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CLINICAL ARTICLE

Multicenter analysis comparing robotic, open, laparoscopic, and vaginal hysterectomies performed by high-volume surgeons for benign indications

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ABSTRACT

Objective: To compare perioperative outcomes between robotic-assisted benign hysterectomies and abdominal, vaginal, and laparoscopic hysterectomies when performed by high-volume surgeons. *Methods:* A multicenter data analysis compared 30-day outcomes from consecutive robotic-assisted hysterectomies performed by high-volume surgeons (≥60 prior procedures) at nine centers with records retrieved from the Premier Perspective database for abdominal, vaginal, and laparoscopic hysterectomies performed by high-volume gynecologic surgeons. Data on benign hysterectomy disorders from January 1, 2012 to September 30, 2013 were included. *Results:* Data from 2300 robotic-assisted, 9745 abdominal, 8121 vaginal, and 11 952 laparoscopic hysterectomies were included. The robotic-assisted patient cohort had a significantly higher rate of adhesive disease compared with the vaginal ($P < 0.001$) and laparoscopic cohorts ($P < 0.001$), a significantly higher rate of morbid obesity than the vaginal ($P < 0.001$) or laparoscopic cohorts ($P < 0.001$), and a significantly higher rate of large uteri (>250 g) than the abdominal ($P < 0.001$), vaginal ($P < 0.001$), or laparoscopic cohorts ($P = 0.017$). The robotic-assisted cohort experienced significantly fewer intraoperative complications than the abdominal ($P < 0.001$) and vaginal cohorts ($P < 0.001$), and experienced significantly fewer postoperative complications compared with all the comparator cohorts ($P < 0.001$). *Conclusion:* When performed by gynecologic surgeons with relevant high-volume experience, robotic-assisted benign hysterectomy provided improved outcomes compared with abdominal, vaginal, and laparoscopic hysterectomy.

1. Introduction

Comparisons of robotic-assisted hysterectomy with laparoscopic, abdominal, and vaginal hysterectomy are many [1–3]. Between 2005 and 2013, the percentage of all hysterectomies with benign indications that were performed as abdominal hysterectomies declined from 59% to 22%, as reported in the Premier Perspective database (Premier Inc., Charlotte, NC, USA) (Fig. 1). Surgeons and patients have increasingly favored robotic-assisted and laparoscopic approaches over open approaches owing to the lower perioperative morbidity and shorter recovery that are associated with these surgeries [4–6]. The da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA, USA) received US Food and Drug Administration clearance in 2005 for use in gynecologic robotic-assisted surgical procedures [7].

Comparative reports can provide insight and opposing views regarding perioperative outcomes and complications among procedures performed by diverse groups of surgeons. Small trials comparing robotic-assisted with laparoscopic and vaginal approaches have demonstrated some bias in favor of non-robotic methods; surgeons in these trials were highly experienced in laparoscopic and vaginal approaches but had limited experience performing robotic hysterectomies [8–10]. To date, comparative reports evaluating outcomes from robotic-assisted benign hysterectomy procedures performed by experienced surgeons are lacking. The aim of the present study was to addresses this gap by evaluating perioperative outcomes from robotic-assisted hysterectomy for benign disease performed by multiple gynecologic surgeons with

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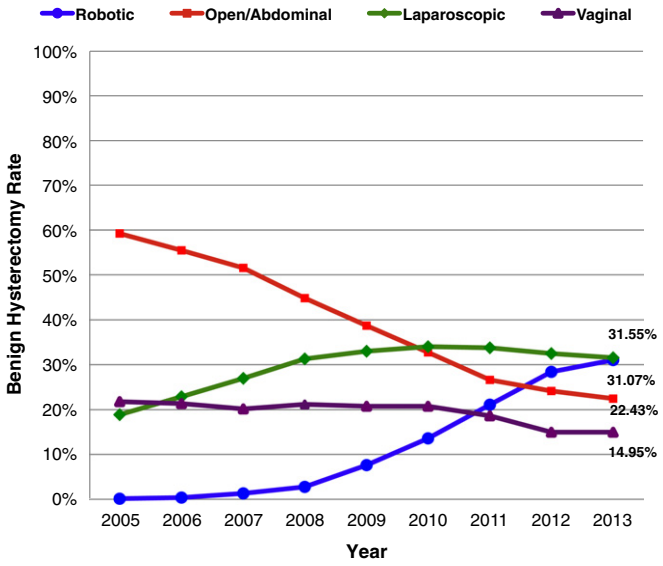

Fig. 1. Trends in the proportion of hysterectomy procedures for benign indications reported in the Premier Perspective database that were performed using robotic-assisted, abdominal, laparoscopic, and vaginal approaches.

high-volume experience in robotic-assisted surgery, and to compare these results to outcomes from vaginal, laparoscopic, and abdominal hysterectomies for benign indications when performed by surgeons experienced (≥60 surgeries) in these surgical approaches.

