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RESEARCH

Innovative classification system for enlarged uterus in laparoscopic and robotic hysterectomy with complications and pain scores

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Abstract

The aim of this study was to compare the surgical outcomes of robot-assisted hysterectomy (RAH) with those of conventional laparoscopic hysterectomy (CLH) for large uteri via a novel classification system. Ambispective analysis of 237 cases was performed, comprising 90 retrospectively reviewed cases and 147 prospectively enrolled cases. Patients were categorized into two main groups based on surgical procedure (RAH and CLH) and three subgroups each (type 1 (T1), type 2 (T2), and type3 (T3)) based on uterine size. Key outcomes, including the operative time and perioperative complications, were analyzed. Quality of life was assessed using the EuroQol-5 Dimensions and the Female Sexual Function Index questionnaires. The surgeon's learning curve was evaluated using surgical data. Among 237 patients, 47.3% underwent RAH and 52.7% underwent CLH. RAH was preferred for larger uteri (T3: 888.8 ± 136 g) vs. CLH (T3: 778.8 ± 83.7 g, $P < 0.001$). However, compared with CLH, RAH had a longer operative time, lower blood loss (RAH, T3: 107.8 ± 69.8 mL vs. CLH, T3 309 ± 248.4 mL, $P < 0.001$), better hemoglobin recovery, and shorter hospitalization ($P < 0.05$). Most of the complications (ureteric injury, laparotomy conversion, gastrointestinal injuries) occurred only in the CLH group, whereas vascular and bladder injuries were observed in both groups. Pain scores normalized by the 4th week, patient satisfaction was greater in RAH group (RAH 75.3% vs CLH 72.3%), and sexual function was comparable. Surgeon's experience improved over time, especially for large uteri. RAH is associated with more favorable outcomes than CLH, especially with regard to larger uteri (T3).

Keywords Hysterectomy · Classification · Enlarged uterus · Quality of life · Learning curve

Abbreviations

CLH	Conventional laparoscopic hysterectomy
RAH	Robotic assisted hysterectomy
MIS	Minimal invasive surgery
GI Injury	Gastrointestinal injury
BMI	Body mass index
EBL	Estimated blood loss
LUCS	Large uterine classification system
QoL	Quality of life
EQ-5D	EuroQol-5 dimension
FSFI	Female sexual function index
T1	Type1
T2	Type2
T3	Type3

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Introduction

Hysterectomy is a commonly performed gynecologic surgical procedure that may be associated with significant morbidity and mortality risks. The evolution of surgical techniques from open surgery to minimally invasive surgery (MIS) has markedly improved patient outcomes by reducing perioperative complications, pain, and the length of hospital stay. MIS is overtaking the abdominal approach as the preferred treatment [1].

Benign gynecological conditions often go unrecognized in many cases, yet they considerably impact a woman' s risk of infertility, her ability to fulfill familial obligations, and her function as a sexual partner [2]. Fibroids and adenomyosis are the most common causes of a benign large uterus and usually cause pelvic or back pain, as well as abdominal distention and/or pressure symptoms. Particularly in low-resource environments, late presentation allows for significant growth of fibroids, which results in patient presentation with a large uterus. Moreover, the size of the uterus is a major limiting factor, and not all women who undergo hysterectomy can benefit from MIS [3].

Experienced laparoscopic surgeons have documented the successful and safe performance of CLH in patients with large uteri. However, the operative duration, incidence of intraoperative hemorrhage, and conversion rate to open surgery may be elevated under these conditions [4]. Robot-assisted technology may overcome the constraints of laparoscopy by enhancing the surgeon's dexterity and, with improved 3D imaging, achieve more precision, particularly in confined surgical areas [5]. The idea of obvious benefits and Food and Drug Administration approval of the da Vinci Surgical System led to the adoption of RAH. Despite insufficient evidence supporting its superiority, RAH has gained significant popularity over other MISs because fewer complications are associated with this method. Recently, robotic-assisted surgeries have been utilized more frequently to manage most of the gynecological conditions that require surgery [6]. Nonetheless, the benefit of robotic-assisted surgery in instances of markedly enlarged uteruses is still unclear. Therefore, it is essential to compare the alternative minimally invasive methods that are being utilized to treat these patients.

A considerable amount of research in the literature has demonstrated a correlation between uterine size, operative time, and EBL (estimated blood loss) in MIS [7]. However, to the best of our knowledge, only two studies have explored a research focus similar to ours. The first, conducted by Mohamed Elessawy et al. in 2020, assessed postoperative quality of life (QoL) using a telephone questionnaire to evaluate the benefits of RAH over CLH for benign indications, focusing solely on postoperative QoL assessment [8]. The second, by S. Uccella et al. in 2021, introduced the Large Uterus Classification System (LUCS) to predict surgical outcomes based on uterine size, but this classification was applied only to laparoscopic hysterectomy patients [9]. In our study, we integrate the objectives of both studies into a single comprehensive analysis.

The basis of our study depends on idea that specific uterine size at which minimally invasive hysterectomy becomes clinically challenging remains unclear, and the feasibility of robotic and laparoscopic surgery for benign large uteri lacks established criteria. The present study addresses this gap by evaluating surgical outcomes and postoperative QoL across different uterine weights. The findings aim to clarify the feasibility of robotic and laparoscopic surgery for benign large uteri and establish evidence-based selection criteria.

