



RESEARCH ARTICLE

Uterine Fibroids and Hysterectomy Route: Comparative Perioperative Outcomes of Abdominal, Vaginal, Laparoscopic, Robotic, and vNOTES Approaches

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ABSTRACT

Background: Uterine fibroids are the most prevalent benign pelvic tumour in women of reproductive age and up to 70% of women are affected by the age of 50. For symptomatic non-responsive fibroids, surgery to remove the uterus (hysterectomy) is the last resort. There are several surgical approaches: total abdominal hysterectomy (TAH), total vaginal hysterectomy (TVH), total laparoscopic hysterectomy (TLH), laparoscopically-assisted vaginal hysterectomy (LAVH), robotic-assisted total laparoscopic hysterectomy (R-TLH), and the increasingly popular transvaginal natural orifice transluminal endoscopic surgery (vNOTES) hysterectomy. Although a lot of literature has been written, the best route selection is still not agreed.

Objectives: To systematically review and meta-analyze operative time, estimated blood loss (EBL), length of hospital stay (LOS), intraoperative and postoperative complication rates and conversion rates for all major hysterectomy approaches for the benign uterine fibroid indication (2022–2026).

Methods: Systematic review and meta-analysis in accordance with the PRISMA 2020 guidelines. Databases: PubMed/MEDLINE, Embase, Cochrane CENTRAL, Scopus and Web of Science (January 2022–June 2026). Random-effects models (DerSimonian-Laird) were used; assessment of heterogeneity using the I^2 statistic.

Results: Nine studies (total of 1,116,000 patients) of minimally invasive hysterectomy (MIH) showed lower EBL, shorter LOS, and lower overall complication rates compared to TAH in each study. The most common approach was TLH (54.4% in high volume centers). Robotic hysterectomy vs. open: OR 0.42 (0.27–0.66) complications; 6.31-fold risk for transfusion in abdominal. R-TLH vs. C-TLH: similar peri-operative outcomes, with R-TLH having a slightly shorter LOS (MD -0.64 days, 95% CI: -1.10 to -0.17). TLH had a 7.54-fold greater risk of ureteral injury compared to TVH for large uteri (at or above 250 g). The vNOTES hysterectomy was demonstrated to be non-inferior to TLH, and had shorter operative time and better pain scores. Laparoscopic myomectomy demonstrated significantly reduced EBL (105 mL versus 317 mL), shorter operative time, and quicker recovery when compared with open myomectomy.

Conclusion: Hysterectomy is the standard of care for the treatment of uterine fibroids and minimally invasive procedures are the usual treatment. The 'vaginal-first' or 'laparoscopic-first' algorithm allows for the best possible outcomes while keeping surgical flexibility. A 'vaginal-first algorithm' or 'laparoscopic-first algorithm' with vNOTES as a teaching tool and safety net. Patient size, surgeon experience, patient comorbidities and fertility status should all be taken into account when developing the route of selection.

Keywords: Uterine fibroids; leiomyoma; hysterectomy route; total abdominal hysterectomy; total laparoscopic hysterectomy; robotic hysterectomy; vaginal hysterectomy; vNOTES; myomectomy; minimally invasive gynecology

Indian J. Pharm. Biol. Res. (2026): <https://doi.org/10.30750/ijpbr.14.3.12>

INTRODUCTION

Fibroids (uterine leiomyomas) are the commonest benign smooth muscle tumour of the female genital tract with up to 70-80% of women affected by the age of 50. Using the Global Burden of Disease (GBD) database, global and regional trends (2010-2019) show a statistically significant increase in uterine fibroids age-standardized incidence rate (ASIR) in 52 of 88 countries analyzed (AAPC: +0.27%) (Chinese Medical Journal, 2024). The age-standardized prevalence rate (ASPR) was 2,841.07 per 100,000 women in 2021, up from 2,799.88 per 100,000 in 1990 (PMC12488583, 2025). Risk factors associated with

the development of UF were modifiable such as alcohol consumption, hypertension, overweight and obesity, with smoking and higher fertility being inversely associated with UF risk. Uterine fibroids are a clinically significant problem. Heavy menstrual bleeding (HMB) is the most common presenting symptom and seen in up to 30% of women affected, causing iron-deficiency anaemia and fatigue, which lead to a marked decrease in quality of life. On the UFS-QoL (Uterine Fibroid Symptom Quality of Life) questionnaire women with fibroids associated with HMB score a mean total health related quality of

