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Minimally Invasive Gynecologic Surgery: Outcomes and Safety- A Multicenter Analytical Evaluation of Perioperative Performance, Oncologic Integrity, and System-Level Determinants

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Abstract — Minimally invasive gynecologic surgery (MIGS) has transformed the management of benign and malignant gynecologic conditions by reducing perioperative morbidity, shortening hospital stay, and improving recovery profiles. However, safety concerns, oncologic integrity, surgical dissemination risks, and training variability continue to generate debate. This study evaluates clinical outcomes, perioperative safety, and structural determinants influencing MIGS effectiveness using a retrospective multicenter cohort of 1,120 patients undergoing laparoscopic, robotic, single-port, or minilaparoscopic procedures. Primary endpoints included complication rate, conversion to laparotomy, length of stay (LOS), 30-day readmission, and oncologic recurrence. Logistic regression modelling identified high surgical volume ($\beta=-0.42$, $p<0.001$), subspecialty training ($\beta=-0.37$, $p<0.001$), and enhanced recovery pathway implementation ($\beta=-0.29$, $p<0.01$) as significant protective factors against adverse outcomes. Robotic approaches demonstrated lower conversion rates (4.8%) compared to conventional laparoscopy (7.6%, $p<0.05$). Morcellation-related concerns were significantly associated with unexpected malignancy dissemination risk ($\beta=0.41$, $p<0.01$). The final model explained 86% of variance in composite surgical outcomes ($R^2=0.86$). Findings reinforce that MIGS offers superior perioperative safety when implemented within structured training, quality monitoring, and enhanced recovery systems.

***Keywords* —** *Minimally Invasive Gynecologic Surgery: Laparoscopy: Robotic Surgery: Gynecologic Oncolog: Enhanced Recovery; Surgical Safety; Morcellation; Perioperative Outcomes; Subspecialty Training; Quality Metrics.*

1. Introduction

Minimally invasive gynecologic surgery (MIGS) has brought about a paradigm shift in the management of both benign gynecologic conditions and gynecologic malignancies, representing a significant departure from traditional open laparotomy procedures. Rapid technological advancement over three decades, including advanced laparoscopic tools, robotic platforms, single-port access technologies, and ultra-minimally invasive surgical techniques, has established reduced tissue trauma, quicker recovery, and improved patient-centric outcomes as standards of contemporary surgical practice.

Ultra-minimally invasive approaches build on standard laparoscopy through extended port size efficiency, improved instrumentation, and ergonomic design, further reducing surgical footprint without compromising procedural efficacy (La Verde et al., 2022). High-definition and three-dimensional visualisation, precise energy equipment, and robotic articulation systems have enhanced operative dexterity, surgical accuracy, and ergonomics (Koo, 2018). Early implementation of minimally invasive procedures in gynecologic oncology demonstrated oncologic performance comparable to open surgery with improved perioperative recovery (Schlaerth and Abu-Rustum, 2006). Koskas et al. (2016) confirmed favourable long-term oncologic safety in high-risk endometrial cancer patients treated with minimally invasive procedures.

Robotic-assisted gynecologic surgery has gained increasing popularity due to enhanced dexterity, tremor filtration, and three-dimensional imaging (Reza et al., 2010). Comparative analyses of laparoscopic, mini-laparoscopic, and single-port hysterectomy reveal similar safety profiles with shorter hospital stays (Rossitto et al., 2017). Safety concerns persist regarding device-related complications and morcellation-related dissemination of occult malignancy, prompting regulatory scrutiny and updated surgical guidelines (Hall et al., 2015). Enhanced Recovery After Surgery (ERAS) protocols have further improved perioperative outcomes (Chapman et al., 2016; Kalogera et al., 2019). Subspecialty training in MIGS has been linked with better surgical efficiency and lower complication rates (Meyer et al., 2025).

2. Review of Literature

La Verde et al. (2022) documented reductions in intraoperative bleeding, postoperative pain, and faster recovery with ultra-minimally invasive surgery. Koo (2018) established reduced hospital stay duration and greater postoperative comfort in advanced laparoscopic surgery. Oncologic safety has been extensively evaluated. Koskas et

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al. (2016) reported comparable survival rates in endometrial cancer patients treated with minimally invasive techniques. Conrad et al. (2015) reported widespread adoption among gynecologic oncologists who affirmed safety against targeted malignancies. Ayoub et al. (2025) indicated continuing controversies in cervical cancer treatment regarding recurrence risk following radical hysterectomy.

Reza et al. (2010) demonstrated lower conversion rates to laparotomy with robotic platforms through meta-analysis, though at the cost of increased operative time. Matsuzaki et al. (2021) highlighted the impact of surgical volume and institutional experience on outcomes, emphasising centralisation and training. Hall et al. (2015) documented risks related to power morcellation and potential dissemination of occult malignancy. Enhanced recovery programmes consistently reduce postoperative complications and hospital stay (Chapman et al., 2016; Kalogera et al., 2019). Burns et al. (2025) demonstrated improved access to fibroid surgery through safety-net clinic models. Subspecialty MIGS training has been linked with better benign hysterectomy outcomes (Meyer et al., 2025).

3. Objectives

- To compare perioperative outcomes across MIGS modalities.
- To evaluate oncologic safety parameters.
- To assess the impact of surgical volume and training on outcomes.
- To analyse enhanced recovery pathway effectiveness.
- To identify predictors of adverse surgical outcomes.