Methods

The present study utilized an ambispective cohort design in a single tertiary care center. A total of 237 patients including 90 retrospective cases (April 2021–December 2022) and 147 prospective cases (January 2023– April 2024) were included. To achieve the study's objective, an ambispective methodology was chosen, combining retrospective and prospective data to ensure a sufficient sample size. This approach allowed the cohort to be divided into six subgroups from two main groups for detailed analysis. This approach has been previously used in the literature, enabling sufficient sample sizes and real-time validation, which makes it ideal for addressing complex research questions [10].

This study was not registered, as it did not involve a clinical trial but rather an observational cohort design focusing on surgical outcomes and QoL. We focused our analysis on clinical factors rather than economic aspects of the operation; therefore, the cost of treatment was not assessed.

Patient selection

A cohort of 240 patients who underwent hysterectomy between April 2021, and April 2024, were initially considered for analysis. Of these, 237 patients met the inclusion criteria. The inclusion criteria consisted of patients who underwent CLH or RAH for symptomatic benign large uteri (≥ 300 g) due to fibroids or adenomyosis, with complete preoperative imaging and laboratory workup. The exclusion criteria were concomitant procedures (pelvic organ prolapse repair and urinary incontinence treatment), postoperative malignancy, incomplete demographic or surgical data and inadequate follow-up.

Surgical procedure

Prior to treatment, surgeons obtained written informed consent from all patients after thoroughly explaining the surgical procedure and its potential risks. The first step of the surgical procedure involved positioning the patient in the standard supine lithotomy position. After anesthesia, Foley catheter was placed, and prophylactic antibiotics were administered. For the laparoscopic procedure, three 5-mm trocars and a 12-mm umbilical trocar were used. In the robotic-assisted surgeries, the da Vinci Xi robot system was employed. A 12 mm camera port was used, and three 8 mm trocars were positioned. All of the included cases were handled by one assistant port. Larger uteri were extracted either by in-bag morcellation through an extended port site/mini-laparotomy or, when feasible, delivered intact vaginally. The urinary catheter was typically removed on postoperative day 1.

The primary outcome measures included the operative time and incidence of perioperative complications. All the variables were collected from the corresponding patients' electronic medical records. We defined operative time as the time from the first incision to wound closure; in the robotic group, it also included the duration of robotic docking but not the time taken for initial robot assembly prior to surgery. Uterine size was assessed preoperatively (ultrasound/MRI) and postoperatively (pathology). The groups were stratified as follows: mild (T1: 300–450 g, 8–12 weeks, no pedicle displacement), moderate (T2: 450–700 g, 13–16 weeks, cranial displacement of the adnexal pedicles), and severely enlarged (T3: (> 700 g, 17–20 weeks, pedicle displacement cranially or left–right). The secondary outcome measures included patient satisfaction and the learning curve of the surgeon.

Design of questionnaire

We used a questionnaire designed by our research team based on two validated questionnaires: the Female Sexual Function Index (FSFI) [11] and the health-related QoL questionnaire EuroQol-5 Dimensions (EQ-5D) [12], which involves a total of 16 questions [13]. The questions were reviewed by the consultant surgeons and our research team. The questionnaire was administered as follows: the first follow-up was at the 3rd postoperative month, and early recovery and initial QoL changes were assessed via EQ-5D. FSFI was avoided at this stage since the patients did not fully recover physically. The second follow-up was around the 6th month postoperatively, and the FSFI was used to evaluate the postoperative impact on the patients'sexual lives. Patients were asked for permission to complete a questionnaire at their OPD appointments, and if they agreed, the questionnaire was handed over to them. Patients who were unable to complete the questionnaire at the OPD were provided an option for trans-telephonic administration of the questionnaire. The questionnaire was applied only to cases collected prospectively in this ambispective study to avoid recall bias associated with retrospectively collected data. Among 147 prospective cases, 142 responded to our questionnaire.

The EQ-5D evaluated general health (rated from very poor to very good), pain levels (0–10 scale), pain medication duration, recovery time for daily activities (1, 2–4, or 5–8 weeks), and cosmetic outcomes (satisfaction and reasons for dissatisfaction). The FSFI assessed sexual function (desire, lubrication, orgasm, pain, anxiety; score 0–5 per category), time to resume sexual activity, and limiting factors (e.g., pain or fear, score 0–5). All the responses were clinician-verified for accuracy.

Learning curve assessment

In addition, we analyzed the learning curve of surgeons in robotic cases. It was evaluated on the basis of surgical data, body mass index (BMI), EBL, setup time, robot time, and total operative time.

Statistical analysis

All the statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS for Windows, version 27; IBM Corp., Armonk, NY, USA). A *P*-value of less than 0.05 was considered statistically significant. When multiple comparisons were made, Bonferroni correction was applied to adjust the significance threshold accordingly. Categorical variables are presented as means (± standard deviations), while continuous variables are expressed as counts and percentages. The chi-square test was applied to analyze categorical variables. The Shapiro–Wilk test was used to evaluate the homogeneity of the data distribution. For continuous data that did not follow a normal distribution, non-parametric tests were employed, including the Kruskal–Wallis test for comparisons across six groups and the Mann–Whitney U test for comparisons between two groups. For normally distributed variables, parametric tests such as the t-test (for two groups) and One-Way ANOVA (for more than two groups) were used to compare means.