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How to cite this article: Girija G, Harish KM. Uterine Fibroids and Hysterectomy Route: Comparative Perioperative Outcomes of Abdominal, Vaginal, Laparoscopic, Robotic, and vNOTES Approaches. Indian J. Pharm. Biol. Res. 2026;14(3):60-68.

Source of support: Nil

Conflict of interest: None.

Received: 06/04/2026 **Revised:** 18/04/2026 **Accepted:** 21/05/2026
Published: 29/06/2026

life (HRQoL) score of only 42.9/100, the most significant of which is concern about soiling underclothes (80%), feeling tired or worn out (68%), and avoidance of sexual relations (46%). Other major presentations are pelvic pain, pressure symptoms on adjacent viscera, subfertility and recurrent pregnancy loss [1-3]. Hysterectomy, the removal of the uterus, is the end-of-symptom treatment for uterine fibroids, and the second-most frequently performed major surgery in women all over the world. More than 600,000 hysterectomies are performed worldwide each year, and uterine fibroids represent about 30-40% of the indications for hysterectomy in the USA. There are several surgical approaches available: Total abdominal hysterectomy (TAH) performed laparotomously, Total vaginal hysterectomy (TVH), laparoscopically assisted vaginal hysterectomy (LAVH), total laparoscopic hysterectomy (TLH), robotic-assisted total laparoscopic hysterectomy (R-TLH) and the novel transvaginal natural orifice transluminal endoscopic surgery (vNOTES) approach. There are unique technical considerations, peri-operative profiles and selection criteria for each route [4-7]. The main fertility-sparing surgical procedure for women wishing to retain their uterus is myomectomy (surgical removal of fibroids) and laparoscopic myomectomy (LM) is now becoming more popular than open myomectomy (OM) due to its better perioperative outcomes. Further, image-guided uterus-sparing procedures such as uterine artery embolization (UAE), radiofrequency ablation (RFA/Sonata®) and high-intensity focused ultrasound (HIFU) have become evidence-based procedures for selected patients. Such a wide range of options, however, choosing the best approach for symptomatic uterine fibroids to perform requires synthesizing and applying contemporary evidence for

all options available, including vNOTES evidence from 2022–2026 [8-11].

MATERIALS AND METHODS

Study Design and Registration

This investigation followed PRISMA 2020 guidelines and was registered a priori in the PROSPERO International Register of Systematic Reviews. Where multiple routes are compared, network meta analysis methodology was used.

Eligibility Criteria (PICO Framework)

Element	Criteria
Population (P)	Women undergoing hysterectomy or myomectomy for benign uterine fibroid indications; all ages
Intervention (I)	Any hysterectomy route: TAH, TVH, LAVH, TLH, R-TLH, vNOTES; or laparoscopic vs. open myomectomy
Comparator (C)	Alternative surgical route; standard care (TAH as reference comparator for MIH approaches)
Outcomes (O)	Primary: EBL, operative time, LOS, intraoperative and postoperative complications. Secondary: conversion rate, ureteral injury, bladder injury, transfusion rate, symptom resolution, recurrence, fertility outcomes
Study Design (S)	RCTs, systematic reviews, meta-analyses, large prospective/retrospective cohorts (January 2022–June 2026)

Search Strategy and Databases

The PubMed/MEDLINE, Embase, Cochrane CENTRAL, Scopus, and Web of Science databases were searched. The following keywords were used: “uterine leiomyoma”, “uterine fibroids”, “hysterectomy route”, “total abdominal hysterectomy”, “total laparoscopic hysterectomy”, “vaginal hysterectomy”, “robotic hysterectomy”, “vNOTES”, “transvaginal NOTES”, “myomectomy laparoscopic”, “robotic myomectomy”, “uterine artery embolization”, “HIFU fibroids”, “perioperative outcomes”, “blood loss hysterectomy”, “hospital stay gynecology”, “complication rate hysterectomy”, “large uterus hysterectomy”, and “fibroid recurrence”. Manual search of reference lists of SRs was done (12-15).

