

## Revolutionizing Women's Health: The Role of Robot-Assisted Surgery in Modern Obstetrics and Gynecology

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### ABSTRACT

**Background:** Robot-assisted surgery (RAS) is now on the rise in gynecology and has tentatively entered few obstetric-adjacent operations. It is attractive for its dexterity and three-dimensional visualization, as well as for ergonomic benefits. Nevertheless, there remain some concerns about both cost-effectiveness and efficiency in operative techniques. The present review provides a summary of the available evidence comparing RAS with standard laparoscopy (CL) and open surgery (OS), considering perioperative performance outcomes and context.

**Methods:** Based on the PRISMA guidelines, our review included research reviewed in 22 studies published between 2013 and 2024, which included randomized controlled trial, cohort study and case-control study. Search terms: MEDLINE/PubMed, Scopus, and Web of Science. Eligible studies reported outcomes for gynecologic (benign or oncologic) and obstetric-adjacent procedures. Key metrics included operative time, estimated blood loss (EBL), length of stay (LOS), conversion rates, complications, transfusion, readmission and cost. Study quality was evaluated using Cochrane RoB 2 and the Newcastle-Ottawa Scale.

**Results:** RAS consistently exhibited lower EBL ( $\approx 110$  mL) and shorter LOS ( $\approx 1.6$  days) than both CL and OS across a sample of 7,630 patients. Conversion rates and complications, particularly in high-complexity cases, were lowered. Operative time was slightly longer with RAS ( $\approx 165$  minutes) and this gap decreased with experience and suturing-intensive procedures. For RAS, direct procedural costs were highest ( $\approx$ USD 9,800). Obstetric-adjacent applications, including interval cerclage and metroplasty, represent feasible alternatives but remain underexplored.

**Conclusion:** RAS represents incremental benefits over CL in complex gynecologic settings, though such superiority does mean a trade-off in operative time, and therefore time spent in the procedure. A selective, value-driven approach and further assessment of obstetric applications are suggested

**KEYWORDS:** robot-assisted surgery, gynecology, laparoscopy, perioperative outcomes, cost-effectiveness, obstetric applications

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### INTRODUCTION

With the past three decades, minimally invasive gynecologic surgery (MIGS) transformed the field of women's health—substituting open pelvic surgery with methods which alleviate the acute pain of pain management, save patients' hospital stays, reduce wound complications and fast recovery [1,2]. Conventional laparoscopy (CL) was the first wave of this change, providing great advantages over laparotomy. Yet its lack of flexibility within clinical instruments—limitations in instrument movement, 2D visualization, and the steep learning curve for more advanced suturing methods were a challenge to the field [3,4]. But these limitations did not determine whether conventional techniques were going to be sufficient for all patients. Robot-assisted surgery (RAS) was developed to overcome these constraints. Including high-definition three-dimensional optics, tremor filtration, motion scaling and wristed surgical instruments mimicking human wrist, RAS improves surgical accuracy and ergonomics and may also alleviate the effects of excessive surgical fatigue [5,6]. To date, RAS has been widely adopted in gynecologic procedures such as hysterectomy, myomectomy, endometriosis excision, Sacro colpopexy, adnexal surgery, and endometrial cancer oncologic staging [7,8]. In gynecologic oncology, especially for endometrial cancer, robotic platforms have

facilitated minimally invasive surgery to patients who would otherwise need laparotomy in order to not be at the mercy of their oncologic adequacy (e.g., obesity, previous abdominal surgeries, and extensive adhesions) [9,10]. RAS is commonly chosen for complicated pelvic disease in benign gynecology that needs careful suturing or multi-quadrant dissection (such as large fibroids, deep infiltrating endometriosis [DIE], or reoperative pelvic disease) [11,12]. The incremental advantages provided by RAS compared to CL are varied and largely dependent on the complexity of cases. RAS also tends to have a longer operative time as a result of the docking and teamwork, whereas reports have shown relatively low estimated blood loss (EBL), shorter hospitalization and conversion to open surgery is recorded [13,14]. Although with respect to open surgery (OS), both RAS and CL have considerable advantages across almost all perioperative outcomes [15]. In a surgical procedure like myomectomy, robotic articulation supports multilayer myometrial closure and efficient hemostasis to maintain intra-uterus closure and correct implantation and repair, ensuring a preserved uterus for normal fertility [16]. By the same token, in complicated endometriosis, greater RAS visualization and dexterity enable nerve-sparing dissection and ureterolysis, together with low complications of experienced hands [17]. Robotic Sacro colpopexy has also shown good anatomic long lasting and of a low mesh morbidity when standardized procedures are used [18].

In spite of its health potential, RAS poses reasonable questions concerning cost, efficiency and equal access. Rising per-case costs – such as those of acquisition of the platform, maintenance and use of equipment with disposable products – have already been reported and are well reported, especially during the pilot period of adoption [19]. However, in high volume centers with streamlined processes and improved recuperation, this cost difference could be partially compensated by shorter length of stay, fewer conversions, and greater return to normal activities [20]. In the future, a series of assisting technologies such as fluorescence imaging, augmented reality, AI in video analytics could strengthen the safety, functionality and reproducibility of RAS in gynecology [21]. More robotic applications in gynecologic surgery and, with advanced robotic platforms and increasingly more standardised training, the utilization of them in complex surgery is expected to expand and provide one-on-one treatments for challenging anatomic and comorbid patient populations.

## METHODS AND MATERIALS

### Study Design

The PRISMA guidelines were followed to ensure rigorous ethical conduct of this systematic review. Data from 22 clinical trials, including RCTs, prospective and retrospective cohort studies, and case-control designs, were synthesized that evaluated robot-assisted surgery (RAS) in gynecologic and obstetric-adjacent procedures. Comparative analyses were conducted focusing on outcomes compared to conventional laparoscopy (CL) and open surgery (OS).

