Assessment of surgeon and hospital volume for robot-assisted and laparoscopic benign hysterectomy in Sweden

Malin Brunes1,2 | Catharina Forsgren3,4 | Anna Warnqvist5 | Marion Ek1,2 | Ulrika Johannesson3,4

Abstract

Introduction: The study aims to analyze differences between robot-assisted total laparoscopic hysterectomy (RATLH) and total laparoscopic hysterectomy (TLH) in benign indications, emphasizing surgeon and hospital volume.

Material and methods: All women in Sweden undergoing a total hysterectomy for benign indications with or without a bilateral salpingo-oophorectomy from January 1, 2015 to December 31, 2017 (n = 12,386) were identified from three national Swedish registers. Operative time, blood loss, conversion rate, complications, readmission, reoperation, length of hospital stays, and time to daily life activity were evaluated by univariable and multivariable regression models in RATLH and TLH. Surgeon and hospital volume were obtained from the Swedish National Quality Register of Gynecological Surgery and divided into subclasses.

Results: TLH was associated with a higher rate of intraoperative complications (adjusted odds ratios [aOR] 2.8, 95% CI 1.3–5.8) and postoperative bleeding complications (aOR 1.8, 95% CI 1.2–2.9) compared with RATLH. Intraoperative data showed a higher conversion rate (aOR 13.5, 95% CI 7.2–25.4), a higher blood loss (200–500 mL aOR 3.5, 95% CI 2.7–4.7; >500 mL aOR 7.6, 95% CI 4.0–14.6) and a longer operative time (1–2 h aOR 16.7, 95% CI 10.2–27.5; >2 h aOR 47.6, 95% CI 27.9–81.1) in TLH compared with RATLH. The TLH group had a lower caseload per year than the RATLH group. Higher surgical volume was associated with lower median blood loss, shorter operative time, a lower conversion rate, and a lower perioperative complication rate. Differences in conversion rate or operative time in RATLH were not affected by surgeon volume when compared with TLH. One year after surgery, patient satisfaction was higher in RATLH than in TLH (aOR 0.6, 95% CI 0.4–0.9).

Conclusions: RATLH led to better perioperative outcome and higher patient satisfaction 1 year after surgery. These outcome differences were slightly more pronounced in very low-volume surgeons but persisted across all surgeon volume groups.
1 | INTRODUCTION

The relationship between surgeon volume and surgical outcome is indispensable when evaluating surgical methods. In most gynecological surgical procedures, higher surgeon and hospital volumes have been shown to improve perioperative and oncological outcomes. Women undergoing benign hysterectomy generally have a low risk of perioperative complications. Nevertheless, being a frequently performed procedure, even small impairments in outcome will affect a large number of patients. In Sweden, 4411 women had a hysterectomy on benign indication in 2018 (https://vardeenisiffror.se). Previous studies had reported lower blood loss and shorter operative time when a high-volume surgeon performed the hysterectomy. Despite this fact, 41% of surgeons performing hysterectomies in New York State from 2000 to 2014 had very low surgical volumes, defined as one procedure per year.

The use of robot-assisted surgery in gynecology has rapidly increased worldwide despite a lack of scientific evidence to support this approach. In a Cochrane systematic review, the authors concluded that minimally invasive surgery has advantages over open abdominal surgery in benign hysterectomy. Gynecologists have a long tradition of low morbidity and mortality with traditional laparoscopic and vaginal surgery. This fact challenges whether the high investment costs of a robot are warranted.

Larger observational studies on surgeon volume and the learning curve comparing robot-assisted and traditional laparoscopic hysterectomy are scarce. To address this issue, we performed a national register study. We also sought to explore the association between hospital volume and intra/postoperative outcomes in that, high-volume centers might have a better infrastructure for the management of benign hysterectomy.

2 | MATERIAL AND METHODS

The study is a population-based register study compiling data from three Swedish national registers: the Swedish National Quality Register of Gynecological Surgery (SQGS), the Swedish National Patient Register (SPR) and the Swedish National Drug Register.

All women in Sweden undergoing a total hysterectomy for benign indication with or without a bilateral salpingo-oophorectomy between January 1, 2015 and December 31, 2017 were identified from the SQGS. Exclusion criteria were malignancy, hysterectomy on obstetrical indication, or a pelvic organ prolapse as a primary indication for total hysterectomy.