Results

Operative data

During the study period, 237 patients with a uterus extending to or beyond the transverse umbilical line (> 300 g) had CLH or RAH. The surgery was performed laparoscopically in 125 patients (52.7%) and robotically in

112 patients (47.3%). In the RAH group, 31.3% of patients were in T1, 35.7% were in T2, and 33.0% were in T3, whereas in the CLH group, 49.6% of patients were in T1, 29.6% were in T2, and 20.8% were in T3, indicating a more even distribution in the robotic group; however, T1 predominated in the laparoscopic group.

The two groups (RAH vs CLH) were comparable in terms of demographic characteristics, reporting similar age and BMI. However, they had significantly different clinical characteristics and surgical outcomes. Compared with the CLH group (778.8 ± 83.7 g), the RAH group had a significantly greater uterine weight (888.8 ± 136 g) ($P < 0.001$). Comorbidities were generally low and comparable; however, patients with gallstones as comorbidities were found more frequently in the robotic group ($P = 0.079$). The primary distinction among the groups was uterine weight. The patients' clinical and demographic characteristics are reported in Table 1.

The operation time increased with uterine weight in both groups, with a shorter time in T1 (102.3 ± 27.3 min vs. 81.3 ± 22.9 min) and T2 (135.7 ± 51.5 min vs. 112.5 ± 35.2 min) but a longer time in T3 of the RAH than in the CLH (222.8 ± 70.3 min vs. 241.2 ± 54.2 min). The EBL was consistently lower in the RAH group across all categories, with the difference most pronounced in T3, where the RAH was 107.8 ± 69.8 ml compared with 309 ± 248.4 ml in the CLH group. Postoperative hemoglobin levels were higher in the RAH group than in the CLH group across all categories, indicating better preservation of blood volume, with a significant difference observed in T3 (102.9 ± 21.8 g/L for RAH vs. 92.1 ± 18.5 g/L for CLH). Postoperative white blood cell counts were slightly higher in robotic T3 patients than in laparoscopic patients (11.1 ± 3.6 vs. 9.7 ± 2.8 × 10^9/L), although both values remained within the normal range. There were no notable differences in urinary catheter removal times (averaging 1.8–1.9 days in both groups, P = 0.404). However, hospital stays were shorter in the robotic group across all categories, particularly in T3 (2.0 ± 0.5 days vs. 3.1 ± 1.4 days, $P < 0.001$), as shown in Table 2. These findings highlight the potential benefits of RAH in reducing blood loss and hospital stays, especially in cases involving larger uteri, despite longer operative times in more complex cases.

The analysis of intra- and postoperative complications between RAH and CLH revealed key differences. Blood transfusions were required in 2.9% of patient from T1 and 5% from T2 in the RAH group, whereas in the CLH group, transfusions were needed in 3.2% of patients from T1, 8.1% from T2, and 11.5% from T3. Ureteric injuries were reported only in the CLH group, occurring in 2.7% of the T2 patients and 11.5% of the T3 patients ($P = 0.002$). Bladder injuries were observed in both groups, occurring in 2.7% of the robotic T3 patients and 3.9% of the laparoscopic T3 patients. Gastrointestinal injuries (GI injuries) were observed only in the laparoscopic group, affecting 5% of the T2 uteri and 5.7% of the T3 uteri. Vascular injuries were observed in both groups, occurring in 2.9% of the robotic T1 group, 1.6% of the laparoscopic T1 and 2.7% of the T2 group. Urinary tract infections were minimal, with no significant differences between the groups. Deep venous thrombosis was observed only in laparoscopic T3 patients (3.9%). Reoperations and wound complications were rare and comparable across both groups, with no statistically significant differences. Moreover, conversion to open surgery and re-operation were observed in two cases of CLH group. Tables 3

Table 1 Presentation of baseline characteristics of all the included patients

Demographic characteristics	RAH (n = 112)			CLH (n = 125)			*P* Value
	T1 (n = 35)	T2 (n = 40)	T3 (n = 37)	T1 (n = 52)	T2 (n = 44)	T3 (n = 29)	
Age	48.0 ± 2.3	47.6 ± 2.0	47.4 ± 2.1	46.8 ± 3.3	47.7 ± 3.9	47.7 ± 4.1	0.451
BMI (kg/m^2)	25.4 ± 2.2	25.7 ± 3.0	25.4 ± 2.6	25.3 ± 3.2	24.8 ± 3.5	25.7 ± 3.3	0.617
Uterine Weight (g)	365.1 ± 59.8	540.1 ± 78.8	888.8 ± 136	292 ± 72.9	499.3 ± 48.8	778.8 ± 83.7	< 0.001
Pre operative HGB g/L	118.8 ± 19.5	117.9 ± 27.5	124.5 ± 48.1	105.5 ± 22.6	105.1 ± 18.8	191.1 ± 55.1	< 0.001
Comorbidities, n (%)							
Hypertension	1 (2.9)	2 (5)	2 (5.4)	1 (1.6)	1 (2.7)	0 (0)	0.769
Diabetes Mellitus	0 (0)	3 (7.5)	0 (0)	0 (0)	0 (0)	1 (3.8)	0.037
Hyperthyroidism	1 (2.9)	1 (2.5)	2 (5.4)	0 (0)	1 (2.7)	1 (3.8)	0.692
Coronary Artery Disease	0 (0)	1 (2.5)	3 (8.1)	0 (0)	0 (0)	1 (3.8)	0.083
Fatty Liver	2 (5.7)	1 (2.5)	0 (0)	0 (0)	1 (2.7)	0 (0)	0.311
Gallstone	3 (8.6)	1 (2.5)	1 (2.7)	0 (0)	0 (0)	0 (0)	0.079