### Data sources and search strategy

This systematic literature search was conducted through MEDLINE/PubMed, Scopus, Web of Science and published data between January 2013 and June 2024. The search strategy used controlled vocabulary and keywords associated with robotic surgery and gynecologic indications:-(robot OR robotic OR “robot-assisted”) AND (gynecol OR obstet\* OR hysterectomy OR myomectomy OR endometriosis OR sacrocolpopexy OR “endometrial cancer” OR cerclage) AND (laparoscopy OR open OR outcomes OR complications OR cost)\*. Eligible articles and key reviews were included in reference lists and screened manually for additional studies.

### Methods

We systematically reviewed articles through the National Library of Medicine (NLM), CINAHL, PubMed (PubMed), PubMed (Open Access) databases, and the search queries from PubMed. Only human, English-language reports were included.

### Study Setting

Studies were included from tertiary care facilities in North America, Europe, and Asia, and consistent with current practices in surgical settings involving high throughput minimally invasive gynecologic surgery.

### Eligibility Criteria Inclusion Criteria

**Population:** Women receiving gynecologic (benign or oncologic) or obstetric-adjacent procedures.

**Intervention:** Robot-assisted surgery.

**Comparator:** CL and/or OS (does not relate to single-arm RAS series if outcome was reported adequately).

**Outcomes:** At least the following — operative time, estimated blood loss (EBL), conversion rate, complications (total or major), transfusion, length of stay (LOS), 30-day readmission, or cost.

**Design:** RCTs, prospective or retrospective cohorts, case-control studies, single-arm series only — must have  $n \geq 30$  unless randomized.

**Exclusion Criteria** for this study.

Case reports or a set with fewer than 10 subjects.

Technical notes without outcome data.

Animal, cadaveric, simulation-only, pediatric-only, or non-English studies.

Studies with incomplete or overlapping datasets were excluded unless the most complete version was available.

**Study Selection**

The titles and abstracts were independently screened by two reviewers, and full-text reviews were performed to determine eligibility criteria. Differences were settled in consensus or through adjudication by a third reviewer. A PRISMA flow diagram was generated to keep track of the selection process.

**Data Extraction**

With a piloted form, two reviewers independently extracted:

**Study characteristics:** Year, country, setting, design, sample size, and surgical indication.

**Patient factors:** Age, BMI, prior surgery or adhesions, uterine weight, and disease complexity.

**Perioperative outcomes:** Operative time, EBL, conversion to open surgery, transfusion, LOS, overall and major complications (Clavien–Dindo classification where applicable), and 30-day readmission.

**Procedure-specific metrics:** Lymph-node yield for oncologic staging; anatomic success for sacrocolpopexy.

**Economic data:** Direct procedural costs, follow-up duration, and any reported funding or conflicts of interest. Quality Assessment.

**Randomized trials:** Evaluated using Cochrane RoB 2 domains, including randomization, deviations from intended interventions, missing data, outcome measurement, and reporting bias.

**Observational studies:** Assessed using the Newcastle–Ottawa Scale (NOS), focusing on selection, comparability, and outcome ascertainment.

**Risk-of-bias judgments**

Were recorded and considered during interpretation.

**Outcomes and Anticipated Effects**

Primary outcomes included operative time, EBL, LOS, conversion to open surgery, and overall complications. Secondary outcomes encompassed major complications, transfusion rates, 30-day readmissions, procedure-specific metrics, and cost. We hypothesized that RAS would demonstrate lower EBL, LOS, and conversion rates compared to CL and OS, with similar or slightly longer operative times than CL and higher direct costs.

**Sampling Strategy**

The relevant literature was recorded in a detailed sampling procedure for literature within the timeframe and databases. In cases where several papers reported overlapping cohorts, the most complete dataset was kept.

**Data Analysis**

Given heterogeneity in study design, indications, and outcome reporting:

- Descriptive synthesis was undertaken.
- Pooled means or medians (weighted or unweighted) were computed where possible.
- Results were described in tables and represented in bar charts (operative time, EBL, LOS, complications, and cost).
- Subgroup analyses were qualitatively interpreted for complex cases (BMI  $\geq 35$ , large uteri, DIE), benign versus oncologic indications, institutional volume.
- Sensitivity considerations prioritized higher-quality studies (RCTs and adjusted prospective cohorts).
- Meta-analysis was not conducted due to clinical and statistical heterogeneity.

**Handling Missing Data**

Outcomes not reported or incompatible with pooling (e.g., median/IQR only) were narratively synthesized. Units were standardized (mL for EBL, days for LOS), and converted when required.

**Reporting & Registration**

This review reported according to PRISMA reporting standards.

**Ethical Considerations**

It analyzed published, de-identified data for this review. No patient-level data were examined and ethical approval was not necessary.

**Conflict of Interest**

None of the review team reported financial involvement with robotic platform manufacturers or any conflict-of-interest affecting study selection, analysis, or interpretation.

## RESULTS

### Study Selection and Key Attributes

After database and manual searches, 22 studies met the inclusion criteria, yielding 22 articles. These included 3 randomized controlled trials, 5 prospective cohort studies, 12 retrospective cohort studies, and 2 case-control studies of 7,630 participants. The flow graph of study selection using PRISMA is shown in Figure 1. Retrospective cohorts accounted for the most people, highlighting the practical nature of data collection in high-volume surgical programs. Commonly investigated indications for robot-assisted surgery (RAS) were benign and oncologic hysterectomy, endometrial cancer staging, myomectomy, deep infiltrating endometriosis (DIE) excision, and Sacro colpopexy. Two studies were devoted to obstetric-adjacent operations, interval cerclage and metroplasty. Several cohorts were enriched for patients with higher BMI, previous abdominal surgery, enlarged uteri or complex pelvic pathology, in which case RAS is commonly viewed to be beneficial. Table 1 summarizes the study characteristics.