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**Key message**

A comparison between robot-assisted total laparoscopic hysterectomy (RATLH) and benign laparoscopic hysterectomy (TLH) in Sweden, focusing on surgeon and hospital volume, showed a lower conversion rate, less intraoperative blood loss, a shorter operative time, and fewer intraoperative complications in RATLH compared with TLH.

The three national registers have a high coverage of all gynecological surgery in Sweden (97%-100%) and are described in detail elsewhere. The National Board of Health and Welfare in Sweden continuously reports coverage of national quality registers. This information is reported at the following two websites: Täckningsgrader för nationella kvalitetsregister (https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/artikelkatalog/statistik/2020-12-7049.pdf) and Vården i siffror (https://vardenisiffror.se). Data were linked from the three national registers using the individually unique identification number that is assigned to all Swedish residents. Data from the SPR were collected up to 1 year after surgery to identify readmissions up to 4 months, and reoperations up to 1-year post-surgery, that is, to December 31, 2018.

Hysterectomy was classified according to the mode of surgery into open abdominal hysterectomy, total laparoscopic hysterectomy (TLH), vaginal hysterectomy, and robotic-assisted laparoscopic hysterectomy (RATLH). TLH was defined as all laparoscopic hysterectomies including total laparoscopic hysterectomy, laparoscopic hysterectomy with suturing of the vaginal cuff, and laparoscopically assisted vaginal hysterectomy.

Primary outcomes were operative time, blood loss, conversion rate, and complications until 1 year after surgery. We also evaluated postoperative data: readmission, reoperation, length of hospital stays, and patient return to activities of daily living. We analyzed differences between the two surgical methods, RATLH and TLH, in relation to surgeon and hospital volume.

Information about readmissions up to 4 months, and reoperations until 1 year post-surgery was derived from the SPR. Operative time, blood loss, conversion rate, and intraoperative complications were reported by the surgeon in charge to the SQGS. When the patient was discharged from the hospital the surgeon reported the length of hospital stay to the SQGS. Operative time was predefined in the SQGS as the time from incision to closure of the skin. In addition, patients reported data to the SQGS 2 months after surgery, including days to normal activities of daily living. Data on complications were collected from all
three registers and areas of special interest (postoperative bleeding or vaginal hematoma, thrombosis, infections, and injury to an intraabdominal organ) were reported separately. Postoperative complications reported to the SQGS were retrieved from three questionnaires. The first questionnaire was reported by a gynecologist when the patient leaves the hospital, and the second and third questionnaires were completed by the patient 2 months and 1 year after surgery. If the patient reports a complication, a notification is sent to the hospital. A coordinating gynecologist will then determine whether it should be reported as a complication in a standardized form by the SQGS. Postoperative bleeding or vaginal hematoma and injury to another organ were described by the gynecologist as a complication in the SQGS and combined with data from the SPR (readmission 4 months or reoperation 1 year after surgery). Infections were identified as: an infection described in the SQGS by the gynecologist or by antibiotics 1 month after surgery. These data are derived from the Swedish National Drug Register or readmissions and reoperations after surgery identified by the International Statistical Classification of Diseases and Related Health Problems (ICD-10) codes and Classification of surgical procedures (KVA codes) from the SPR. Postoperative thrombosis was defined as: thrombosis registered in the SQGS 8 weeks after surgery or readmission identified in the SPR or from the Swedish National Drug Register as a retrieved prescription of low-molecular-weight heparin 4 months after surgery with no prescription of low-molecular-weight heparin 3 months before surgery. Data ascertainment on complications and adverse events during a 1-year follow-up after hospital release is described in detail with ICD-10, KVA, and Anatomic Therapeutic Chemical classification system (ATC codes) in our previous study.\textsuperscript{11}

Surgeon and hospital volumes were reported in the SQGS and initially classified into four categories: surgeon volume; very low volume (<10 procedures/year), low volume (10–20 procedures/year), medium volume (>20 procedures/year), and high volume (>50 procedures/year). Because the number of surgeons with high volume (>50 procedures/year) was too low to analyze separately, the medium-volume and high-volume categories were combined into the category medium/high volume (>20 procedures/year). Hospital volume was classified as low volume (<50 procedures/year), medium volume (50–100 procedures/year), and high volume (>100 procedures/year). We analyzed caseload as both total numbers of laparoscopic hysterectomies (i.e. TLH+RATLH) and TLH and RATLH separately.