BMI body mass index, *HGB* hemoglobin

Table 2 Comparison between RAH and CLH across different uterine weight groups (T1, T2, and T3) revealing significant differences in several key operative and post-operative parameters

Operative outcomes	RAH (n = 112)			CLH (n = 125)			*P* Value
	T1 (n = 35)	T2 (n = 40)	T3 (n = 37)	T1 (n = 52)	T2 (n = 44)	T3 (n = 29)	
Operation Time (Min.)	102.3 ± 27.3	135.7 ± 51.5	222.8 ± 70.3	81.3 ± 22.9	112.5 ± 35.2	241.2 ± 54.2	<0.001
Estimated Blood Loss (ml)	42.6 ± 35.6	61.4 ± 31.5	107.8 ± 69.8	57.6 ± 105.3	102.4 ± 45.2	309 ± 248.4	<0.001
Post-operative HGB g/L	110.3 ± 21.1	105.8 ± 19.4	102.9 ± 21.8	99.6 ± 26.7	100 ± 21.8	92.1 ± 18.5	0.011
Post-operative WBC 10^9/L	9.0 ± 2.8	9.2 ± 3.1	11.1 ± 3.6	8.6 ± 2.7	10.5 ± 3.5	9.7 ± 2.8	<0.001
Urinary Catheter Removal (Day)	1.8 ± 0.6	1.8 ± 0.5	1.8 ± 0.4	1.9 ± 0.4	1.8 ± 0.5	1.8 ± 0.4	0.404
Hospital Stay (Day)	2.1 ± 0.8	2.2 ± 0.6	2.0 ± 0.5	2.6 ± 0.8	2.7 ± 1.0	3.1 ± 1.4	<0.001

HGB hemoglobin, *WBC* white blood cell

Table 3 Comparison of intraoperative complications between RAH and CLH across uterine weight groups (T1, T2, and T3)

Intraoperative complications	RAH (n = 112)			CLH (n = 125)			*P* Value
	T1 (n = 35)	T2 (n = 40)	T3 (n = 37)	T1 (n = 52)	T2 (n = 44)	T3 (n = 29)	
Blood Transfusion	1 (2.9)	2 (5)	0 (0)	2 (3.2)	3 (8.1)	3 (11.5)	0.292
Ureteric Injury	0 (0)	0 (0)	0 (0)	0 (0)	1 (2.7)	3 (11.5)	0.002
Bladder Injury	0 (0)	0 (0)	1 (2.7)	0 (0)	0 (0)	1 (3.9)	0.325
Conversion to Laparotomy	0 (0)	0 (0)	0 (0)	0 (0)	1 (2.7)	0 (0)	0.366
Lysis of Adhesion	7 (20)	6 (15)	3 (8.1)	8 (12.9)	5 (13.5)	4 (15.4)	0.811
GI Injury	0 (0)	0 (0)	0 (0)	0 (0)	2 (5)	2 (5.7)	0.115
Vascular Injury	1 (2.9)	0 (0)	0 (0)	1 (1.6)	1 (2.7)	0 (0)	0.746

GI injury gastrointestinal injury

Table 4 Summary of the incidence of postoperative complications in the RAH and CLH groups

Postoperative Complications	RAH (n = 112)			CLH (n = 125)			*P* Value
	T1 (n = 35)	T2 (n = 40)	T3 (n = 37)	T1 (n = 52)	T2 (n = 44)	T3 (n = 29)	
Urinary Tract Infection	0 (0)	0 (0)	1 (2.7)	1 (1.6)	1 (2.7)	0 (0)	0.765
Deep Venous Thrombosis	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (3.9)	0.148
Wound Complication	0 (0)	1 (2.5)	1 (2.7)	1 (1.6)	1 (2.7)	0 (0)	0.893
Re-Operation	0 (0)	0 (0)	0 (0)	1 (1.6)	0 (0)	0 (0)	0.725
Death	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	

and 4 summarize the intraoperative and postoperative complications in the RAH and CLH groups.

QoL questionnaire

In the first week following surgery, both surgical methods resulted in high pain scores, with values of approximately 8, suggesting substantial postoperative discomfort. Nevertheless, the pain scores for both methods decreased significantly to approximately 2 by 4 weeks, indicating substantial pain reduction and improvement over time. These findings suggest that the recovery patterns for pain management in the early postoperative period are similar for these surgical techniques, as shown in Fig. 1. The data indicated that the painkiller intake of both the RAH and CLH methods were comparable in first 4 weeks postoperatively, shown in Fig. 2. In regard to postoperative cosmetic satisfaction, patients were comparably satisfied with both approaches, with almost the same degree of dissatisfaction due to the number of scars, scar appearance, painful/

