lower risks]. This approach allows many women to get back to everyday life sooner. But what about MR-HIFU? Not everyone can do it. It can be expensive. Insurance often won't cover it. And you need (trained staff and special equipment) to make it work safely (Anneveldt et al., 2021; Verpalen et al., 2019).

Even though GnRH antagonists, like relugolix, work well in the short term, there are still concerns about their long-term effects on bone health, the chance of fibroids coming back, and overall quality of life (Al-Hendy et al., 2021).

AI and radiomics are starting to help a lot. They look promising, especially for (figuring out how well MR-HIFU will work and assisting doctors in planning treatments). But in real life, they're still not used that much. Doctors need more experience. They need more studies. For many women, these tools are not yet available (Wen et al., 2024).

4. CONCLUSION

Fibroid treatment has undergone significant changes, yet it hasn't solved every problem. There are now more (patient-focused, individualized, tailored) options. Drugs used to be the main thing, but they didn't cover everything - fertility, keeping the uterus, and quality of life. Now, women have more ways to avoid hysterectomy, more options, and more control. For many women, that really makes a difference. Oral GnRH antagonists, such as relugolix, when combined with (hormonal add-back therapy), can reduce fibroid size and bleeding simultaneously. They also avoid many of the side effects that older drugs commonly cause. Another option is MR-HIFU - magnetic resonance-guided high-intensity focused ultrasound - a (non-invasive, non-drug treatment) that uses precise imaging to target fibroids. Recovery is generally fast. Still, not everyone can get this treatment. It can be expensive, and access is limited.

Artificial intelligence and radiomics are revolutionizing the way fibroid care is delivered. They can significantly help doctors better diagnose, pick the right patients, and plan treatments more carefully. And yet, these tools still need more testing. They also need to be brought slowly into regular clinical practice. Surgery is still essential. Minimally invasive options, like (mainly laparoscopic or robot-assisted myomectomy), often let patients recover faster. For many women, maintaining fertility is a significant benefit of these approaches. Fibroid treatment has come a long way, yet there are still challenges. Things like (unequal access, limited long-term safety data, and getting treatments into everyday care) are still issues. Slowly, things are getting better step by step. Over time, for many women, these improvements can make a significant difference in their everyday lives.

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Conflict of interest

The authors declare that they have no conflicts of interests, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Data and materials availability

All data associated with this study will be available based on the reasonable request to corresponding author.

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