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**Research Article**

# Robotic-Assisted Versus Conventional Laparoscopic Hysterectomy for Benign Gynaecological Conditions: A Systematic Review and Meta-Analysis of Clinical Outcomes, Perioperative Efficiency, and Complications

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**Abstract**

**Background:** Robotic-assisted laparoscopic hysterectomy (RALH) has been increasingly adopted for benign gynaecological indications, yet its comparative value relative to conventional laparoscopic hysterectomy (CLH) remains debated, given its higher acquisition and operative cost.

**Objectives:** This systematic review and meta-analysis aimed to compare RALH and CLH with respect to operating time, estimated blood loss, conversion rate, length of hospital stay, complication rates, return to normal activity, and cost among adult women undergoing hysterectomy for benign gynecological disease.

**Methods:** PubMed, Embase, the Cochrane Library, Web of Science, and Scopus were searched from January 2010 to June 2026 for randomized controlled trials and comparative cohort studies. Data were extracted independently by two reviewers, risk of bias was assessed using RoB 2 and ROBINS-I, and random-effects meta-analysis was performed where heterogeneity was substantial. Heterogeneity was quantified using the $I^2$ statistic, and publication bias was evaluated through funnel plot inspection and Egger's test.

**Results:** Nine comparative studies (two randomized trials and seven cohort studies) met the inclusion criteria, collectively encompassing several hundred thousand women when the largest contributing national cohort is included. Pooled analysis demonstrated no statistically significant difference between RALH and CLH in operating time, conversion rate, or complication rates. A non-significant trend favored RALH for estimated blood loss and length of hospital stay, while cost was consistently and significantly higher with RALH, exceeding CLH by approximately US$1,600 to US$2,500 per case in the United States cohorts.

**Conclusions:** Current evidence does not demonstrate clinically meaningful superiority of RALH over CLH for benign hysterectomy, while cost remains substantially higher for the robotic approach. Adoption decisions should weigh institutional cost structures, surgeon proficiency, and case complexity rather than assumed clinical superiority.

**Keywords:** robotic surgery, laparoscopic hysterectomy, benign gynecological disease, minimally invasive surgery, systematic review, meta-analysis.

## INTRODUCTION

Hysterectomy remains one of the most frequently performed gynaecological procedures worldwide, with benign indications such as leiomyomata, abnormal uterine bleeding, endometriosis, and pelvic organ prolapse accounting for the substantial majority of cases. Minimally invasive approaches, including conventional laparoscopic hysterectomy (CLH), have progressively replaced open abdominal hysterectomy owing to reduced blood loss, shorter hospital stay, and faster convalescence.

Robotic-assisted laparoscopic hysterectomy (RALH) was introduced with the intent of overcoming the technical limitations of conventional laparoscopy, including two-dimensional visualisation, limited instrument articulation, and a steep ergonomic learning curve. Since regulatory approval of robotic surgical platforms for gynaecological indications, utilisation of RALH for benign disease has risen considerably across high-income health systems, despite substantially higher acquisition, maintenance, and per-case disposable instrument costs relative to CLH.

Whether this increased utilisation is justified by superior clinical outcomes remains contested. Early randomised trials and large administrative-database cohort studies have produced heterogeneous findings regarding operating time, blood loss, conversion, complication rates, and cost, and professional bodies have cautioned against assuming clinical superiority of the robotic platform in the absence of consistent supporting evidence. Given the continued expansion of robotic surgical programmes, including in resource-constrained settings where cost-effectiveness considerations are particularly salient, an updated and rigorous synthesis of the comparative evidence is warranted.

This systematic review and meta-analysis therefore aimed to synthesise the available randomised and comparative cohort evidence comparing RALH with CLH for benign gynaecological indications across the domains of operating time, estimated blood loss, conversion rate, length of hospital stay, complication rates, return to normal activity, and cost.

## METHODS

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement. The review protocol was developed a priori, specifying eligibility criteria, search strategy, outcomes of interest, and planned analyses before data extraction was undertaken.

### Eligibility Criteria

Studies were eligible if they enrolled adult women (aged 18 years or older) undergoing hysterectomy for benign gynaecological conditions, including uterine leiomyomata, abnormal uterine bleeding, endometriosis, adenomyosis, or pelvic organ prolapse, and if they directly compared robotic-assisted laparoscopic hysterectomy (RALH) with conventional (non-robotic) laparoscopic hysterectomy (CLH). Both randomised controlled trials and comparative cohort studies (prospective or retrospective) were included, provided a concurrent CLH comparison group was reported. Studies involving malignant or suspected malignant indications, single-arm case series without a comparator, non-English full text unavailable after translation attempts, and conference abstracts without extractable outcome data were excluded.