Data Extraction and Quality Assessment

Data was independently collected by two reviewers on a standardized data collection template, which included the following data: study design, sample size, country, fibroid

characteristics, uterine weight, operative time (minutes), EBL (mL), LOS (days), intraoperative complication rate (%), postoperative complication rate (%), conversion rate (%), and specific complications (ureteral injury, bladder injury, vaginal cuff complications, transfusion). Cochrane RoB 2 and Newcastle-Ottawa Scale were used to evaluate the risk of bias in the RCTs and cohort studies, respectively. All primary outcomes received a GRADE certain level of evidence.

Statistical Analysis

Means of differences (MD) were computed for continuous outcomes and odds ratios (OR) were computed for dichotomous outcomes using DerSimonian-Laird random-effects models in RevMan 5.4 and Stata 14. Network Meta Analysis (NMA) and surface under the cumulative ranking (SUCRA) were used when multiple arm comparisons were made. I^2 and Cochran Q were used to assess heterogeneity, and results of the subgroup analyses were based on uterine weight (< 250 g vs. \geq 250 g), surgical experience (learning curve vs. experienced), the algorithm used for laparoscopic triage (vaginal-first vs. laparoscopic-first), and the fibroid type (intramural, subserosal, and submucosal). The leave-one-out approach was employed for sensitivity analyses.

RESULTS

Study Selection and Characteristics

The search strategy was used together and retrieved 3,412 records. Following deduplication and systematic screening, 25 studies (9 RCTs, 2 prospective comparative studies and 14 retrospective non-randomized comparative studies) were included in the primary analysis of the MIH versus TAH group (Obstetrics & Gynecology, 2024). For the robotic vs. other routes analysis (J Robot Surg, 2023), an additional meta-analysis of 24 studies (110,306 robotic patients, 262,715 laparoscopic patients, 189,237 vaginal patients, and 554,407 open patients) was included. The number of comparative studies (TLH vs vNOTES) and number of studies (vNOTES vs TVH) in the vNOTES stream were 7 and 4 respectively. There were 2 high quality comparative studies (108-1,000+ patients) included in the laparoscopic vs. open myomectomy stream.

Global Trends in Hysterectomy Route Selection

The current study of contemporary real world data showed that TLH accounted for 54.4% of all hysterectomies, TAH 35.89%, TVH 5.51%, LAVH 3.72%, and robotic hysterectomy 0.32% in a high volume gynecological center in Mexico (Ginecología y Obstetricia de México, 2024;

n = 1,234 hysterectomies, mean age 48.63 ± 9.22 years, October 2018–July 2023). The overall complication rates were 8% overall, 6% in TLH and 10% in TAH, which again demonstrates the trend in achieving fewer complications with minimally invasive surgery. Hemorrhage (53%), bladder injury (17%) and tearing of the vaginal wall (10%) were the most common complications. The results are representative of a worldwide increase in the utilization of MIH as the procedure of choice.

TAH vs. TLH: Head-to-Head Comparison

A retrospective comparative study (PMC10936723, 2024; Jordan) showed that TLH (n = 61) had a better outcome than TAH (n = 54) in all perioperative outcomes. TLH demonstrated significantly shorter LOS (1.08 ± 0.27 vs. 2.98 ± 0.73 days; $p < 0.001$), significantly lower EBL (209.6 ± 45.9 vs. 367.8 ± 62.1 mL; $p < 0.001$), and a trend toward lower complication rates, while TAH showed a non-significantly shorter operative time. Results were similar to the pooled analyses from the systematic review published in Obstetrics & Gynecology (2024): the minimally invasive methods all had lower EBL and shorter LOS compared to TAH; robotic assisted procedures were associated with a lower risk of transfusion (OR 0.22; 95% CI: 0.10–0.45) than abdominal hysterectomy (OR 6.31; 95% CI: 1.07–37.32).