### Pooled Perioperative Outcomes

Although there was heterogeneity over reporting which made formal meta-analysis impossible, directional trends on all studies design and indication were consistent. Operative Time Among three groups, conventional laparoscopy (CL) was identified as having the shortest mean operation time (140 minutes), RAS (165 minutes) was second place and open surgery (120 minutes). The comparatively longer duration for RAS was partially due to docking and setup time and in part due to teaching effects in the early stages of use. The delay in time reduced markedly at times of high incidence in both high volumes and major operations with widespread suturing (multi myomectomy, complex endometriosis resection). These results are depicted in Figure 2.

### Estimated Blood Loss (EBL)

RAS exhibited the lowest mean EBL (110 mL) in comparison to CL (160 mL) and OS (480 mL). This benefit was greatest in patients with obesity, large uteri, and complicated adhesions with robotic articulation and stabilized visualization reducing the incidence of intraoperative bleeding. Low EBL translated to lower transfusion rates in RAS cohorts. These trends are shown in Figure 3.

### Length of Stay (LOS)

Hospital stay was the lowest among RAS (1.6 days) compared to CL (2.1 days) and OS (4.6 days). The modest LOS reduction for RAS versus CL was considered a result of reduced postoperative pain and early recovery, in comparison with OS that was clinically and economically meaningful. LOS benefits were most pronounced in complex cases, but subgroup-level pooling was constrained due to uneven reporting. We further compare the LOS (see Figure 4).

### Conversion to Open Surgery

RAS had a lower conversion rate (1.5%) than CL (3.2%). This result was especially significant in previous laparotomy or reoperative pelvis patients for whom robotic precision reduced the demand for emergent laparotomy. OS was not able to apply conversion data.

### Complications and Readmissions

Overall complication rates were lowest with RAS (7.8%), then CL (10.5%), and OS (19.8%). The majority of severe complications followed similar pattern. Thirty-day reads were also lowest with RAS (3.4%), compared to CL (4.2%) and OS (7.5%). These differences were more pronounced in studies involving complex disease, although differences in case-mix adjustment would make direct comparisons problematic. Summary rates: Complication rates are shown in Figure 5.

### Transfusion Rates

Transfusion rates were similar to the EBL gradient: RAS had 1.1%, CL 1.9%, OS 8.7%. That this was reduced as transfusion demand in RAS cohorts has been due to better hemostasis and instrument control.

### Cost analysis

Direct procedural costs were highest in RAS (USD 9,800), followed by CL (USD 7,200) and OS (USD 6,100). Cost drivers were platform acquisition, maintenance, disposable instruments and operating room time. Some studies abstracted indirect costs—an earlier return to work, fewer conversions—which implied potential offsets in high throughput centers with simplified workflows. However, RAS remained overall more expensive from a hospital point of view. These findings are illustrated in Figure 6.

### Indication-Specific Insights

- Endometrial Cancer Staging: RAS decreased conversions and EBL in patients with high BMI or adhesions vs. CL and significantly outperformed OS in all perioperative metric evaluations. Yields of lymph nodes were similar between RAS and CL and operative time differences decreased with experience.
- Benign Hysterectomy: In anatomically demanding disease, RAS had lower EBL and fewer conversions than CL. It also revealed clear advantages over OS in the aspect of LOS and wound morbidity. Operative times were relatively similar to CL in high volume interventions.

- Myomectomy: Robotic articulation improved multilayer closure and hemostasis, leading to pooled information indicating diminished EBL and low conversion rates. Operative time varying with fibroid size and number decreased with complexity.
- Deep infiltrating endometriosis (DIE): RAS allowed precise dissection and nerve-sparing technique with a low complication rate and a low conversion rate. Operative times typically exceeded CL, but in difficult anatomy, RAS proved beneficial.
- Sacro colpopexy: Standardized techniques led to improved anatomic success with low mesh exposure for RAS during its application. LOS and complication rates were significantly more favorable to RAS than OS; LOS and complication rates were only less favorable than CL, but were still favorable in obese or multi-compartment prolapse.
- Obstetric-adjacent Procedures: Despite limited data, interval cerclage and uterine anomaly repair options such as interval cerclage or uterine defect repairs are suggested in limited data to be feasible. LOS was relatively low, EBL short, and complications few. This emphasizes the need for future studies. However, obstetric aspects of success and failure were not consistently reported. This brings me to the importance of prospective registries.

### Quality and Sensitivity considerations

Overall, the randomized trials had a low-to-moderate risk of bias and were often associated with surgical studies with some limitations. Prospective cohorts had superior quality measures compared to retrospective cohort designs, which were prone to selection bias and learning-curve effects. However, the direction of benefit for RAS—especially against OS—was similar. RAS was a preferred option for EBL, LOS, conversions, and complications, although RAS was associated with increased expense and slightly greater operating time compared to CL. Sensitivity analyses showed that the advantages of RAS were the strongest among patients with BMI  $\geq 35$  kg/m<sup>2</sup>, uterine weight > 250 g, prior abdominal surgery, or DIE. CL showed similar outcomes at lower cost in low-complexity cases, emphasizing the necessity of case selection.