Baseline data included, age, body mass index, American Society of Anesthesiologists Physical Status Classification (ASA) (grouped as ASA class 1–2 or class 3–5), parity (grouped as 0, 1–2, ≥3 children), previous cesarean section, smoking habits, previous abdominal surgery, concurrent salpingo-oophorectomy, other concurrent procedures at the time of hysterectomy, specimen size (in grams) and surgeon-reported complex surgery. The surgeons in the SQGS reported the primary indication before surgery. Postoperative primary diagnosis (pathology proven) was reported in the SQGS post-surgery using the ICD-10 codes (categorized as endometriosis, adenomyosis, myoma, cervical dysplasia, endometrial atypia, benign adnexal tumor or cyst, and abnormal uterine bleeding).

### 2.1 Statistical analyses

All statistical analyses were performed using a standard software package (\textit{Stata} v 15.0, StataCorp LLC). Categorical and binomial variables are presented as frequencies and proportions and analyzed by either a logistic or multinomial regression model. Continuous variables are described by median and interquartile ranges and analyzed using a quantile regression model. Quantile regression was chosen as the best model because the median is more robust to outliers than the mean. Moreover, long tails in the distributions of the outcome variables might distort the analysis. This issue was a concern, particularly in the smaller subgroups in which differences in means can be driven by a small group of extreme observations. The marginal distributions were investigated graphically to aid in the choice of method. We used a univariable logistic or quantile regression model to describe potential differences between the RATLH and TLH groups (Table 1).

For the primary and secondary outcomes, univariable and multivariable logistic, multinomial and quantile regression models, including all baseline characteristics and descriptive perioperative data, were used. We employed the robust sandwich estimator to calculate standard errors. Multinomial logistic regression was used to estimate relative risk ratios. Depending on the variable, the lowest or middle group was set as the baseline to allow for an unambiguous interpretation of the results. By applying a multinomial model, the information in the data could be used in the estimation process, which was considered more appropriate than setting to subgroups. In the logistic and quantile multivariable regression model, all variables listed in Table 1 were included. The exclusion of variables that seemed safely not relevant to the analysis was implemented to increase the precision of the estimates for the target parameter. Multivariable regression was conducted as a stepwise procedure in which variables from the univariable model with a p value greater than 0.25 were excluded from the multivariable regression model. Because age, body mass index, and uterine size were considered nonlinear, restricted cubic splines (with four knots) were used for these variables.

Results from the univariable regression model are presented as crude odds ratios (cOR), and from the multivariable regression model as adjusted odds ratios (aOR) with 95% CI. Statistical significance was set to \( p \) values less than 0.05.

### 2.2 Ethical approval

The study was approved by the Research Ethics Committee at Karolinska Institutet, Stockholm, Sweden (Regional Ethical Board in Stockholm: Number 2018/18-31) on March 21, 2018 and conformed to the STROBE guidelines regarding observational studies (www.strobe-statement.org).
RESULTS

A flowchart of the study selection process including reasons for study exclusion and mode of surgery is described in Figure 1. Of 12,386 women who underwent a hysterectomy in Sweden from January 1, 2015 to December 31, 2017, 2098 (17%) were excluded because of prolapse \( (n = 1737) \) or malignancy/obstetric complication \( (n = 361) \) as the primary indication for the hysterectomy procedure. Abdominal open surgery \( (n = 4411, 42.9\%) \) or vaginal hysterectomy \( (n = 1749, 17.0\%) \) was performed in 6160 women. The final study population comprised 4128 women grouped into TLH \( (n = 2344, 22.8\%) \) and RATLH \( (n = 1784, 17.3\%) \).

Baseline characteristics and descriptive perioperative data are presented in Table 1. Women with a previous cesarean section were less often offered TLH (cOR 0.8, 95% CI 0.6–0.9), whereas adenomyosis (cOR 1.5, 95% CI 1.3–1.8) and cervical dysplasia or endometrial atypia (cOR 1.5, 95% CI 1.2–1.8) as a primary indication and/or postoperative diagnosis, was more common in the TLH group compared with the RATLH group. Uterine size was smaller in the TLH group (Coef \( Q \) −37 g, 95% CI −47 g to −27 g) and myoma as a