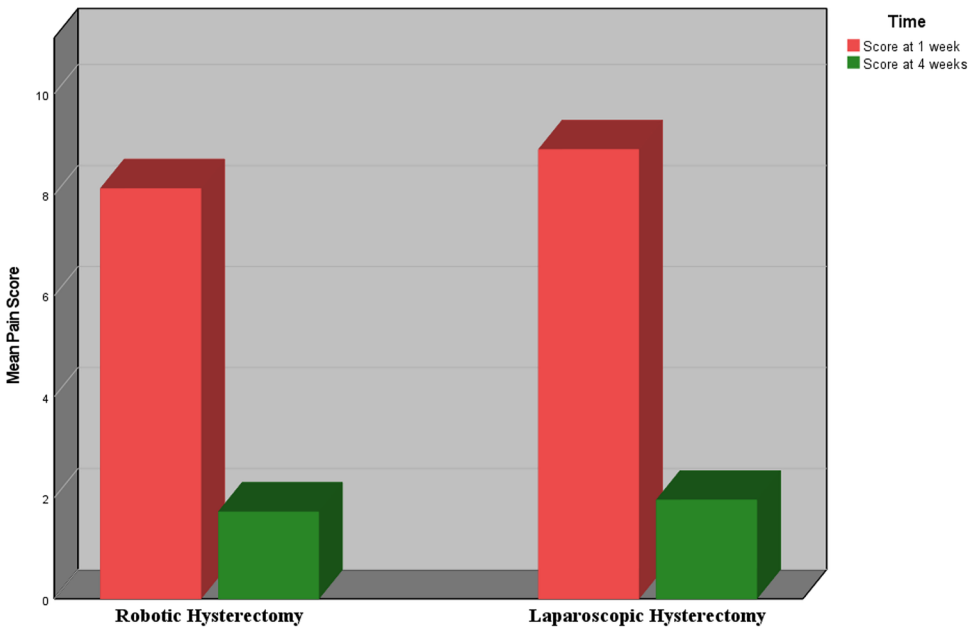

Fig. 1 Comparison of mean pain scores between the RH and LH groups at 1 st week and 4 th week postoperatively, highlighting the trend in pain reduction over time and differences in recovery outcomes between the two surgical approaches

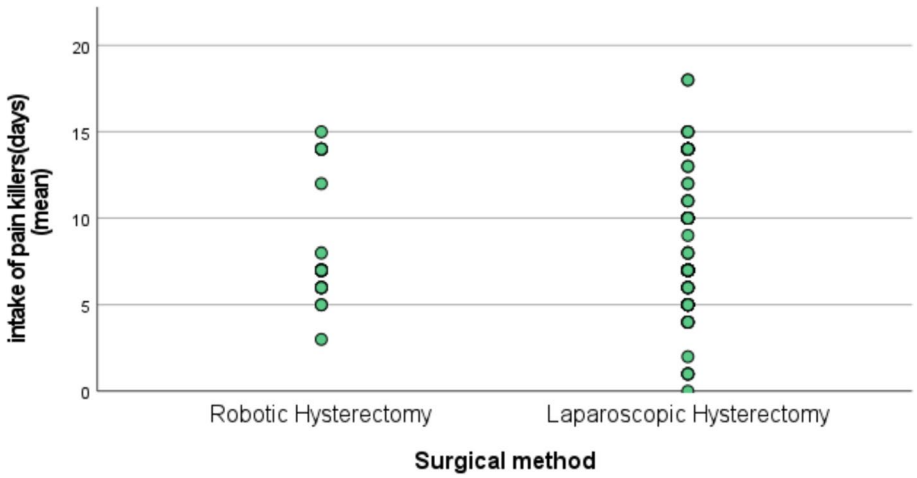

Fig. 2 Duration of postoperative pain medication use in both groups based on how long patients required pain medications: (3 weeks postoperatively)

sensitive scarring and position of the scar, as described in Fig. 3.

In the RAH, 28.6% of patients reported no sexual dysfunction, whereas this percentage was slightly higher at 31.2% in the CLH. Fear was more common in the CLH, affecting 23.2% of the CLH, whereas it affected 20.5% of the RAH. Issues with sexual desire/pleasure were similar, reported by 28.6% in the RAH and 26.4% in the CLH as demonstrated in Fig. 4.

Learning curve

The surgeon's learning curve was influenced by variations in uterine size. As the uterine weight increased, the operative time also increased, reflecting the added complexity of the procedure. Larger uteri (T2 and T3) require more setup time due to adjustments in equipment, positioning, and stabilization, as well as customization of the surgical approach. The robotic time and total operative time also increased with increasing uterine size, and there was a significant increase in blood loss. These factors suggest that the learning curve was steeper for more challenging cases, requiring the surgeon to adapt to the complexities of handling larger uteri as evident in Fig. 5.

Discussion

This study aimed to compare the outcomes of RAH and CLH on the basis of uterine size in patients with large uteri and revealed that RAH has a longer operative time but lower EBL. Postoperative WBCs were lower in the CLH, hospital