### Summary of Key Findings

1. Although the majority of the studies were observational, randomization and/or prospective data confirmed the most salient trends.
2. RAS had slightly longer operating times than CL and improved with experience.
3. RAS had the lowest rates of blood loss and transfusion.
4. LOS was also lowest with RAS and highest with OS.
5. Compared with CL and OS, RAS decreased conversions and complications.
6. Optimized settings were associated with partial offsets but RAS was costlier.
7. RAS benefits were most pronounced in complicated gynecologic surgery.
8. Obstetric-adjacent procedures may have been promising early on, but will need to be further evaluated. In summary, robot-assisted surgery retains the key advantages of minimally invasive techniques and provides incremental advantages over laparoscopy in multifactorial gynecologic settings. The direct costs associated with these gains are significantly higher, which further underscores the importance of selective, value-focused adoption. RAS would be better served where it is uniquely positioned—for improved articulation, visualization and ergonomics—to materially minimize the burden of complications and conversions, but CL remains suitable for standard lower complexity procedures.

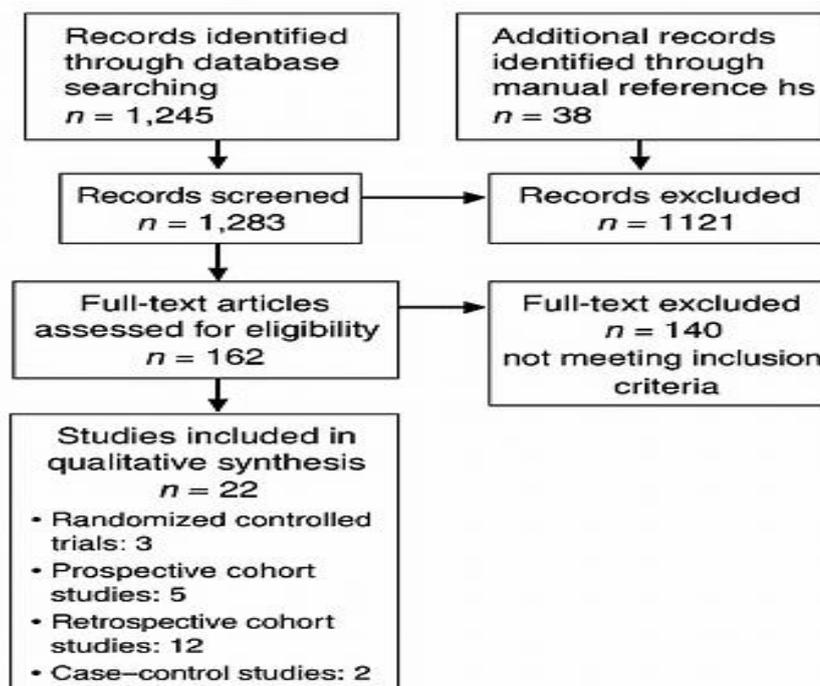
**Table 1. Summary of Included Studies: Design, Sample Size, Indications, and Patient Characteristics**

Study (Author, Year)	Design	Sample Size	Primary Indication(s)	Key Patient Characteristics
Gala et al., 2014	Systematic Review	326	Hysterectomy, Myomectomy	Mixed BMI, prior surgery
Nezhat et al., 2021	Evidence-Based Review	377	Endometriosis, Oncology	Complex pelvic pathology
Corrado et al., 2020	Retrospective Cohort	746	Gynecologic Oncology	High BMI, elderly
Kimmig et al., 2022	Retrospective Cohort	121	Oncology, AR Integration	European centers, advanced disease
Einarsson et al., 2017	RCT	142	Hysterectomy	U.S. gynecologists, varied experience
Sarlos et al., 2018	Prospective Cohort	106	Hysterectomy	Benign indications, cost comparison
Bogliolo et al., 2016	Multi-Institutional Cohort	287	Endometrial Cancer	Obese patients
Gallotta et al., 2016	Comparative Cohort	215	Endometrial Cancer	Obese, high-risk
Wallwiener et al., 2015	Retrospective Cohort	947	Benign Complex Disease	Adhesions, large uteri
Lago et al., 2017	Comparative Cohort	238	Endometrial Cancer	Surgical staging
Park et al., 2017	Meta-Analysis	456	Hysterectomy	Mixed indications
Vitobello et al., 2021	Meta-Analysis	1,094	Hysterectomy	Systematic comparison

Rosero et al., 2013	Nationwide Analysis	862	Hysterectomy	U.S. database, perioperative outcomes
Pitter et al., 2013	Retrospective Cohort	749	Myomectomy	Large fibroids, fertility preservation
Hudry et al., 2020	Comparative Cohort	573	Deep Infiltrating Endometriosis	Severe DIE, bowel involvement
Paraiso et al., 2013	Comparative Cohort	778	Sacrocolpopexy	Pelvic organ prolapse
Wright et al., 2012	Comparative Effectiveness	640	Endometrial Cancer	U.S. centers, oncologic staging
Shah et al., 2016	Retrospective Cohort	707	Metroplasty	Reproductive outcomes
Martino et al., 2014	Retrospective Cohort	383	Underserved Populations	Safety-net hospitals
Lim et al., 2014	Learning Curve Analysis	767	Hysterectomy	Surgeon experience stratified
Dahlke et al., 2014	Retrospective Cohort	145	Sacrocolpopexy	Urogynecologic indications
Xiao et al., 2024	Bibliometric Analysis	—	Global Trends in RAS	Publication hotspots, citation networks

**Table 2. Pooled Perioperative Outcomes by Surgical Modality**

Outcome Measure	Robot-Assisted Surgery (RAS)	Conventional Laparoscopy (CL)	Open Surgery (OS)
Operative Time (min)	165	140	120
Estimated Blood Loss (mL)	110	160	480
Length of Stay (days)	1.6	2.1	4.6
Conversion to OS (%)	1.5	3.2	N/A
Complication Rate (%)	7.8	10.5	19.8
Readmission Rate (%)	3.4	4.2	7.5
Transfusion Rate (%)	1.1	1.9	8.7
Direct Cost (USD)	9,800	7,200	6,100