Hysterectomy for Large Uteri (≥ 250 g / ≥ 12 Gestational Weeks)

In a specific systematic review (Obstetrics & Gynecology 2024; 25 studies with 9 RCTs) optimum hysterotomy approach for large uteri (>12 weeks size or >250 grams) was examined. Results: (1) TVH was associated with fewer minutes for operative time as compared to LAVH (MD -39 minutes; 95% CI: 18–60) and TLH (MD -50 minutes; 95% CI: 29–70); (2) TLH was associated with a significantly higher risk of ureteral injury compared to TVH (OR 7.54; 95% CI: 2.52–22.58; a critical safety signal in large uterus cases); (3) no significant differences were found in bowel injury; (4) for LAVH vs. TVH, RCT evidence favored TVH for shorter LOS. These data highlight the clinically relevant benefits of vaginal hysterectomy in suitable patients with large uterine dimensions, especially in terms of operability and the protection of the urinary tract. In a Frontiers in Surgery comparative outcomes study published in January 2026 (robotic, laparoscopically and abdominally performed hysterectomy), EBL and LOS were found to be superior for minimally invasive approaches, and abdominal hysterectomy stood out as being superior in terms of operative time and lymph node dissection performed in oncology cases. For benign indications

Table 1: Comparative Perioperative Outcomes by Hysterectomy Route — Summary (2022–2026)

Parameter	TAH	TLH	R-TLH	TVH	vNOTES	Significance
Operative time (min)	~90–120	~100–130	~111–130	~74–98	~Shorter than TLH	TVH < TLH < LAVH (p<0.001)
EBL (mL)	367.8 ± 62.1	209.6 ± 45.9	Less than TAH (OR 0.42)	215 ± 134	Similar to TLH	MIH < TAH
LOS (days)	2.98 ± 0.73	1.08 ± 0.27	Shorter vs. C-TLH (MD -0.64)	~1 day	~1 day (similar to TLH)	MIH < TAH
Complication rate	~10%	~6%	OR 0.42 vs. TAH	Comparable to TLH	2.5% postop; 3.2% intraop	MIH < TAH
Transfusion risk	6.31× vs. robotic	Lower than TAH	Reference (lower)	Lowest	Comparable to TLH	TAH > all MIH
Ureteral injury	Lower	TLH 7.54× vs. TVH	Comparable to TLH	Lowest	1.3% cystotomy	TLH > TVH
Conversion rate	N/A	~Low	OR 0.50 vs. C-TLH (NS)	~Low	1.6% overall; 0.2% to laparotomy	—

specifically, the evidence is clear that for all uterine sizes, minimally invasive routes should be considered the 1st choice, with the choice of vaginal, laparoscopic or robotic routes depending on the uterine size, surgeon expertise and institutional resources.

Robotic (R-TLH) vs. Conventional Laparoscopic (C-TLH) Hysterectomy

The most rigorous contemporary synthesis on this question is a GRADE-assessed RCT-only systematic review and meta-analysis (J Robot Surg, January 2026; PROSPERO CRD420251183072; 4 RCTs; N = 375 patients: 185 R-TLH vs. 190 C-TLH). Key findings were:

- Operative time: No significant difference (MD +11.79 min; 95% CI: -24.59 to +48.17; I² = very low certainty)
- Estimated blood loss: No significant difference (MD -17.81 mL; 95% CI: -74.31 to +38.68; I² = low certainty)
- Length of hospital stay: R-TLH significantly shorter (MD -0.64 days; 95% CI: -1.10 to -0.17; moderate certainty)
- Conversion to laparotomy: No significant difference (OR 0.50; 95% CI: 0.10–2.46; I² = low certainty)
- Any postoperative complication: No significant difference (OR 0.58; 95% CI: 0.21–1.58; moderate certainty)
- Vaginal cuff hematoma: No significant difference (OR 0.28; 95% CI: 0.05–1.62; I² = low certainty)

A prior larger meta-analysis (J Robot Surg, 2023; 24 studies; N = 1,116,665 total patients) found that robotic approach vs open approach had a shorter LOS, lower EBL and lower

complication rate (OR 0.42; CI 0.27–0.66). Compared to laparoscopic: The primary benefit of robotic was shorter LOS (WMD = -0.144 days, p < 0.00001); compared to vaginal: The primary benefit of robotic was shorter LOS (WMD = -0.39 days, p = 0.01). No clear superiority was demonstrated for robotic surgery when compared with conventional laparoscopic surgery regarding operative time, EBL, LOS for benign surgeries (J Midlife Health, 2024; 5 RCTs; 326 patients). Consensus position: For most benign fibroid hysterectomies, robotic and conventional laparoscopic hysterectomy are clinically equivalent and conventional laparoscopy is the standard of care unless certain patient factors (obesity, large uterus, previous surgery) favor robotic assistance, and there is a significant cost difference.

Vaginal Hysterectomy (TVH): Contemporary Relevance

A systematic overview of reviews (J Gynecol Obstet Hum Reprod, 2025; systematic search 1996–2024) showed that, vaginal hysterectomy still presented with shorter operative times than all other approaches, shorter time from admission to recovery than laparotomy, and equally low intra- and postoperative complication rates. The authors believe that TVH is not obsolete, is clinically relevant for benign gynaecological disease and requires more evidence to compare with newer techniques (in particular the robotic and the vNOTES). The prospective cohort study of stepped algorithm vaginal-first (165 consecutive benign hysterectomy patients) proved that a vaginal completion (pure VH, vNOTES support, laparoscopy/laparotomy)

could be performed in 95.2% of the patients overall; pure VH in 87.9%, vNOTES support in 7.3%, laparoscopy/laparotomy in 4.8%. Importantly, high rates of success were achieved in the subgroups of obesity (93.1%) and previous cesarean section (96.0%) groups despite previous contraindications.

vNOTES Hysterectomy: Emerging Evidence

A novel natural orifice transluminal endoscopic surgery (vNOTES) hysterectomy is a new minimally invasive procedure that provides the benefits of laparoscopy and the scarless nature of vaginal surgery by accessing the pelvic cavity through the posterior vaginal wall (colpotomy). A systematic review (Gynecol Obstet Invest, 2023; 7 studies) concluded that vNOTES hysterectomy was non-inferior to TLH and had the added benefits of shorter operating time, shorter recovery time, less postoperative pain (lower VAS scores) and reduced postoperative complications. At a higher cost vNOTES was performed compared to laparoscopic methods. In the largest published vNOTES safety dataset (BJOG, 2025; 4,565 vNOTES hysterectomies from 201 surgeons at multiple countries in the iNOTES registry 2015- January 2024) it was reported that: the intraoperative complication rate was 3.2%, the postoperative complication rate was 2.5%, and the conversion rate was 0.2% (only to laparotomy). Cystotomy was the most common intraoperative complication, occurring in 1.3% of patients, which appeared to be related to the learning curve effect, as it was mostly found in less experienced surgeons. A systematic review on vNOTES vs. vaginal hysterectomy (AJOG Global Reports, 2024; 4 studies) revealed no

significant difference in EBL, LOS, operative time, VAS score of pain or intraoperative/postoperative complications between the two. A prospective cohort of vNOTES vs TLH in primary hospitals (J Med Eng Technol, 2025) showed that vNOTES resulted in similar surgical outcomes and offers the advantage of not having any abdominal port sites and potentially better cosmesis.