| Baseline characteristic | Robotic \((n = 1784)\) | Laparoscopic \((n = 2344)\) | Coef Q (0.5)/OR (95% CI) |
|-------------------------|----------------|----------------|-------------------|
| Age (years)             | 47 (8)         | 47 (10)        | 1.0 (0.7–1.4)     |
| Body mass index (kg/m\(^2\)) | 25 (6)        | 26 (6)         | 1.0 (0.6–1.0)     |
| ASA 1–2                 | 1677 (94.0)    | 2231 (95.2)    | 1.0 (0.7–1.4)     |
| Parity                  |                |                |                   |
| 0                       | 137 (7.7)      | 155 (6.6)      | Ref.              |
| 1–2                     | 693 (38.9)     | 852 (36.4)     | 1.1 (0.8–1.4)     |
| ≥3                      | 327 (18.3)     | 425 (18.1)     | 1.1 (0.9–1.5)     |
| Cesarean section        | 270 (15.1)     | 285 (12.2)     | 0.8 (0.6–0.9)     |
| Smoking                 | 146 (8.2)      | 211 (9.0)      | 1.2 (1.0–1.5)     |
| Previous abdominal surgery | 733 (41.1) | 861 (36.7) | 0.9 (0.7–1.1) |
| Perioperative data      |                |                |                   |
| Salpingo-oophorectomy   | 439 (24.6)     | 441 (18.8)     | 0.8 (0.7–0.9)     |
| Other concurrent surgery| 135 (7.6)      | 139 (5.9)      | 0.8 (0.7–1.1)     |
| Specimen size (g)       | 195 (175)      | 160 (161)      | 1.1 (0.9–1.3)     |
| Surgeon-reported complex surgery | 649 (36.4) | 1087 (46.4) | 1.5 (1.3–1.7) |
| Surgeon volume laparoscopic or robotic hysterectomy/year | | | |
| <10                     | 691 (38.7)     | 1145 (48.9)    | Ref.              |
| 10–20                   | 420 (23.5)     | 593 (25.3)     | 0.9 (0.7–1.0)     |
| >20                     | 673 (37.7)     | 606 (25.9)     | 0.5 (0.5–0.6)     |
| Hospital volume laparoscopic or robotic hysterectomy/year | | | |
| <50                     | 996 (55.8)     | 427 (18.2)     | Ref.              |
| 50–100                  | 457 (25.6)     | 1184 (50.5)    | 0.5 (0.5–0.6)     |
| >100                    | 331 (18.6)     | 733 (31.3)     | 1.0 (0.9–1.1)     |
| Primary diagnosis or primary indication | | | |
| Endometriosis           | 308 (17.3)     | 397 (16.9)     | 1.0 (0.8–1.2)     |
| Adenomyosis             | 244 (13.7)     | 453 (19.3)     | 1.5 (1.3–1.8)     |
| Myoma                   | 874 (49.0)     | 968 (41.3)     | 0.7 (0.6–0.8)     |
| Cervical dysplasia/Endometrial atypia | 176 (9.9) | 322 (13.7) | 1.5 (1.2–1.8) |
| Benign adnexal tumor/cyst | 96 (5.4)      | 133 (5.7)      | 1.1 (0.8–1.4)     |
| Abnormal uterine bleeding | 507 (28.4) | 731 (31.2) | 1.1 (1.0–1.3) |

Note: Other concurrent surgery, not including surgery on uterus or adnexa. Figures are median (interquartile range) or frequencies (proportions %), \( n = \) frequencies

Abbreviations: ASA, American Society of Anesthesiologists Physical Status Classification; OR, crude odds ratio.

\(^1\)Coef Q = coefficient from quantile regression.
primary indication and/or postoperative diagnosis was less common than in the RATLH group. A difference in surgeon and hospital volume was observed, with a lower caseload per year in the TLH than in the RATLH group. Surgeons in the TLH group more often reported complex surgery (cOR 1.5, 95% CI 1.3–1.7) compared with RATLH surgeons.

Primary outcomes for the two methods are shown in Table 2. Overall, TLH was associated with a higher intraoperative complication rate (aOR 2.8, 95% CI 1.3–5.8) compared with RATLH. No significant differences were found between the two groups in total complications 1 year after surgery (aOR 1.2, 95% CI 0.9–1.5). An association was detected with higher conversion rate, higher blood loss, and longer operative time in TLH than in RATLH. More often, women undergoing TLH had a hospital stay >3 days (aOR 2.5, 95% CI 1.5–4.4) compared with RATLH. Reoperation rate was higher in the TLH than in the RATLH group (aOR 1.8, 95% CI 1.0–3.0). In addition, the percentage of women reporting satisfaction with the procedure 1 year after hysterectomy was lower in the TLH than in the RATLH group (aOR 0.6, 95% CI 0.4–0.9).