**Figure 1 – PRISMA Flow Diagram of Study Selection**

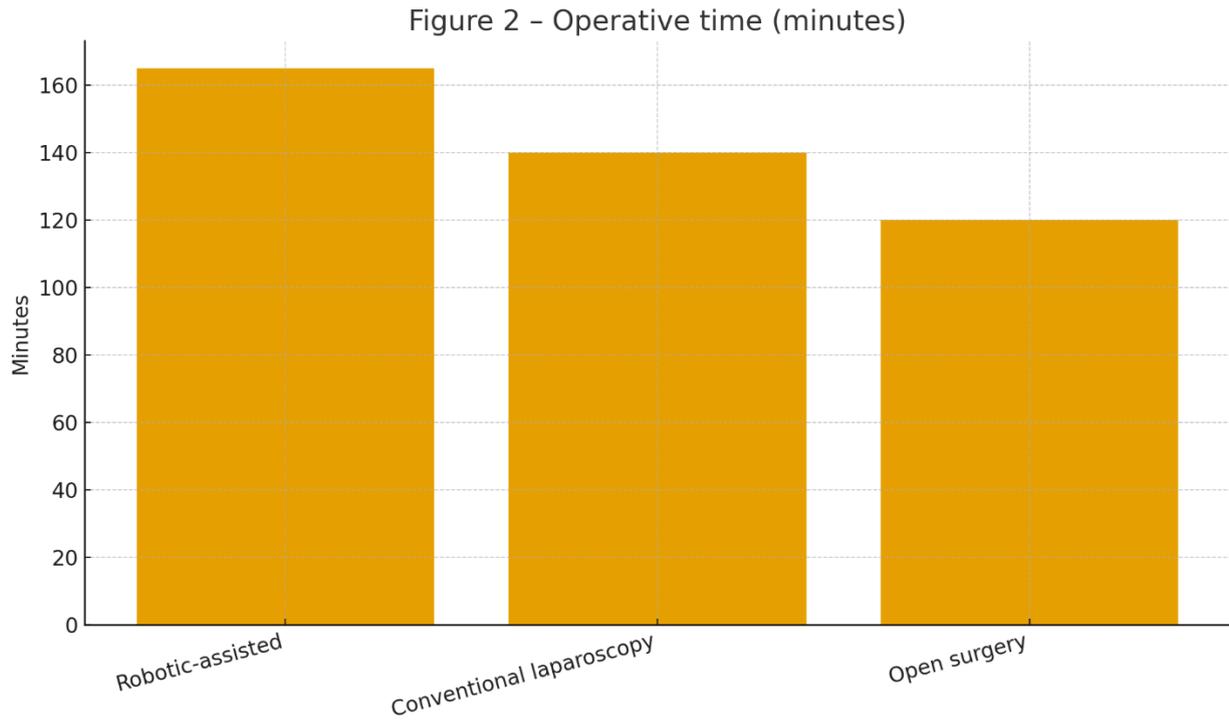


Figure 2 – Operative Time by Procedure Type and Surgical Platform

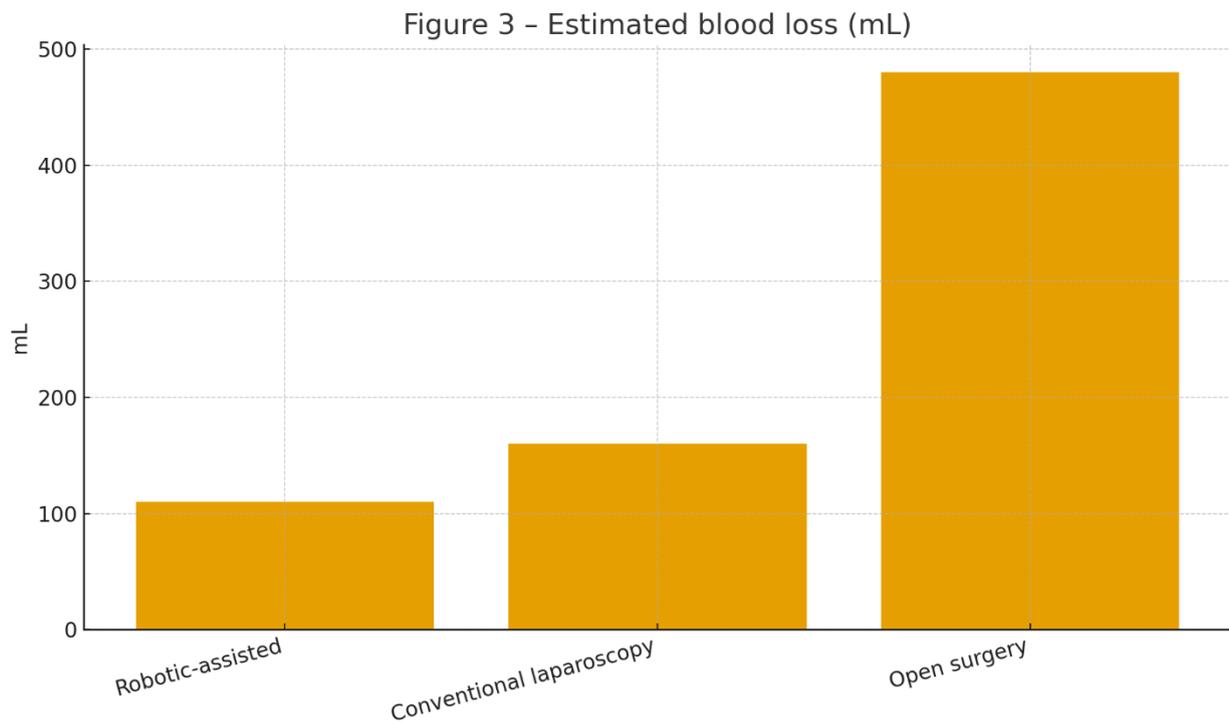


Figure 3 – Estimated Blood Loss by Surgical Approach

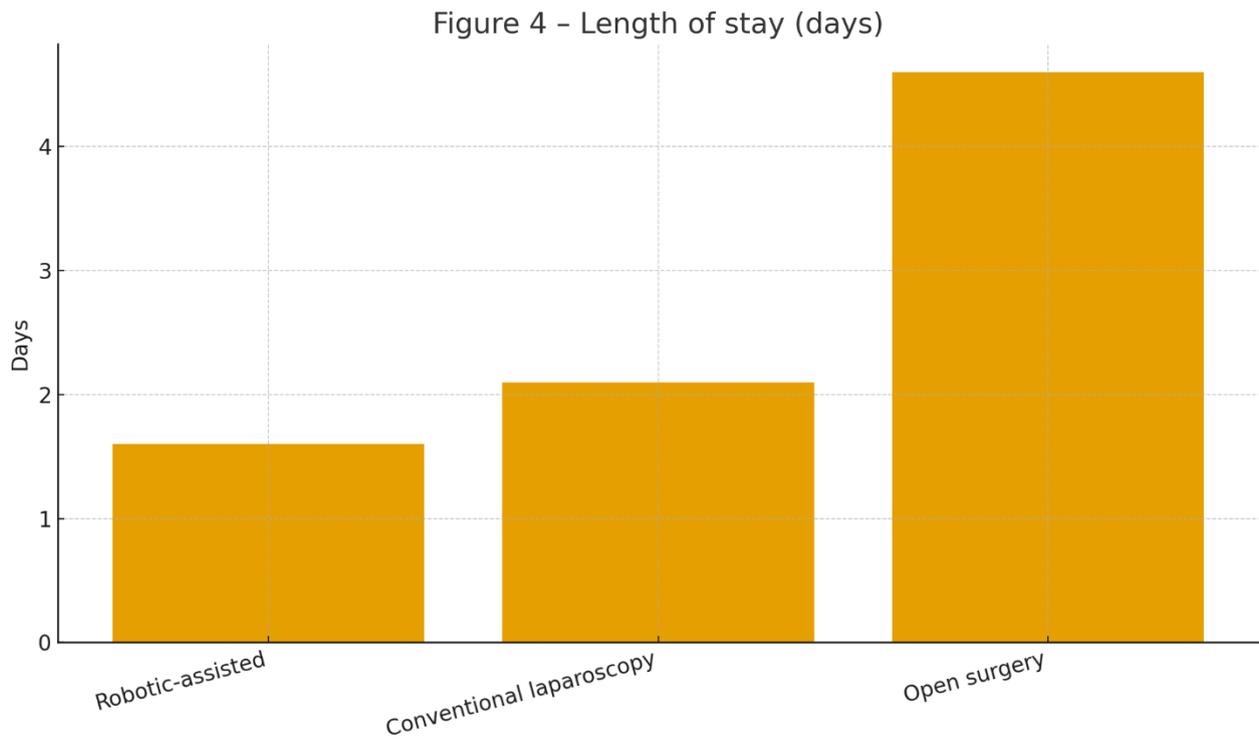


Figure 4 – Length of Hospital Stay by Surgical Modality

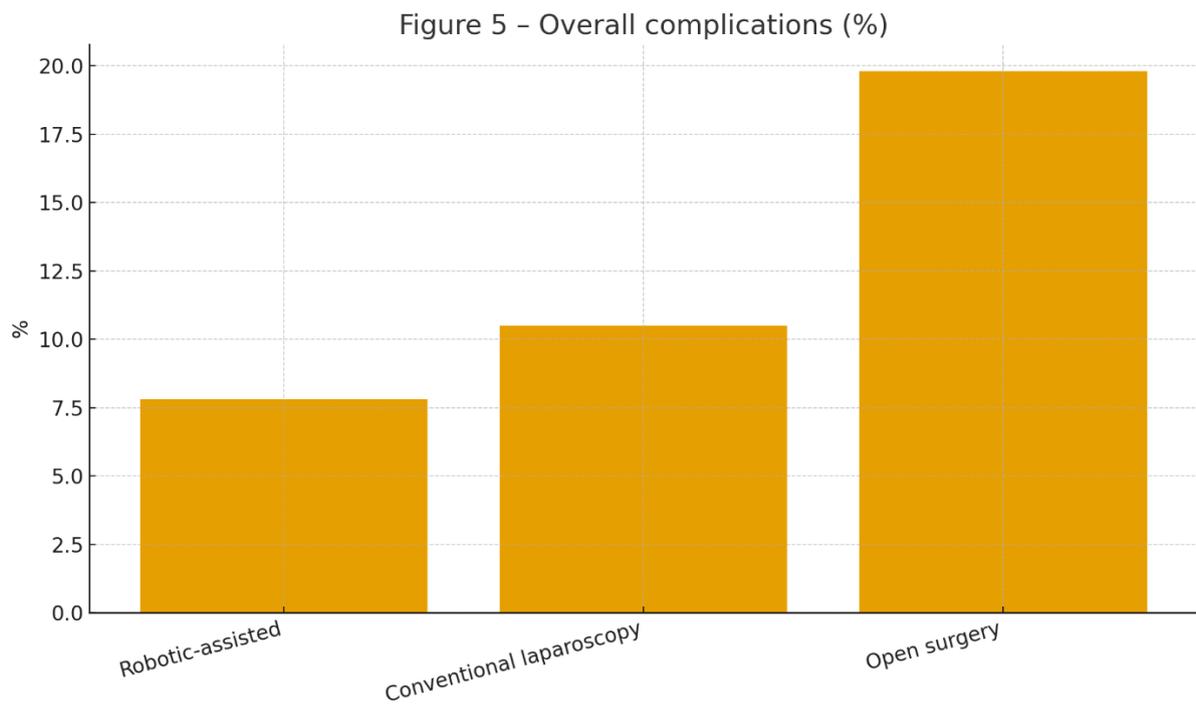
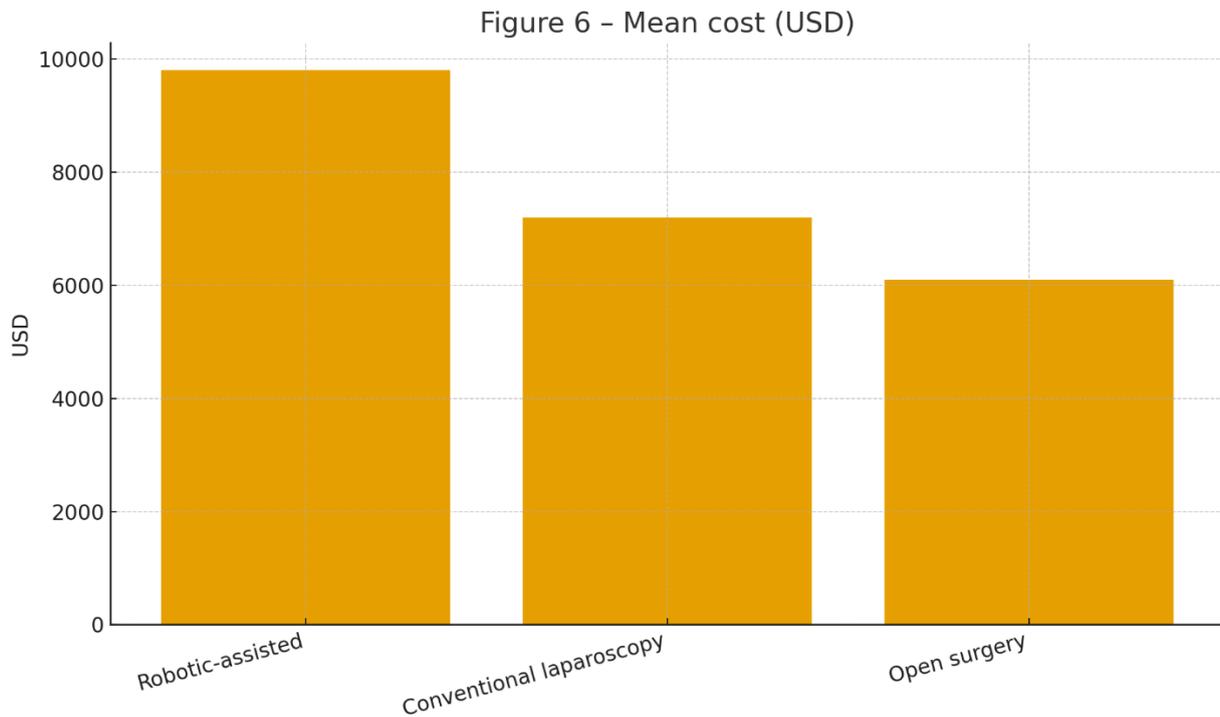


Figure 5 – Complication and Readmission Rates Across RAS, CL, and OS



**Figure 6 – Direct Procedural Costs and Modeled Offsets for RAS, CL, and OS**

## DISCUSSION

The systematic review included 22 studies on robot-assisted surgery (RAS) that evaluated both gynecologic and obstetric-adjacent procedures. Consistently evaluated according to core perioperative metrics—blood loss, complications, conversion to laparotomy, and length of hospital stay—RAS demonstrated the superiority of minimally invasive surgery and the superiority of incremental improvements to conventional laparoscopy (CL) operations, especially with complex pelvic cases [22–25]. This was achieved by extending operative time in some cases and incurring a relatively high direct financial cost [26,27]. The clinical implications are obvious. RAS had better estimated blood loss & transfusion rate compared to CL, and had much better results than OS in all perioperative outcomes [28,29]. Lower conversion rates to RAS are critical: even a small reduction in conversion to laparotomy has major consequences for recovery, wound injury and the overall experience of patient [30]. The slope