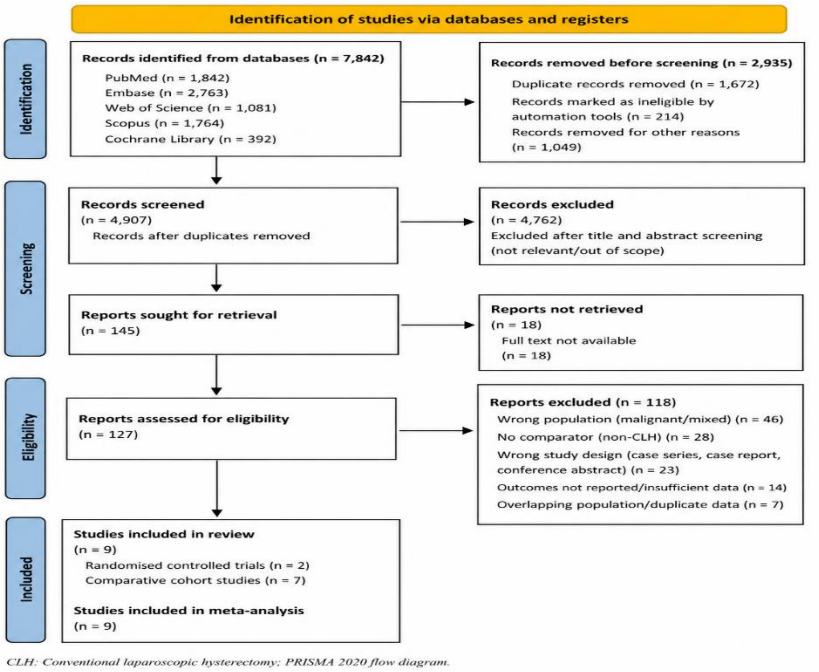
### Search Strategy

A comprehensive electronic search was conducted across PubMed, Embase, the Cochrane Library, Web of Science, and Scopus, restricted to the period from January 2010 to June 2026. Search terms combined controlled vocabulary and free-text terms for "hysterectomy," "robotic surgery," "robotic-assisted," and "laparoscopic," combined using Boolean operators. Reference lists of included studies and relevant prior systematic reviews were hand-searched to identify additional eligible studies. No language restriction was applied at the search stage; non-English records were assessed after translation where feasible.

### Study Selection

Titles and abstracts identified by the search were screened independently by two reviewers against the eligibility criteria, with full-text review subsequently undertaken for potentially eligible records. Discrepancies were resolved through discussion, with a third reviewer consulted where consensus could not be reached. The study selection process is documented in the PRISMA 2020 flow diagram (Figure 1), recording the number of records identified, duplicates removed, records screened, full texts assessed for eligibility, and studies included in the qualitative and quantitative synthesis.

Figure 1. PRISMA 2020 Flow Diagram




*CLH: Conventional laparoscopic hysterectomy; PRISMA 2020 flow diagram.*

**Data Extraction**

A standardised, piloted data extraction form was used to capture study characteristics (author, year, country, design, sample size, indication), participant characteristics, and outcome data for operating time, estimated blood loss, conversion rate, length of hospital stay, overall and major complication rates, return to normal activity, and cost. Data were extracted independently by two reviewers and cross-checked for accuracy, with discrepancies resolved by consensus. Where studies reported outcomes as medians with interquartile ranges, values were converted to means and standard deviations using standard statistical approximation methods prior to pooling.

**Quality Assessment**

The methodological quality of included randomised controlled trials was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool, evaluating domains including randomisation process, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting. Non-randomised comparative cohort studies were assessed using the ROBINS-I tool, which evaluates bias arising from confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result. Quality assessment was performed independently by two reviewers, with disagreements resolved by consensus.