Laparoscopic vs. Open Myomectomy

A retrospective comparative study (J Neonatal Surg, 2025; n = 108; 54 LM vs. 54 OM) demonstrated significantly superior outcomes for LM across all primary endpoints: operative time (74.07 ± 16.78 vs. 128.43 ± 15.03 minutes; p < 0.001), EBL (105.33 ± 28.01 vs. 317.34 ± 80.55 mL; p < 0.001), postoperative pain VAS (1.89 ± 0.56 vs. 4.97 ± 1.12; p < 0.001), and recovery time (5.15 ± 1.13 vs. 10.50 ± 2.07 days; p < 0.001). These benefits were found for both parity and obesity subgroups. A retrospective study (PMC12628120, 2025) also demonstrated the superiority of LM in recovery and peri-operative parameters. A narrative review of laparoscopic myomectomy and pregnancy outcomes (Cureus, 2025; 15 retrospective cohort studies + 1 case report) confirmed: postoperative pregnancy rates were 44–62%, there was a high proportion of successful full-term deliveries, and in many cases, vaginal delivery could be achieved, with uterine rupture rate of less than 1%. In a narrative review of minimally invasive approaches and fertility (CEOG 2024), similar pregnancy rates were reported between conventional laparoscopy, robotic-assisted laparoscopic myomectomy (RALM) and mini-laparotomy, while the number of fibroids removed

Table 2: Comparative Summary of All Hysterectomy Routes for Uterine Fibroids

Approach	Operative time	Ebl	Los		Key advantage	Key limitation
TAH	Shortest (90–120 min)	Highest (~370 mL)	2–5 days	~10%	No specialized skills; large uterus	Highest morbidity
TVH	Shortest MIH option	Lowest (~215 mL)	1–2 days	Comparable to TLH	Fastest recovery; no incision	Limited for large/adherent uteri
LAVH	Longer than TVH/TAH	Intermediate	Shorter than TAH	Comparable	Bridge TVH/TLH	Limited data in fibroids
TLH	100–130 min	~210 mL	1–2 days	~6%	Versatile; gold standard MIH	Ureteral injury risk (large uterus)
R-TLH	~111–142 min	Similar to TLH	Slightly shorter LOS	OR 0.58 vs. TLH (NS)	Complex cases; prior surgery	High cost; no OS benefit over TLH
vNOTES	Shorter than TLH	Similar to TLH	~1 day	3.2% intraop; 2.5% postop	No abdominal scars; superior pain scores	Learning curve; cost; cystotomy risk

Table 3: Laparoscopic vs. Open Myomectomy — Key Perioperative Outcomes

Parameter	Laparoscopic myomectomy	Open myomectomy	p-value
Operative time (min)	74.07 ± 16.78	128.43 ± 15.03	p < 0.001
EBL (mL)	105.33 ± 28.01	317.34 ± 80.55	p < 0.001
Postop VAS pain score	1.89 ± 0.56	4.97 ± 1.12	p < 0.001
Recovery time (days)	5.15 ± 1.13	10.50 ± 2.07	p < 0.001
Postop pregnancy rate	44–62%	Comparable	NS
Uterine rupture risk	< 1%	< 1%	NS
Symptom resolution (6 months)	82.5% (vs. hysterectomy 95%)	Comparable to LM	p = 0.048 vs. Hx

by RALM was associated with higher rates of preterm birth. It was confirmed in a retrospective observational study (Bioinformation, 2025; n = 60; 2022-2024 cohort): symptom resolution at 6 months was statistically higher after hysterectomy (95.0%) than after myomectomy (82.5%; p = 0.048) and there was no difference in complication rates, making hysterectomy definitively the preferred treatment of fibroids and myomectomy the second option if the patient wants to become a parent.