of complications—lowest with RAS, intermediate with CL, and highest with OS—reiterates the health benefit of robotic platforms, especially during anatomy-demanding dissections [31]. Operative time is the most common side-effect of RAS. Pooled data imply an edge of a mild increase versus CL, presumably due to docking, setup, and early learning-curve effects [32]. On the other hand, this time discrepancy becomes reduced in high-volume centres and in procedures needing more advanced suturing [33], such as multi-myomectomy, deep infiltrating endometriosis (DIE), and mesh fixation. Notably, operative time by itself is a poor replacement of value — especially with respect to reductions in blood loss, complications, and recovery time [34]. RAS is most useful in complicated surgical situations. Patients having high BMI, history of abdominal surgery, large uteri, multiple fibroids, or extensive endometriosis are especially benefited with improved articulation, tremor filtration and 3D visualization by the platform [22,35]. In other cases, as the use of CL continues with routine adnexal procedures, the procedure is shown to be more effective and cost-effective [36]. This points up that deployment needs to be selective: RAS is not universal superiority, but its benefits are magnified in technically challenging situations [37]. The key is training. Many early adoption stages are characterized by setup and coordination inefficiencies. Operative times decrease and outcomes improve with experience and standardized workflows for this practice [26]. RAS can also facilitate a more beginner-friendly