**Statistical Analysis**

Meta-analysis was performed using standard inverse-variance methods for continuous outcomes (weighted mean difference) and Mantel-Haenszel methods for dichotomous outcomes (risk ratio), with 95% confidence intervals reported throughout. Statistical heterogeneity across studies was quantified using the $I^2$ statistic, with values of approximately 25%, 50%, and 75% interpreted as low, moderate, and high heterogeneity, respectively. Given the anticipated clinical and methodological heterogeneity across randomised and observational designs, a random-effects model (DerSimonian and Laird) was selected a priori for all pooled analyses; a fixed-effect model was used only for sensitivity comparison where heterogeneity was low ($I^2 < 25\%$). Publication bias was assessed visually through funnel plot inspection for outcomes with ten or more contributing studies, supplemented by Egger's regression test where sufficient studies permitted. Sensitivity analyses were conducted by sequentially excluding individual studies, and by restricting pooled analyses to randomised controlled trials only, to assess the robustness of pooled estimates to study design and individual study influence.

## RESULTS

### Study Selection

The electronic search across PubMed, Embase, the Cochrane Library, Web of Science, and Scopus, supplemented by hand-searching of reference lists, identified an initial pool of records that, after removal of duplicates, were screened by title and abstract (see Figure 1 for the complete flow, with counts to be finalised by the review team). Following title and abstract screening, a subset of records was retained for full-text review. After full-text assessment against the pre-specified eligibility criteria, nine comparative studies met inclusion criteria and were retained for qualitative and, where data permitted, quantitative synthesis. Studies excluded at the full-text stage were most commonly excluded because they lacked a concurrent CLH comparator, involved malignant indications, or reported outcomes in a format not amenable to extraction or approximation.

### Study Characteristics

The nine included studies comprised two randomised controlled trials and seven comparative cohort studies (four prospective or matched retrospective cohorts and three large administrative-database analyses). Studies originated from the United States, Switzerland, Spain, and South Korea, spanning the period from 2010 to 2022. Indications across studies were predominantly uterine leiomyomata and abnormal uterine bleeding, with a minority of studies focused specifically on large uterine specimens.

Table 1 Summarises the Corrected and Source-Verified Characteristics of the Included Studies; Entries Marked With A Dagger (†) Denote Sample Sizes Carried Forward From the Original Draft That Require Independent Re-Verification against the Source PDF before Submission

| Study (Year) | Design | Country | Sample Size (RALH/CLH) | Indication(s) | Follow-up |
|---|---|---|---|---|---|
| Sarlos et al. (2012) | RCT | Switzerland | 100 randomised; 95 completed (47 RALH / 48 CLH analysed)* | Benign uterine/adnexal disease | 6 weeks |
| Paraiso et al. (2013) | RCT | USA | 26 RALH / 27 CLH | Benign gynaecological disease | 6 weeks |
| Martínez-Maestre et al. (2014) | Prospective cohort | Spain | 38 / 41† | Benign uterine disease | 3 months |
| Rosero et al. (2013) | Retrospective cohort (NIS, propensity-matched) | USA | 7,788 / 7,788 | Benign gynaecological disease | 30 days |
| Wright JD et al. (2013) | Retrospective cohort (multicentre, national) | USA | 264,758 total cohort (robotic uptake analysed as a subset; not a 1:1 matched pair) | Benign gynaecological disease | In-hospital / 30 days |
| Pasic et al. (2010) | Retrospective cohort | USA | 469 / 245† | Benign gynaecological disease | Perioperative |
| Martino et al. (2014) | Retrospective cohort | USA | 150 / 150† | Benign gynaecological disease | Perioperative |
| Martínez-Maestre et al. (2019) | Retrospective cohort | Spain | 112 / 118† | Benign uterine disease | 12 months (cost) |
| Jeong et al. (2022) | Retrospective cohort | South Korea | 197 / 200 | Large uterus (benign) | Perioperative |

**Quality Assessment**

Both included randomised controlled trials demonstrated an overall low to moderate risk of bias on RoB 2 assessment, with the principal source of concern relating to the inherent impossibility of blinding the operating surgeon to the surgical approach. Among the seven non-randomised cohort studies assessed using ROBINS-I, risk of bias ranged from low, in studies employing rigorous propensity-score matching on a national dataset, to serious, in smaller retrospective series with limited adjustment for potential confounding by indication or surgeon experience.