The purpose of the study was to contribute to the presently limited literature of perioperative outcomes [11–13] from robotic-assisted benign hysterectomy procedures, and to evaluate those outcomes over the same period with outcomes from laparoscopic, abdominal, and vaginal hysterectomies that had also been performed by high-volume gynecologic surgeons.

2. Materials and methods

The present retrospective cohort study evaluated baseline, intraoperative, and 30-day postoperative outcomes from multiport robotic-assisted, abdominal, laparoscopic, and vaginal hysterectomies performed for benign indications. All hysterectomies performed for benign indications between January 1, 2010 and September 30, 2013 were included and the only exclusion criterion was the presence of malignancy. The institutional review board of each study institution granted approval or exemption for the study protocol and the need for informed consent from patients was waived.

Data from robotic-assisted benign hysterectomies performed by high-volume gynecologic surgeons who had completed at least 60 robotic-assisted benign hysterectomies prior to the study were included. Experience of 60 surgeries was selected based on the reported 50–91 surgeries required to reach surgical proficiency in robotic-assisted techniques [14,15]. The robotic-assisted surgeries were performed at nine medical centers in the USA by a diverse group of seven physicians with pelvic pain, oncology, urogynecology, and infertility sub-specialties. Retrospective data were collected from the medical records of all eligible patients at the surgeons' institutions and were recorded by each institution's research coordinator in a validated electronic database.

Data on abdominal, laparoscopic, and vaginal hysterectomies were obtained from the Premier Perspective database and included all eligible patients with benign indications who underwent surgery during the study period. The annual surgical case volume of benign hysterectomy procedures performed between 2008 and 2012 was used to determine high-volume experience for each surgeon who contributed to the database. To be included in the analysis, surgeons had to have performed at least 60 surgeries in the respective approach prior to the study period.

Data from the high-volume hysterectomy cohorts in the Premier database were available from hospitals throughout the USA. Patients were identified using International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure codes and patients had to have 30-day follow-up data available to be included. Patient follow-up data included age, presence of comorbid conditions (specifically, body mass index [BMI calculated as weight in kilograms divided by the square of height in meters] ≥40, the presence of adhesive disease, or large uterus [>250 g]), indications for surgery, hysterectomy type and concomitant procedures, conversion to open surgery, presence of intraoperative and postoperative (≤30 days) complications, intraoperative and postoperative blood transfusions, inpatient or outpatient designation, inpatient length of hospital stay, and hospital readmission or reoperation related to the primary surgery through the 30-day postoperative follow-up period. Patients were considered to have adhesive disease if patient records included a diagnosis of adhesive disease and/or if pelvic and/or intra-abdominal adhesiolysis was performed at the time of the hysterectomy. Current procedural terminology codes distinguishing hysterectomies with uteri larger or smaller than 250 g were only available for vaginal and laparoscopic procedures.

Perioperative complications were determined by reviewing ICD-9-CM diagnosis codes for morbidity not present on admission and were classified as intraoperative or postoperative. Postoperative complications were further categorized as having been surgical (including bleeding, wound disruption, surgical-site infection, abscess, hematoma, seroma, fistula, postoperative prolapse of vaginal wall, incisional or port-site hernia, peripheral neuropathy), medical (including post-hemorrhagic anemia, fever, adverse medication effects, dehydration, hypokalemia, septicemia, shock, transfusion reactions), genitourinary (including urinary retention, urinary tract infection, acute renal failure, hydronephrosis, ureteric obstruction), gastrointestinal (including paralytic ileus, nausea/vomiting, bowel obstruction), respiratory (including pulmonary collapse, hypoxemia, pneumonia, pulmonary insufficiency, acute respiratory failure, pleural effusion), thromboembolic events, pain, cardiovascular (including cardiac arrhythmias, cardiac arrest, acute myocardial infarction), and central nervous system (including syncope and collapse, altered consciousness/mental status, convulsions, intracranial hemorrhage). Hemorrhage complications were defined as bleeding that complicated a procedure or that required a blood transfusion. Necessitated reoperations were determined from a review of ICD-9-CM procedure codes. Reoperation categories included repair of intraoperative injury, wound repair/reconstruction, genitourinary and gastrointestinal procedures, control of hemorrhage and vascular procedures, fistula repair, and non-specific general exploratory or diagnostic surgery.