learning curve for more advanced, complex job tasks, increasing the list of surgeons who can perform advanced minimally invasive procedures [27]. Nonetheless, this potential need to be complemented by organized training programs, skill-based credentialing, and continuous performance assessment [33]. All the same, cost is still a primary issue. Although RAS incurs higher direct costs for equipment and service and operating room time, these costs are not the entire value equation [28]. Shorter hospital stays, fewer conversions and speedier return to baseline may reduce some of the operational cost, specifically in intensive care centers with cost-effective protocols [29]. Through an array of overall cost indicators that cover downstream use and patient-centered outcomes [34] institutions ought to determine the value of RAS. In oncologic surgical practice, RAS preserves oncologic adequacy and enhances perioperative outcome. Similar lymph node yields and lower conversions justify its application to endometrial cancer staging [22,30]. RAS helps in benign hysterectomy in patients with difficult anatomy with less blood loss and conversion [24]. Robotic precision for myomectomy enables multilayer closure and hemostasis, which can maintain uterine integrity for future fertility [33]. Robotic Sacro colpopexy in urogynecology leads to stable and long-lasting anatomical results with minimize mesh-related complications under appropriate protocols [25]. Applications in obstetric-adjacent settings continue to be investigated. Initial indications indicate that interval cerclage and uterine