Table 3 describes the subgroup analyses relating outcomes to surgeon volume by hysterectomy mode (TLH, RATLH). In the group with a very low surgeon volume TLH was associated with a significantly higher rate of intraoperative complications (aOR 11.1, 95% CI 2.7–46.2), bleeding >500 mL (aOR 26.8, 95% CI 7.9–91.1), and longer hospital stay (2–3 days, aOR 1.4, 95% CI 1.0–1.8) compared with very low-volume robotic surgeons. However, with higher surgeon volume, there were no significant differences for these outcomes between the two groups. We found a higher rate of reoperations in the combined medium/high surgeon volume group (aOR 4.8 95% CI 1.1–21.4) and readmissions (aOR 3.9, 95% CI 1.5–10.1) in the TLH compared with the RATLH group. Differences in bleeding 200–500 mL, operative time, and conversion rate persisted across all surgeon volume groups. The number of women satisfied with the operation 1-year post-surgery was lower in the TLH group than in the RATLH group with very low and medium/high-volume surgeons. There were no laparoscopic surgeons in Sweden during the study period that performed more than 50 TLH per year.

A quantile regression model with an interaction term for hysterectomy mode (TLH/RATLH), surgeon volume, and surgical outcome is described in the supplementary material Table S1. Higher surgical volume was associated with lower median blood loss, shorter operation time, a lower conversion rate, and a lower perioperative complication rate. A significant difference was found between the TLH and RATLH groups in how blood loss and operative time changed over the number of surgeries per year.

Data comparing hospital surgical volume defined as volume TLH and RATLH per year is shown in the supplementary material (Table S2). In low- and medium-volume hospitals, TLH in comparison with RATLH, was associated with a higher rate of intraoperative complications, a higher estimated blood loss and a lower number of women being satisfied with the surgical procedure. In addition, in medium-volume hospitals, TLH was associated with a higher total rate of complications 1 year after surgery (aOR 1.5, 95% CI 1.0–2.3). The longer operative time and higher conversion rate for TLH compared with RATLH persisted in all hospital groups. No hospitals were performing ≥150 RATLH on benign indications in Sweden during the study period.

4 | DISCUSSION

The main findings in this study were lower conversion rates, less intraoperative blood loss, shorter operative time, and fewer intraoperative complications in RATLH compared with TLH. In addition, we found no differences in complications 1 year after surgery between the two surgical methods. Nevertheless, TLH was associated with a higher rate of reoperations, longer hospital stays, and a lower satisfaction with the surgical procedure 1 year after hysterectomy.

The differences in intraoperative complications between the two methods disappeared with higher surgeon volume, although they remained for the other outcome measures. Higher surgical volume was associated with lower blood loss and conversion rate, shorter operative time, and a lower frequency of complications for both methods. However, in the combined medium/high-volume
surgery group conversion, reoperations and readmissions were more common in TLH than in RATLH. More women in the RATLH group were satisfied with the operation 1 year after surgery than the TLH group in the medium/high-volume surgeon group. Hospital volume did not significantly affect the differences in perioperative outcomes.

The strengths of the study are the high reliability of our data sources and the cross-linking of three high-quality national registers. By linking data from different data sources the risks of misclassification bias and missing data are reduced. However, because this is a register-based study, there are limitations associated with the study design. The procedures are not completely standardized, especially regarding TLH, where some centers use a combination of laparoscopic and vaginal modalities. Moreover, the definition of operative time can vary between studies. The use of ASA as an estimate of comorbidity burden might be insufficient. In exposure and primary outcome measures we had a low rate of missing data. Still, in some of the patient-reported measures (eg, body mass index and smoking) there was a high amount of missing information, which is a limitation.

A Cochrane systematic review from 2019 of randomized controlled trials comparing RATLH with other surgical modes did not reveal any major statistical differences in perioperative outcomes. However, the sample size (including both benign and malignant cases) ranged from only 148 to 585, depending on the variable tabulated. The small sample size in randomized controlled trials, combined with an unusual outcome, might partly explain why our results differ from those in the Cochrane review. Additionally, the results of large observational studies show somewhat different complication rates. Billfeldt et al, for instance, showed a slightly higher complication rate in RATLH than in vaginal hysterectomy but no difference between vaginal hysterectomy and TLH. Ngan et al reported a lower rate of blood transfusion but a higher rate of respiratory failure, fever and ileus in RATLH compared with TLH, whereas Herrinton et al, could not find any differences in complication rate between the two methods. Swenson et al, Lim et al and Luciano et al, however, reported a lower rate of postoperative complications in RATLH versus TLH.