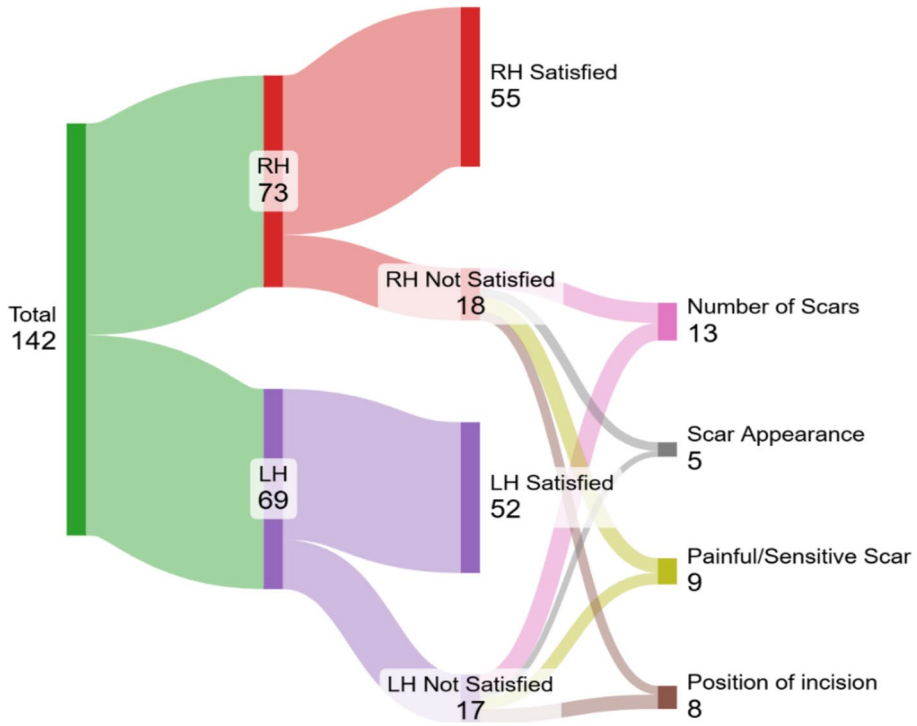

Fig. 3 Cosmetic outcomes in both surgical groups, including patient satisfaction, dissatisfaction and reasons for dissatisfaction

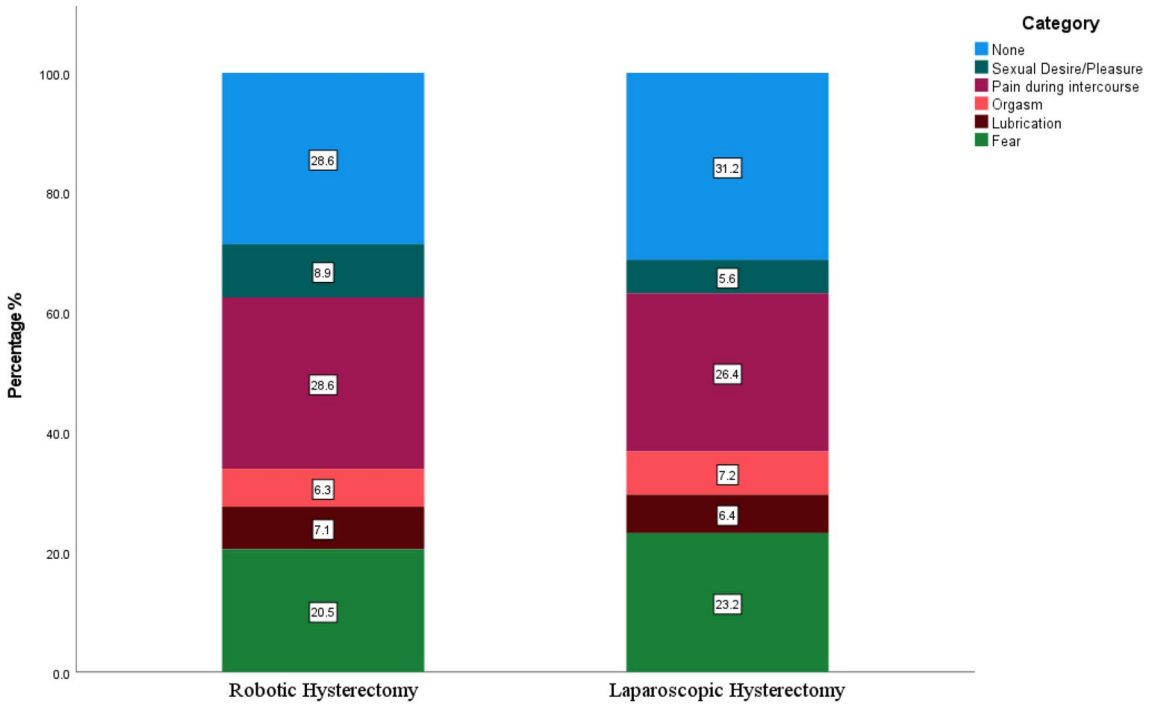

Fig. 4 Postoperative comparison of sexual activity revealing that fear and pain during intercourse were the most frequent limitations