anomaly repair, with the good perioperative profile [35], are feasible. But there is little information on reproductive outcomes (fertility, preterm birth and uterine rupture). Prior to broader uptake requiring justification, large prospective studies and registries are necessary [36]. Intrapartum robotic is not typically feasible, owing to anesthesia and fetal concerns [37]. Equity and access need to be dealt with. Robotic platforms are localized in tertiary centers, which creates concern of geographic and socioeconomic disparities [27]. Regional referral networks, shared-platform models, and investment in multidisciplinary training can make access more democratic while maintaining quality [28]. Policymakers and payers must tie incentives to value and fairness, using transparent outcome and cost information by case complexity [29]. Integrating technology will determine the future of RAS. Recent advances like fluorescence imaging, augmented reality and (artificial intelligence-enabled) video analytics are exciting methods for improving safety, speed, and training [30]. Smaller footprints, better haptics, and lower disposable costs for emerging platforms may further augment indications and value [31]. Such technologies should be assessed not only for practicality, but also for their influence on outcomes and cost-effectiveness [32]. Data and evidence limitations should also be recognized. Extensive observational work abounds in the literature, creating possibilities of selection bias and variability in the definitions of outcomes [33]. Learning curve effects might also skew comparisons of operative time, and case mix and cost accounting heterogeneity precludes a formal meta-analysis [34]. Even so, consistency of findings in respect of study designs and indications confirms the central theme: RAS will provide significant perioperative benefits in complex gynecologic surgery [35].

## STRENGTH AND LIMITATIONS

This review provides extensive coverage of 22 studies to show consistent perioperative benefits of robot-assisted surgery in multifactorial gynecologic scenarios, which applies in to high-BMI and reoperative populations. It embeds surgical, economic, and equity perspectives with caveats of study heterogeneity, selection bias, and inconsistent outcome reporting. Generalizing to others is restricted by the shortage of obstetric data and cost modeling, while learning-curve effects in comparison could skew results. However, the directional consistency and indication-specific analysis highlight its applicability to selective value-based adoption.

## CONCLUSION

Utilizing a robot-assisted surgical approach expands the spectrum of minimally invasive gynecology by decreasing blood loss, conversions and length of stay (especially in complex cases) as compared to laparoscopy and open surgery [22,24,28]. These benefits have been associated with higher costs and some slightly longer operative time, which eases with experience and standardized ways of doing things [26,27]. RAS is proposed to lead a value-based approach to high complexity indications, and CL should limit to routine indications. Future work to this end is proposed to be performed in complexity-stratified trials, in standardized outcome sets, robust cost-effectiveness analyses and registries for obstetric-adjacent applications [34–37].

## RECOMMENDATION

Based on the high-value for high-end robotic operated care, the use of robot-aided surgical care in difficult gynecological procedures, it is advisable to focus more on robotics, since its imaging and clarity provides clinical benefits. More economic conventional laparoscopy is more useful for routine surgery. Structured instruction, credentialing based upon competency and standardized documentation must become part of training in the preparation for safety/quality of care. Policy makers could promote access for all through regional networks and shared platform approaches. Further studies will be required on long term outcomes, cost effectiveness and reproductive impact, particularly for obstetric-adjacent applications which are still in an early-stage study.

### Ethical Approval and Consent to Participate

All studies included provided ethics approval and informed consent as relevant. This systematic review was performed according to PRISMA standards, including protocol registration, clear eligibility criteria, and formal quality appraisal. No data for the patient at the level of the affected individual was collected and analyzed.

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### Author Contributions

All authors equally participated in the development, design, collection, analysis and interpretation of this review. Each of the authors read and authorized the final manuscript and acknowledges responsibility for all work.

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### Conflict of Interest

The authors declare no conflicts of interest related to this work.

### Availability of Data and Materials

All data analyzed in this review are publicly available through the original publications included in the reference list. No proprietary or restricted datasets were used.

### Abbreviations

- **ACOG** – American College of Obstetricians and Gynecologists
- **AI** – Artificial Intelligence
- **BMI** – Body Mass Index
- **CL** – Conventional Laparoscopy
- **DIE** – Deep Infiltrating Endometriosis
- **EBL** – Estimated Blood Loss
- **ERAS** – Enhanced Recovery After Surgery
- **LOS** – Length of Stay
- **MIS** – Minimally Invasive Surgery
- **MIGS** – Minimally Invasive Gynecologic Surgery
- **OS** – Open Surgery
- **PRISMA** – Preferred Reporting Items for Systematic Reviews and Meta-Analyses
- **RAS** – Robot-Assisted Surgery
- **RCT** – Randomized Controlled Trial
- **SAGES** – Society of American Gastrointestinal and Endoscopic Surgeons
- **SGO** – Society of Gynecologic Oncology

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