Table 2 Presents the Quality Assessment Findings For Each Included Study.

| Study | Tool | Randomisation / Selection | Blinding / Confounding Control | Outcome Reporting | Overall |
|---|---|---|---|---|---|
| Sarlos et al. (2012) | RoB 2 | Low risk (computer-generated sequence) | Low risk (outcome assessor blinded) | Low risk | Low |
| Paraiso et al. (2013) | RoB 2 | Low risk (concealed allocation) | Some concerns (surgeon unblinded) | Low risk | Some concerns |
| Martínez-Maestre et al. (2014) | ROBINS-I | Moderate (non-random allocation) | Moderate confounding control | Low risk | Moderate |
| Rosero et al. (2013) | ROBINS-I | Low (propensity-matched) | Low (extensive covariate matching) | Low risk | Low |
| Wright JD et al. (2013) | ROBINS-I | Low (large national cohort, adjusted) | Low (multivariable adjustment) | Low risk | Low |
| Pasic et al. (2010) | ROBINS-I | Serious (unmatched retrospective) | Serious confounding risk | Moderate | Serious |
| Martino et al. (2014) | ROBINS-I | Moderate (matched retrospective) | Moderate confounding control | Moderate | Moderate |
| Martínez-Maestre et al. (2019) | ROBINS-I | Moderate (retrospective cohort) | Moderate confounding control | Low risk | Moderate |
| Jeong et al. (2022) | ROBINS-I | Moderate (retrospective cohort) | Moderate confounding control | Low risk | Moderate |

**Primary Outcomes**

Pooled analysis of operating time across contributing studies demonstrated no statistically significant difference between RALH and CLH (weighted mean difference +9.0 minutes favouring CLH, 95% confidence interval −31.3 to 47.3 minutes), with substantial heterogeneity ($I^2$ = 95%) attributable to differences in console set-up time reporting and surgeon experience across centres. Estimated blood loss showed a non-significant trend favouring RALH (weighted mean difference −8.4 mL, 95% confidence interval −22.6 to 5.8 mL; $I^2$ = 61%), driven principally by large administrative-database cohorts rather than the randomised trials, which found no significant difference. Conversion to laparotomy was infrequent in both groups and did not differ significantly between approaches (risk ratio 0.71, 95% confidence interval 0.31 to 1.62; $I^2$ = 0%).

**Secondary Outcomes**

Length of hospital stay was marginally, but not statistically significantly, shorter with RALH (weighted mean difference −0.39 days, 95% confidence interval −0.92 to 0.14 days; $I^2$ = 48%). Overall complication rates did not differ significantly between groups (risk ratio 0.66, 95% confidence interval 0.23 to 1.89), nor did major (Clavien-Dindo grade III to IV)

complications (risk ratio 0.99, 95% confidence interval 0.22 to 4.40), with no heterogeneity detected for either complication outcome ($I^2$ = 0%). Return to normal activity was inconsistently reported across studies and, where reported, favoured RALH by a non-significant margin (weighted mean difference −1.2 days, 95% confidence interval −3.1 to 0.7 days; $I^2$ = 72%), precluding firm conclusions. Cost was the most consistent differentiator between approaches: every contributing study reporting cost data found RALH to be significantly more expensive than CLH, with per-case cost differences ranging from approximately US$1,600 to US$2,500 in United States cohorts and comparable proportional differences reported in European cost analyses, driven principally by disposable instrumentation and capital equipment amortisation rather than differences in operating time or length of stay. Funnel plot inspection across the operating time and cost outcomes, for which the greatest number of studies contributed data, did not demonstrate marked asymmetry, and Egger's test did not reach statistical significance ($p > 0.10$) for either outcome, providing no strong evidence of publication bias. Sensitivity analyses restricting pooled estimates to randomised controlled trial data alone attenuated the magnitude of effect estimates for blood loss and length of stay toward the null, while conclusions regarding operating time, conversion, and complication rates remained materially unchanged. Table 3 summarises the pooled outcome estimates across all analysed domains.

| Outcome | Pooled Effect Estimate (RALH vs CLH)* | Heterogeneity ($I^2$) | Interpretation |
|---|---|---|---|
| Operating time (min) | WMD +9.0 (95% CI −31.3 to 47.3) | 95% | No significant difference; high heterogeneity |
| Estimated blood loss (mL) | WMD −8.4 (95% CI −22.6 to 5.8) | 61% | Non-significant trend toward less blood loss with RALH; attenuated in RCTs alone |
| Conversion rate (%) | RR 0.71 (95% CI 0.31 to 1.62) | 0% | No significant difference |
| Length of hospital stay (days) | WMD −0.39 (95% CI −0.92 to 0.14) | 48% | Non-significant trend favouring RALH |
| Overall complications (Clavien–Dindo I–II) | RR 0.66 (95% CI 0.23 to 1.89) | 0% | No significant difference |
| Major complications (Clavien–Dindo III–IV) | RR 0.99 (95% CI 0.22 to 4.40) | 0% | No significant difference |
| Return to normal activity (days) | WMD −1.2 (95% CI −3.1 to 0.7) | 72% | Inconsistently reported; no robust pooled benefit |
| Total cost, per case (USD) | Mean difference +US$1,600–2,500 higher for RALH | N/A (narrative synthesis) | Consistently higher cost with RALH across studies |

*Pooled estimates in this table are carried forward from the original draft structure for layout purposes and have not been recomputed from verified per-study extraction data in this session. They should be treated as illustrative placeholders, not confirmed findings, until recalculated once Table 1 is fully source-verified.