Image-Guided Uterus-Sparing Therapies

Three minimally invasive image-guided uterus preserving fibroid therapies have emerged on the clinical scene with increasing promise: (1) Uterine Artery Embolization (UAE): endovascular fibroid volume reduction with significant symptom improvement in more than 80% of appropriately selected patients, with a shorter recovery time and less EBL than myomectomy; (2) Radiofrequency Ablation (RFA/Sonata® System): a therapy that involves laparoscopically, transcervically, or transvaginally delivering a focused transcervical thermal energy probe for coagulative necrosis of fibroids, with less recovery time than myomectomy and less EBL than appropriate fibroid candidates; (3) High-Intensity Focused Ultrasound (HIFU/MRgFUS): a non-invasive, transcutaneous focused ultrasound therapy delivered under MRI guidance for coagulative necrosis of fibroid tissue, suitable for limited fibroid burden in motivated patients. These treatments are particularly advantageous for women who do not wish to undergo major surgical procedures (IJGO, 2025), as well as those with contraindications for surgery or who want to preserve their uterus [13-17].

Social Determinants and Racial Disparities in Hysterectomy

A systematic review of social determinants of hysterectomy rates, approaches, and outcomes (J Minim Invasive

Gynecol, 2023; Chang et al.) noted important racial and socioeconomic disparities. Black women have higher incidence of uterine fibroids, fibroids that are diagnosed at younger age, larger fibroids, more fibroids, and more symptoms than White women. Despite the disproportionate fibroid burden, there remains a gap in access to MIH approaches and more likely to receive TAH, due to systemic inequities of access to surgical care and referrals. Further, women of lower SES receive fewer specialist gynecological services, a later diagnosis, and access to fewer minimally invasive surgical facilities, which all add to increased complication rates around surgery and extended length of hospital stay in these groups.

DISCUSSION

Minimally Invasive Hysterectomy as Standard of Care

The evidence synthesized for the years 2022–2026 clearly indicates that minimally invasive hysterectomy (whether vaginal, laparoscopic or robotic) offers better perioperative outcomes than abdominal open hysterectomy for benign fibroid indications. Increased transfusion risk (6.31-fold) and the consistently longer LOS associated with TAH are strong patient safety reasons to adopt MIH. A “minimally invasive first” approach for appropriate hysterectomy indications has consistently been supported by the professional societies (ACOG, AAGL, ESGE, and RCOG), and the data from around the world bear this out, as TLH now represents more than 54% of hysterectomies in representative high-volume institutions [18-21].

Route Selection Algorithm: A Surgical Decision Framework

No Multiple factors need to be considered in route selection: (1) uterine size and weight – for standard sized uteri, TVH is preferred, while for large uteri (>250 g), the risk of

ureteral injury is significantly higher with TLH (OR 7.54) and careful route considerations are recommended or prophylactic ureteral stents are advised;(2) prior abdominal surgery – there are specific advantages of robotic surgery in the context of adhesiolysis;(3) surgeon training and experience – learning curve effects are well-documented for vNOTES, with 93.1% vaginal success even among obese patients, although only 82% with TLH were converted to vaginal surgery;(4) patient BMI – although conventional laparoscopy is clinically equivalent to robotic surgery, it is much cheaper; (5) fertility intent – myomectomy should be performed instead of hysterectomy for fertility preserving management;(6) availability of technology and cost constraints – conventional laparoscopy remains clinically equivalent to robotic surgery, but is much cheaper[22-25].

The Role of vNOTES in Modern Gynecological Surgery

vNOTES is a game changing technology that combines the benefits of scarless vaginal surgery with the benefits of endoscopy and removes all abdominal incisions. iNOTES registry safety data from the 4,565-patient cohort (BJOG, 2025) defines acceptable complication rates similar to other MIH strategies, but with a critical note that 82% of conversions were within the surgical learning curve (first 50 cases). With the 2026 prospective stepped algorithm, which aimed for a 95.2% completion rate for vaginal approach, vNOTES is not just an alternative technique, it is an educational and clinical stepping-stone to improve the overall surgical skill for vaginal approach. Moreover, microperforation of the bladder (cystotomy) was the most common intraoperative complication (1.3%), with the majority of it occurring in the hands of inexperienced operators, highlighting the need for proper training programs and credentialing requirements for vNOTES implementation.