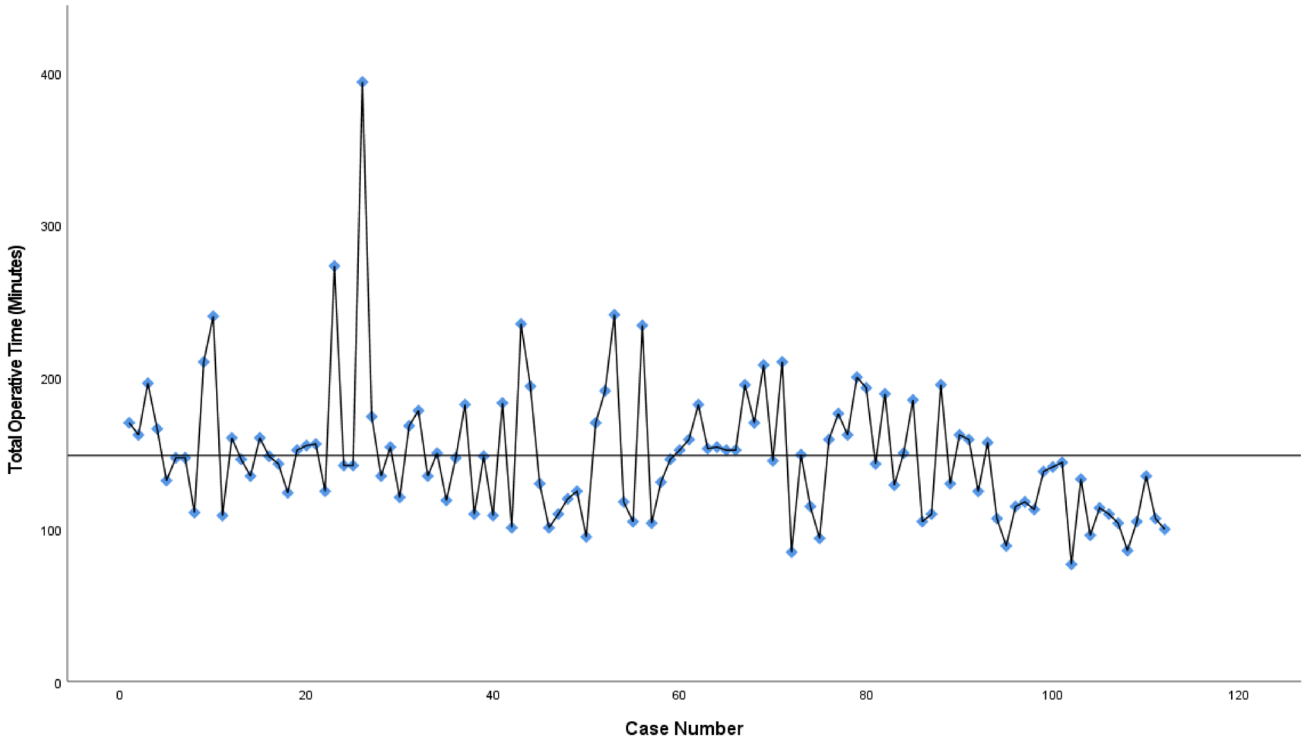

Fig. 5 Surgeon's gradual mastery of RH, with operative time progressively decreasing, signifying the positive impact of experience and skill development on the surgical process

stay was shorter in the RAH group, intraoperative and postoperative complications were slightly more prevalent in the CLH group. QoL was slightly higher in the RAH group, whereas no significant difference was observed in postoperative pain, the use of painkillers, cosmetic satisfaction and sexual function improvement.

The robotic-assisted group included patients with significantly larger mean uterine weight, likely due to the greater adoption of robotic surgery, fewer laparoscopic procedures, and increased complexity of surgeries involving larger uteri. A study by A. Perutelli et al. revealed that RAH is a feasible and safe alternative for managing large uteri, offering favorable perioperative outcomes such as the conversion rate, EBL, length of hospital stay, and complications [14]. However, laparoscopic surgery does not establish itself as the standard of care for complex cases, as seen in our study, where it was less frequently used for T3 uterine removal. This is likely due to the need for advanced laparoscopic skills and extended training. Despite this, laparoscopic surgery has acceptable perioperative outcomes, although it is associated with more intraoperative complications.

Compared with CLH, RAH resulted in slightly longer operative times but with lower EBL and favorable postoperative recovery. This aligns with a 2017–2023 review highlighting the high incremental cost and longer operative times of robotic surgery but better postoperative outcomes [15]. The extended operative time for high-weight uteri is mainly due to prolonged extraction and setup times, which are influenced by equipment changes and surgical techniques. Our study revealed that uterine weight significantly impacted the operative time, with extraction and setup times increasing for uteri > 700 g, especially those > 1000 g. Previous studies reported median operative times of 76 min for uteri < 250 g, 79.5 min for those 250–500 g, and 100 min for those > 500 g [10]. Similarly, in our study, the total operative time for the RAH group increased from 102.3 ± 27.3 min for small uteri (T1) to 222.8 ± 70.3 min for large uteri (T3), reflecting the impact of uterine size on surgical duration. Prolonged extraction times were due to in-bag morcellation or coring for large myomatous uteri, either vaginally or through mini-laparotomy. However, a previous study demonstrated that using the same team for all robotic gynecologic cases that are extremely proficient in docking and undocking can decrease the operative time. Moreover, the use of robot will decrease the operative time by allowing faster dissection [16].