Data analyses were performed using SAS version 9.2 (SAS Institute Inc., Cary, NC, USA). Standard univariate methods were used to express the mean, standard deviation, and 95% confidence intervals for continuous variables. Discrete variables were expressed as proportions and percentages and were compared using the χ^2 test. Continuous variables were compared using the Student t test. Tests for trends were performed using the Jonckheere–Terpstra test. In all instances, two-sided $P < 0.05$ was considered significant.

3. Results

Data were retrieved for 2300 eligible patients who underwent robotic-assisted hysterectomy for benign indications at the nine institutions during the study period. Patient data were obtained from 4 (44%) teaching and 5 (56%) non-teaching hospitals. Patient records were retrieved for 9745 abdominal, 8121 vaginal, and 11 9521 laparoscopic hysterectomies from the Premier Perspective database. The abdominal, vaginal, and laparoscopic procedures were performed at 405 hospitals, including 118 (29.1%) teaching and 287 (70.9%) non-teaching hospitals.

Table 1
Patient characteristics.[a]

Variable	Robotic hysterectomy (n = 2300)	Premier database hysterectomy procedures		
		Abdominal hysterectomy (n = 9745)	Vaginal hysterectomy (n = 8121)	Laparoscopic hysterectomy (n = 11 952)
Age, y	49.3 ± 11.5 (48.8–49.7)	46.7 ± 10.7 (46.5–46.9)	48.7 ± 13.3 (48.4–49.0)	43.9 ± 9.4 (43.7–44.1)
P value[b]	Ref.	<0.001	<0.001	<0.001
Morbid obesity[c]	181 (7.9)	884 (9.1)	250 (3.1)	446 (3.7)
P value[d]	Ref.	0.074	<0.001	<0.001
Adhesive disease	431 (18.7)	2573 (26.4)	106 (1.3)	1427 (11.9)
P value[d]	Ref.	<0.001	<0.001	<0.001
Large uterus[e]	366 (15.9)	368 (3.8)	589 (7.3)	1671 (14.0)
P value[d]	Ref.	<0.001	<0.001	0.017
Surgical indications[f]				
Abnormal uterine bleeding	1145 (49.8)	2444 (25.1)	2908 (35.8)	5246 (43.9)
Fibroids	758 (33.0)	4146 (42.5)	1201 (14.8)	3531 (29.5)
Endometriosis	335 (14.6)	842 (8.6)	454 (5.6)	1186 (9.9)
Prolapse	511 (22.2)	530 (5.4)	3320 (40.9)	796 (6.7)
Other	1011 (44.0)	2623 (26.9)	976 (12.0)	3189 (26.7)
P value[d]	Ref.	<0.001	<0.001	<0.001

[a] Values are given as mean ± SD (95% confidence interval) or number (percentage), unless indicated otherwise.
[b] Student *t* test.
[c] Defined as body mass index (calculated as weight in kilograms divided by the square of height in meters) ≥40.
[d] χ^2 test.
[e] Defined as >250 g.
[f] Surgical indications for each surgical approach do not total the number of patients included owing to patients having multiple surgical indications.

Patient characteristics are presented in Table 1. The most common indications for hysterectomy across all patients were abnormal uterine bleeding and fibroids. Patients who underwent robotic-assisted hysterectomy were generally more complex; they were older, had higher rates of adhesive disease, and had higher rates of large uteri than patients in the other cohorts. The robotic surgery patients also had a higher rate of morbid obesity than the vaginal and laparoscopic cohorts (Table 1).