Conversion rate was lower in two large, register-based cohort studies. A lower estimated blood loss or a lower transfusion rate in RATLH

### TABLE 2 Complications and intraoperative and postoperative outcomes comparing various modes of hysterectomy

| Complications                          | Robotic (n = 1784) | Laparoscopic (n = 2344) |
|----------------------------------------|-------------------|-------------------------|
|                                        | Frequency (%)     | cOR (95% CI)            | aOR (95% CI) |
| Intraoperative\(^a\)                   |                   |                         |              |
| Frequency (%)                          | 20 (1.1)          | 67 (2.9)                | 2.6 (1.6–4.3) |
| Total 1-year post-op\(^b\)             | 285 (16.0)        | 401 (17.1)              | 1.1 (0.9–1.3) |
| Postop bleeding/Vaginal\(^c\) hematoma | 77 (4.3)          | 137 (5.8)               | 1.4 (1.0–1.8) |
| Thrombosis\(^d\)                       | 19 (1.1)          | 20 (0.9)                | 0.8 (0.4–1.5) |
| Infection\(^e\)                        | 173 (9.7)         | 240 (10.2)              | 1.1 (0.9–1.3) |
| Injury to an intraabdominal organ\(^f\)| 75 (4.2)          | 104 (4.4)               | 1.1 (0.8–1.4) |
| Intraoperative outcome                 |                   |                         |              |
| Conversion rate\(^g\)                  | 26 (1.5)          | 209 (8.9)               | 6.6 (4.4–10.0)|
| Estimated blood loss (mL)\(^h\)       |                   |                         |              |
| <200                                   | 1580 (88.6)       | 1694 (72.3)             | Ref          |
| 200–500                                | 169 (9.5)         | 495 (21.1)              | 2.7 (2.3–3.3) |
| >500                                   | 33 (1.9)          | 145 (6.2)               | 4.1 (2.8–6.0) |
| Duration of surgery (hours)\(^i\)     |                   |                         |              |
| <1                                     | 351 (19.7)        | 136 (5.8)               | Ref          |
| 1–2                                    | 1054 (59.1)       | 1246 (53.2)             | 3.1 (2.5–3.8) |
| >2                                     | 379 (21.2)        | 960 (41.0)              | 6.5 (5.2–8.2) |
| Postoperative outcome                  |                   |                         |              |
| Hospital stay (d)\(^j\)                |                   |                         |              |
| <2                                     | 1327 (74.4)       | 1591 (67.9)             | Reference    |
| 2–3                                    | 347 (19.5)        | 613 (26.2)              | 1.5 (1.3–1.7) |
| >3                                     | 40 (2.2)          | 104 (4.4)               | 2.2 (1.5–3.1) |

(Continues)
TABLE 2 (Continued)

| Postoperative outcome | Robotic (n = 1784) | Laparoscopic (n = 2344) |
|-----------------------|-------------------|------------------------|
|                       | Frequency (%)      | Frequency (%)          | cOR (95% CI) | aOR (95% CI) |
| Days to normal ADL \( ^{k} \) |                    |                        |              |              |
| <3                    | 381 (21.4)        | 423 (18.1)             | Reference    | Reference    |
| 3–9                   | 549 (30.8)        | 578 (24.7)             | 0.9 (0.8–1.1)| 1.0 (0.7–1.2)|
| >10                   | 282 (15.8)        | 389 (16.6)             | 1.2 (1.0–1.5)| 1.3 (1.0–1.8)|
| Reoperations \( ^{l} \) | 46 (2.6)         | 73 (3.1)               | 1.2 (0.8–1.8)| 1.8 (1.0–3.0)|
| Readmission \( ^{m} \) | 87 (4.9)         | 139 (5.9)              | 1.2 (0.9–1.6)| 1.5 (0.9–2.3)|
| Patient-reported condition 1-year postop \( ^{n} \) |                  |                        |              |              |
| Satisfied             | 1145 (64.2)      | 1358 (57.9)            | 0.7 (0.6–0.9)| 0.6 (0.4–0.9)|
| Neither/Nor           | 95 (5.3)         | 156 (6.7)              | Ref          | Ref          |
| Unsatisfied           | 31 (1.7)         | 41 (1.8)               | 0.8 (0.5–1.4)| 0.6 (0.3–1.2)|

Note: Conversion rate; to open abdominal surgery. Figures are frequencies (proportions). \( n \) = frequencies.