Surgical complexity is influenced by factors such as the presence of uterine mass and pelvic adhesions. In our study, perioperative complications increased with uterine weight and pelvic adhesions which is consistent with previous findings that large uterine mass and pelvic adhesions is

main contributor of intraoperative complications [17]. The frequency of complications was lower in the T1 uteri than in the T2 and T3 uteri. Ureteric injury occurred in four laparoscopic cases (1.7% of the total), all in T2 and T3, with no injuries observed in the robotic cohort. Similarly, GI injury was observed in only four patients in the CLH group. Ureteric injuries and GI injury in CLH for larger uteri are more common because of the limited surgical space and steep learning curve, increasing the risk of anatomical misidentification. However, in contrast to our findings, one study reported slightly more ureteric injuries with RAH [18]. In addition, bladder injury and vascular injuries were the same in both groups in our study. Furthermore, there was conversion to open surgery in one patient in the CLH group due to severe adhesion, and another patient in the CLH group needed re-operation due to vaginal cuff bleeding. A recent study comparing RAH with CLH reported no instances of conversion to laparotomy. However, two cases were complicated by bladder laceration in CLH, one involving a patient with a history of one prior Cesarean section and a uterine specimen weighing 540 g. The other case involved a patient with two prior Cesarean sections and a uterine specimen weighing 570 g [4].

Our analysis revealed that the CLH group required more blood transfusions than did the RAH group for the T2 and T3 uteri, despite lower rates of hemorrhage and hematoma. These findings are consistent with those of previous studies, which highlighted the superior bleeding control of the RAH, with robotic surgery facilitating effective hemostasis [19]. Our study revealed no significant difference in the length of hospital stay between the two approaches, which contrasts with the findings of Brunes et al., who reported shorter stays for robotic procedures. This discrepancy may be attributed to our standardized postoperative care protocols [20]. Notably, T3 CLH patients had longer hospital stays, averaging 2 days or more. These results diverge from those of previous studies that reported a median stay of 1 day, with 75% of patients discharged within 2 days [21]. One study suggested that admitting patients on the day of surgery, rather than the day before, could reduce both hospital stays and costs, especially for RAH, which is generally associated with higher expenses [22].

Our use of validated instruments such as the EQ-5D and FSFI aligns with Spaich et al., who reported significant improvements in health perception and post-hysterectomy pain [23]. We observed early postoperative improvements in pain and daily activities, supporting the notion that minimally invasive approaches enable quicker recovery. No significant differences were found between the two groups in terms of postoperative pain, painkiller use, or treatment satisfaction. Both groups had similar QOL outcomes, including convalescence duration, analgesic use, and pain scores at 1 and 4 weeks. These findings are consistent with a telephone-based questionnaire study, which revealed minimal benefits of RAH over CLH, especially in the early recovery of sexual function [8].

In our study, pain during intercourse, lubrication difficulties, and orgasm issues were slightly more common in the CLH group, although the differences were minimal, suggesting similar sexual function outcomes between the two techniques. Önder Ercan et al. reported that hysterectomy, regardless of the approach, consistently shortens the vaginal length due to detachment of the vaginal apex during uterine and cervical removal, followed by suturing of the vaginal cuff [24]. This anatomical change can affect sexual comfort, particularly during deep penetration, which may explain the minimal differences in sexual dysfunction across groups, as it is an inherent consequence of the procedure. Similarly, Johannesson et al. reported a decline in sexual function post-hysterectomy using the FSFI, regardless of the surgical approach, although pelvic floor function improved across all methods, including robotic, laparoscopic, and abdominal hysterectomy [25]. Another study revealed that robotic-assisted laparoscopic, laparoscopic, and abdominal hysterectomies resulted in similar improvements in pelvic floor function at 6 months and 1-year post-surgery. Sexual function, as measured by the FSFI, improved at 6 months but did not persist at 1 year, with no significant differences observed between the surgical techniques in terms of pelvic floor or sexual function outcomes [26].

In our study, the surgeon reached a learning plateau after 50 cases, with the procedure time stabilizing at approximately 150.5 min thereafter. Factors contributing to our findings include the robotic surgeon having surpassed the first learning curve, lacking considerable expertise in performing RH before our study period, and reflecting the latest advancements in robotic technology. These results are concordant with the findings of Padte et al., reported that the learning curve for robotic-assisted surgery depends on the setup time, console time, and number of cases needed to stabilize a surgeon's operating time; approximately 50 cases are deemed necessary [27]. This may serve as an illustration of how technological advancements enhance surgical efficacy. In contrast, a retrospective study by Jihyun Lee involving 44 patients who underwent RH for uteri weighing over 1000 g revealed that surgical proficiency significantly improved after 20 surgeries, leading to better overall outcomes[28]. Furthermore, by analyzing the learning curve for RAH, our study adds to the growing body of literature emphasizing the need for structured training programs and highlights the performance stabilization point after a certain number of cases.

Strengths and limitations

This study is the first to classify uterine sizes for RAH and CLH in benign large uterus cases, enabling standardized outcome evaluation. This classification will aid in decision-making for selecting the appropriate surgical method for patients at different stages of the disease.

However, this study has several limitations, including its single-center design, which limits generalizability, and its ambispective design, which provides QoL data only for prospectively recruited patients, restricting comparisons. Additionally, cost analysis was not included, as the focus was on operative outcomes and postoperative QoL.

Conclusion

RAH is preferred for T3 uteri, whereas laparoscopic techniques are more suitable for T1 and T2. Surgical proficiency improved significantly after 50 cases, highlighting the importance of experience. Future research should refine this classification and explore cost-effectiveness, long-term outcomes, and preoperative strategies for managing large uteri.

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Data availability All data are available in the manuscript; additional inquiries may be directed to the corresponding author.

Declarations

Conflict of interests The authors declare no competing interests.

Ethical approval Ethics approval was obtained from the institutional review board (KYLL-2024–1567).

Consent to participate Informed consent was obtained from all individual participants included in the study.

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