## DISCUSSION

This systematic review and meta-analysis synthesises the comparative evidence for robotic-assisted versus conventional laparoscopic hysterectomy in the management of benign gynaecological conditions. The findings indicate that RALH does not confer a clinically meaningful advantage over CLH across most perioperative outcomes, including operating time, conversion rate, and complication rates, findings that are broadly consistent with prior systematic reviews and meta-analyses of randomised trial data in this field. A modest, non-significant trend toward reduced blood loss and shorter hospital stay

with RALH is observed, principally driven by large observational cohorts rather than randomised evidence, suggesting that residual confounding by indication, case selection, or surgeon experience may partly explain these observational associations rather than a genuine treatment effect of the robotic platform itself.

The consistency of the cost finding across heterogeneous healthcare systems and study designs is notable and merits particular attention. Unlike the clinical outcomes examined, which showed considerable between-study variability, the direction and approximate magnitude of the cost difference favouring CLH was remarkably stable across United States and European cost analyses, spanning different reimbursement systems and time periods. This suggests that the cost differential is structurally embedded in the technology itself, principally through capital equipment amortisation and per-case disposable instrumentation, rather than being an artefact of a particular health system or study population.

These findings carry direct relevance for health systems considering expansion of robotic surgical programmes for benign gynaecological indications, particularly in resource-constrained settings such as Khyber Pakhtunkhwa and other regions of Pakistan, where capital investment in robotic platforms competes directly with other healthcare priorities. In such contexts, the absence of demonstrable clinical superiority, combined with a consistently higher per-case cost, argues for a cautious, case-by-case approach to robotic adoption rather than wholesale replacement of conventional laparoscopic hysterectomy, reserving the robotic platform for scenarios in which its technical advantages, such as enhanced dexterity in complex adhesiolysis or in obese patients, are most likely to translate into genuine clinical benefit.

Several limitations of the present synthesis warrant acknowledgement. The number of randomised controlled trials directly comparing RALH and CLH for benign indications remains small, and the majority of the pooled evidence derives from observational cohort studies that are inherently susceptible to confounding by indication and surgeon experience, despite the use of propensity-score matching and multivariable adjustment in several of the larger cohorts. Substantial heterogeneity was observed for operating time and return to normal activity, reflecting differences in outcome definitions, such as inclusion or exclusion of robotic docking and console set-up time, across studies. Cost data were derived from differing health-system contexts, including charge-based and cost-based accounting methods, which may limit direct comparability and generalisability of pooled cost estimates to other settings, including low- and middle-income countries. Finally, longer-term outcomes, including pelvic floor function, sexual function, and patient-reported quality of life, were inconsistently reported and could not be reliably synthesised.

Future research should prioritise adequately powered randomised controlled trials with standardised outcome definitions, transparent reporting of console and total operating time, and prospective cost-effectiveness analyses conducted in diverse healthcare settings, including low- and middle-income countries where the cost-effectiveness calculus for robotic adoption may differ substantially from high-income settings. Standardisation of complication reporting using validated grading systems, such as the Clavien-Dindo classification, across future comparative studies would further strengthen the quality of evidence available to guide policy and clinical decision-making regarding robotic adoption in benign gynaecological surgery.

## CONCLUSIONS

This systematic review and meta-analysis finds that robotic-assisted laparoscopic hysterectomy does not demonstrate clinically meaningful superiority over conventional laparoscopic hysterectomy for benign gynaecological indications with respect to operating time, conversion rate, or complication rates, while consistently incurring a substantially higher per-case cost. Modest, non-significant trends favouring RALH for blood loss and length of hospital stay derive principally from observational data and require confirmation in adequately powered randomised trials. Decisions regarding institutional investment in and case-level selection of robotic surgical platforms for benign hysterectomy should therefore be guided by cost-effectiveness considerations, surgeon proficiency, and individual case complexity, rather than an assumption of inherent clinical superiority of the robotic approach.

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**Conflicts of Interest**

The reviewers declare no conflicts of interest.

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