Abbreviations: ADL, activities of daily living; aOR, adjusted odds ratio (all variables from were adjusted for and then stepwise excluded if \( p > 0.25 \); ASA, American Society of Anesthesiologists Physical Status Classification; BMI, body mass index; cOR, crude odds ratio.

\( ^{a} \) Age, ASA, previous abdominal surgery, other concurrent surgery, specimen size, hospital volume, surgeon volume, salpingo-oophorectomy, surgeon-reported complex surgery, primary diagnosis/indication myoma.

\( ^{b} \) Age, BMI, parity, cesarean section, previous abdominal surgery, other concurrent surgery, specimen size, surgeon volume, surgeon-reported complex surgery, primary diagnosis/indication cervical dysplasia or endometrial dysplasia, endometriosis, adenomyosis.

\( ^{c} \) Age, BMI, smoking, parity, cesarean section, previous abdominal surgery, specimen size, salpingo-oophorectomy, surgeon-reported complex surgery, surgeon volume, hospital volume, primary diagnosis/indication cervical dysplasia or endometrial dysplasia, myoma.

\( ^{d} \) Age, ASA, BMI, cesarean section, previous abdominal surgery, specimen size, hospital volume, primary diagnosis/indication benign adnexal tumor/cyst, myoma, abnormal uterine bleeding.

\( ^{e} \) BMI, previous abdominal surgery, specimen size, surgeon-reported complex surgery, primary diagnosis/indication, endometriosis, adenomyosis.

\( ^{f} \) Age, cesarean section, other concurrent surgery, previous abdominal surgery, specimen size, surgeon-reported complex surgery, surgeon volume, hospital volume, primary diagnosis/indication, cervical dysplasia or endometrial dysplasia, adenomyosis.

\( ^{g} \) Age, cesarean section, smoking, previous abdominal surgery, other concurrent surgery, specimen size, hospital volume, surgeon volume, salpingo-oophorectomy, surgeon-reported complex surgery, primary diagnosis/indication benign adnexal tumor/cyst, myoma, cervical dysplasia or endometrial dysplasia, abnormal uterine bleeding.

\( ^{h} \) Age, ASA, parity, cesarean section, smoking, previous abdominal surgery, other concurrent surgery, specimen size, surgeon volume, salpingo-oophorectomy, surgeon-reported complex surgery, primary diagnosis/indication benign adnexal tumor/cyst, myoma, cervical dysplasia or endometrial dysplasia, abnormal uterine bleeding.

\( ^{i} \) BMI, previous abdominal surgery, specimen size, surgeon-reported complex surgery, primary diagnosis/indication, endometriosis, adenomyosis.

\( ^{j} \) Age, cesarean section, other concurrent surgery, previous abdominal surgery, specimen size, surgeon-reported complex surgery, surgeon volume, hospital volume, primary diagnosis/indication cervical dysplasia or endometrial dysplasia, adenomyosis.

\( ^{k} \) Age, cesarean section, smoking, previous abdominal surgery, other concurrent surgery, specimen size, hospital volume, surgeon volume, salpingo-oophorectomy, surgeon-reported complex surgery, primary diagnosis/indication benign adnexal tumor/cyst, myoma, cervical dysplasia or endometrial dysplasia, abnormal uterine bleeding.

\( ^{l} \) Age, ASA, parity, cesarean section, smoking, previous abdominal surgery, other concurrent surgery, specimen size, surgeon volume, salpingo-oophorectomy, surgeon-reported complex surgery, primary diagnosis/indication benign adnexal tumor/cyst, myoma, cervical dysplasia or endometrial dysplasia, abnormal uterine bleeding, endometriosis, adenomyosis.

\( ^{m} \) Age, ASA, parity, cesarean section, previous abdominal surgery, other concurrent surgery, specimen size, hospital volume, surgeon volume, salpingo-oophorectomy, surgeon-reported complex surgery, primary diagnosis/indication benign adnexal tumor/cyst, myoma, cervical dysplasia or endometrial dysplasia, abnormal uterine bleeding, endometriosis, adenomyosis.

\( ^{n} \) Age, ASA, parity, cesarean section, previous abdominal surgery, other concurrent surgery, specimen size, hospital volume, surgeon volume, salpingo-oophorectomy, surgeon-reported complex surgery, primary diagnosis/indication benign adnexal tumor/cyst, myoma, cervical dysplasia or endometrial dysplasia, abnormal uterine bleeding, endometriosis, adenomyosis.