4. Methodology

A retrospective multicenter cohort study assessed perioperative and oncologic outcomes of MIGS across three tertiary care institutions. The study group comprised 1,120 women who underwent minimally invasive procedures: laparoscopic (52%), robotic-assisted (28%), single-port (12%), and minilaparoscopic (8%). Inclusion criteria required adult women undergoing elective MIGS for benign or malignant indications with complete perioperative data and follow-up. Data were sourced from institutional surgical registries and electronic medical records. Major covariates included age, BMI, surgical indication, operative time, estimated blood loss, LOS, conversion status, 30-day readmission, recurrence rates in oncologic cases, annual surgeon operative volume, and ERAS protocol implementation. Descriptive statistics presented baseline demographic and surgical characteristics. One-way ANOVA compared continuous perioperative outcomes across surgical modalities; chi-square analysis examined categorical variable relationships. Multivariate logistic regression determined independent predictors of adverse perioperative events, adjusting for age, BMI, indication, surgeon volume, training, and ERAS implementation. For the oncologic subset, Cox proportional hazards models analysed recurrence-free survival. Proportional-hazard assumptions were assessed; likelihood-ratio tests and goodness-of-fit measures assessed model adequacy. Statistical significance was set at $p<0.05$.

5. Analysis and Discussion

Table 1: Comparison of Perioperative Outcomes by Surgical Modality

Modality	Mean LOS (days)	Conversion (%)	Complication (%)	p
Laparoscopy	2.8	7.6	11.2	—
Robotic	2.3	4.8	9.5	< .05
Single-Port	2.5	6.2	10.1	—
Mini-Lap	2.4	5.7	9.8	—

Robotic surgery showed significantly lower conversion rate ($p<0.05$) and the shortest mean LOS. The reduction in conversion from 7.6% (laparoscopy) to 4.8% (robotic) represents a clinically meaningful improvement in operative predictability. All minimally invasive modalities demonstrated superior outcomes compared to historical open surgery benchmarks, confirming the overall safety advantage of MIGS across platforms.

Table 2: Influence of Surgical Volume and Training

Variable	Complication Rate (%)	p
High Volume (>100/year)	7.9	< .001
Low Volume (<50/year)	14.8	—
MIGS Fellowship Trained	8.2	< .001
Non-Fellowship	13.9	—

Subspecialty training is strongly protective (Meyer et al., 2025). High surgical volume reduced complication rates by nearly 50% compared to low-volume surgeons, consistent with Matsuzaki et al. (2021). Fellowship training produced a comparable reduction, demonstrating that both structured education and procedural experience independently contribute to improved surgical outcomes. The similar complication profiles of trained and high-volume surgeons suggest that fellowship training effectively compensates for volume differences in early career surgeons.

Table 3: Logistic Regression Predicting Composite Adverse Outcome

Predictor	β	OR	p
High Surgical Volume	−0.42	0.65	< .001
MIGS Fellowship Training	−0.37	0.69	< .001
ERAS Implementation	−0.29	0.74	< .01
Morcellation Use	0.41	1.51	< .01
BMI > 35	0.33	1.39	< .05

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Model $R^2 = 0.86$; $\chi^2 = 512.4$, $p < .001$. High surgical volume and training reduce adverse outcomes; morcellation use increases risk. The model explains 86% of outcome variance. ERAS implementation as an independent protective factor confirms Chapman et al. (2016) and supports universal protocol adoption. Morcellation-associated risk (Hall et al., 2015) reinforces the need for strict preoperative risk stratification and adoption of containment systems. BMI >35 as a modifiable risk factor suggests that perioperative optimisation programmes targeting surgical fitness may reduce obesity-related complications.

6. Recommendations

Expansion of MIGS fellowship training programmes is critical to guarantee standardised skills acquisition and procedural competence across institutions. Structured subspecialty certification programmes reduce outcome variability and improve patient safety, particularly for complex oncologic surgeries. Quality assurance models should include standardised outcome measures incorporating conversion rates, complication indices, readmission rates, and recurrence reporting (Abel et al., 2019).

A minimum surgeon volume requirement is recommended for complex oncologic minimally invasive procedures, with high-risk cases concentrated in experienced centres. ERAS implementation should be universal to maximise postoperative recovery and shorten hospital stay. Solid preoperative risk stratification measures and containment system compliance should be enhanced to address morcellation-related dissemination risk. National surgical outcome registries should be established for longitudinal surveillance of perioperative safety and quality indicators.

7. Conclusion

Minimally invasive gynecologic surgery demonstrates superior perioperative safety, reduced morbidity, and favourable recovery outcomes when implemented within well-organised systems emphasising surgical skill, standardised practice, and enhanced recovery pathways. While robotic platforms reduce conversion rates, surgeon training and procedural volume represent the most persuasive determinants of safety and quality. Governance through standardised quality metrics and long-term outcome monitoring is necessary to address dissemination risks, cost considerations, and oncologic controversies. MIGS is a developed but continuously evolving surgical paradigm requiring ongoing assessment, structured training expansion, and data-driven oversight to maintain clinical and oncologic excellence.

8. Future Research Directions

Randomised multicentre trials comparing long-term oncologic survivorship across minimally invasive surgical platforms should be prioritised. Cost-effectiveness analyses comparing robotic and conventional laparoscopic procedures are needed to inform policy and resource allocation decisions. AI-directed intraoperative risk prediction systems hold potential for improving real-time decision-making, complication prediction, and conversion risk assessment. Patient-reported outcome measures should be incorporated into safety and quality assessment models to capture functional recovery, pain perceptions, and quality-of-life outcomes.

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