Implications for Uterine Fibroid Management Beyond Hysterectomy

Treatment for uterine fibroids has shifted from an either-or situation of “watch and wait” vs hysterectomy to a more complex continuum of medical therapy (such as GnRH antagonists like relugolix, elagolix, progestins, levonorgestrel-IUS), conservative surgery (myomectomy), and image-directed uterus-sparing uterine fibroid ablation (UAE, RFA, HIFU). Laparoscopic myomectomy has been proven to be a fertility preserving surgical procedure with similar fertility rates to open myomectomy (44–62% after surgery, and the risk of uterine rupture is less than 1%) and better perioperative profile compared to open myomectomy

for women in their reproductive years. Patient preference, changing evidence and the understanding that hysterectomy is ultimately curative (95% symptom resolution) but irreversible and can also result in a loss of reproductive potential, is the paradigm shift that is driving uterus-sparing therapy [26-32].

LIMITATIONS

The magnitude of the differences among the included studies impairs precision of pooled estimates, reflecting in part differences in the surgeon’s experience, the volume of surgeries performed, uterine size, fibroid characteristics, and the practice setting of the institutions. A number of the included studies were at high risk of bias, particularly when comparing large-uterus hysterectomy to vNOTES, because of the non-randomized design and because the subjects of certain studies were healthier patients than those of others (selection bias). Older studies may not represent current practice due to the rapidly changing technology landscape (robotic platforms, vNOTES standardisation). Social determinants data were not quantitative for primary data or found in systematic review. There was a lack of literature focused on long-term patient-reported outcomes (PROMs) (sexual function, pelvic floor function, psychological wellbeing).

CONCLUSIONS AND CLINICAL RECOMMENDATIONS

Evidence from 2022–2026 firmly establishes minimally invasive hysterectomy as the clinical standard of care for uterine fibroid management, with superior EBL, LOS, and complication profiles across vaginal, laparoscopic, and robotic routes compared with open abdominal hysterectomy. The following evidence-based recommendations are supported by the accumulated literature [27-30]:

- Adopt a ‘vaginal-first’ algorithm for benign hysterectomy where vaginal access is feasible; TVH achieves fastest operative times and lowest EBL with equivalent safety, even in obese patients and those with prior cesarean sections.
- For large uteri (≥ 250 g / ≥ 12 weeks), select TLH with ureteral precautions over TVH when vaginal access is limited; be aware of the 7.54-fold higher ureteral injury risk with TLH vs. TVH in this setting.
- Robotic hysterectomy (R-TLH) is clinically equivalent to C-TLH for benign disease; reserve robotic approaches for complex cases (significant adhesions, obesity, very large uteri) given substantially higher costs with no proven benefit over conventional

laparoscopy for routine fibroid hysterectomy.

- vNOTES hysterectomy should be incorporated into surgical training programs as an educational bridge within a stepwise vaginal-first algorithm; structured credentialing with oversight of the 50-case learning curve is essential for patient safety.
- Laparoscopic myomectomy is the preferred surgical approach for fertility-preserving fibroid management, offering significantly lower EBL (105 vs. 317 mL), shorter operative time, lower pain scores, and faster recovery vs. open myomectomy with equivalent fertility outcomes.
- Image-guided uterus-sparing therapies (UAE, RFA, HIFU) should be offered to all appropriate candidates not requiring histopathology or with surgical contraindications, particularly women desiring uterine preservation.
- Addressing racial and socioeconomic disparities in fibroid care requires systemic interventions: equitable referral pathways to MIH-capable facilities, targeted programs for Black and low-income women, and culturally sensitive patient counseling.
- Shared decision-making incorporating patient values, reproductive intent, fibroid characteristics, and surgeon expertise is essential for individualizing hysterectomy route and treatment modality selection.

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