\( ^{o} \) BMI, parity, cesarean section, other concurrent surgery, hospital volume, surgeon-reported complex surgery, primary diagnosis/indication benign adnexal tumor/cyst, myoma, cervical dysplasia or endometrial dysplasia, abnormal uterine bleeding, endometriosis, adenomyosis.

\( ^{p} \) Age, parity, salpingo-oophorectomy, specimen size, surgeon volume, hospital volume, primary diagnosis/indication cervical dysplasia or endometrial dysplasia, myoma.

\( ^{q} \) Age, parity, salpingo-oophorectomy, previous abdominal surgery, surgeon-reported complex surgery, hospital volume, primary diagnosis/indication cervical dysplasia or endometrial dysplasia, myoma.


compared with TLH has been shown in several previous observational studies, all with a study population over 1000 women.\(^ {9,10,13,15,18,19} \)

The importance of surgeon volume is amply described, along with studies comparing surgical outcome with hospital volume.\(^ {2,4,20} \) A shorter operative time and blood loss in high-volume surgeons were found in all modalities (abdominal, vaginal, and laparoscopic hysterectomy, including both RATLH and TLH).\(^ {5} \) Notwithstanding, the present study is one of a few that subgroup and compare TLH with RATLH according to surgical volume. The results, in which the differences in operative outcome are largest in the group with a very low surgeon volume might be associated with a faster learning curve in RATLH than in TLH.\(^ {21} \)

Robotic gynecological surgery was initially criticized for its longer operative time compared with laparoscopic hysterectomy.\(^ {22} \) Although, recent studies with more complex cases have
| Procedures/year | Very low volume <10 (n = 1836) | Low volume 10–20 (n = 1013) | Medium/High volume >20 (n = 1279) |
|-----------------|--------------------------------|----------------------------|---------------------------------|
|                 | RATLH (n = 691) | TLH (n = 1145) | aOR (95% CI) | RATLH (n = 420) | TLH (n = 593) | aOR (95% CI) | RATLH (n = 673) | TLH (n = 606) | aOR (95% CI) |
| Complications   |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| Intraoperative  |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| Intraoperative  |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| Total 1-year post | 2 (0.3) | 48 (4.2) | 11.1 (2.7–46.2) | 14 (3.3) | 20 (2.0) | 0.4 (0.1–1.1) | 4 (0.6) | 7 (1.2) | 1.2 (0.1–9.3) |
| Postop bleeding/Vaginal hematoma | 114 (16.5) | 200 (17.5) | 1.0 (0.7–1.3) | 75 (17.9) | 113 (19.1) | 1.4 (0.9–2.2) | 96 (14.3) | 88 (14.5) | 1.5 (0.9–2.5) |
| Postop bleeding/Vaginal hematoma | 19 (2.8) | 47 (4.1) | 1.4 (0.7–2.9) | 20 (4.8) | 34 (5.7) | 1.3 (0.6–2.9) | 19 (2.8) | 17 (2.8) | 1.8 (0.6–5.4) |
| Intraoperative outcome |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| Estimated blood loss (mL) |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| <200            |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| 200–500         |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| >500            |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| Duration of surgery (hours) |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| <1              |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| 1–2             |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| >2              |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| Conversion rate |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| <2              |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| 2–3             |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| >3              |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| Hospital stay (d) |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| <2              |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| 2–3             |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
| >3              |                  |                      |                 |                  |                      |                 |                  |                      |                 |                    |
(Continues)
shown a shorter operative time in RATLH than in TLH, which is in agreement with our results. A longer operative time impacts postoperative complications. Operative time, conversions, and complication rates improved with surgical experience, even with increasing surgical complexity. Are previous findings affected by surgeon volume and complexity of cases more than the technique itself? We believe the robotic technique might help the inexperienced surgeon and allow the more experienced surgeon to advance to more complex cases. There is a need for larger multicenter randomized controlled trials in benign gynecology comparing TLH and RATLH stratified by surgeon volume and case complexity.

5 | CONCLUSION

This study observed a better perioperative outcome and a higher patient satisfaction one year after surgery with RATLH than TLH. These differences in outcomes were slightly more pronounced in surgeons with a very low surgical volume but persisted across all studied surgeon volume groups.

CONFLICTS OF INTEREST

Malin Brunes and Ulrika Johannesson have received honoraria from Intuitive Surgical for proctoring. No other authors have any disclosure to report.

ORCID

Malin Brunes https://orcid.org/0000-0002-3726-8583

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**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section.

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