Among the 2300 robotic-assisted hysterectomies, 1938 (84.3%) were total hysterectomies (Table 2). Of the 9745 abdominal hysterectomies, 9186 (94.3%) were total abdominal hysterectomies, and of the 11 952 laparoscopic hysterectomies, 5395 (45.1%) were laparoscopic-assisted vaginal hysterectomies. A higher rate of concomitant procedures, including pelvic-floor repair and reconstruction, was reported in the robotic-assisted cohort ($P < 0.001$). Concomitant procedures performed at the time of hysterectomy included adhesiolysis, cystoscopy, endometriosis resection, hernia repair, appendectomy, cholecystectomy, bowel and colorectal procedures, and plastic and reconstructive procedures (Table 2).

The rates of conversion to open surgery were similar among the robotic-assisted, vaginal, and laparoscopic cohorts (Table 3). Among inpatients, the mean length of hospital stay was shorter for the robotic-assisted group (1.37 days) than the open (3.0 days), vaginal (1.9 days), and laparoscopic (1.7 days) groups (all $P < 0.001$). Overall, patients undergoing robotic-assisted procedures experienced significantly fewer intraoperative complications (0.74%) compared with individuals in the abdominal (1.8%; $P < 0.001$) and vaginal (1.8%; $P < 0.001$) cohorts, and fewer complications than patients in the laparoscopic group (1.2%; $P = 0.077$); however, this difference was not significant (Table 4). No patients in the robotic-assisted group experienced intraoperative hemorrhage, nerve injury, foreign bodies left in the peritoneal cavity, mechanical failure, or medical accidents. Significantly fewer patients in the robotic-assisted cohort required intraoperative blood transfusions compared with patients in the abdominal ($P < 0.001$), vaginal ($P = 0.001$), and laparoscopic ($P = 0.011$) cohorts.

Of the 2095 patients in the robotic-assisted cohort with 30-day postoperative data available, 131 (6.3%) experienced postoperative complications compared with 2047 (21.0%) patients in the abdominal cohort,

Table 2
Procedures performed.[a]

Characteristics	Robotic hysterectomy (n = 2300)	Premier database hysterectomy procedures		
		Abdominal hysterectomy (n = 9745)	Vaginal hysterectomy (n = 8121)	Laparoscopic hysterectomy (n = 11 952)
Procedure				
Hysterectomy, NOS	0	0	0	0
Laparoscopic vaginal hysterectomy	0	0	0	5394 (45.1)
Laparoscopic total abdominal hysterectomy	1938 (84.3)	0	0	2131 (17.8)
Laparoscopic supracervical hysterectomy	362 (15.7)	0	0	4427 (37.0)
Subtotal abdominal hysterectomy	0	560 (5.7)	0	0
Total abdominal hysterectomy, NOS	0	9185 (94.3)	0	0
Vaginal hysterectomy, NOS	0	0	8121 (100.0)	0
Patients undergoing concomitant procedures				
None	366 (15.9)	1605 (16.5)	2450 (30.2)	3812 (31.9)
Adnexectomy only	423 (18.4)	3860 (39.6)	1035 (12.7)	4286 (35.9)
Pelvic floor repair/reconstruction	732 (31.8)	677 (6.9)	1785 (22.0)	634 (5.3)
Other[b]	779 (33.9)	3603 (37.0)	2851 (35.1)	3220 (26.9)
P value[c]	Ref.	<0.001	<0.001	<0.001

Abbreviation: NOS, not otherwise specified.
[a] Values are given as number (percentage) unless indicated otherwise.
[b] Patients who underwent concomitant procedures other than bilateral/unilateral salpingectomy/oophorectomy or pelvic floor repair/reconstruction.
[c] χ^2 test.

Table 3
Perioperative outcomes.[a]

Perioperative outcome	Robotic hysterectomy (n = 2300)	Premier database hysterectomy procedures		
		Abdominal hysterectomy (n = 9745)	Vaginal hysterectomy (n = 8121)	Laparoscopic hysterectomy (n = 11 952)
Conversion to open surgery	2 (0.1)	NA	1 (0.0)	11 (0.1)
P value[b]	Ref.	NA	0.243	>0.99
Inpatient length of hospital stay, d	1.37 ± 1.1 (1.31–1.43)	3.0 ± 1.6 (2.98–3.03)	1.9 ± 1.0 (1.86–1.96)	1.7 ± 1.2 (1.64–1.75)
P value[c]	Ref.	<0.001	<0.001	<0.001

Abbreviation: NA, not applicable.
[a] Values are given as number (percentage) or mean ± SD (95% confidence interval), unless indicated otherwise.
[b] χ^2 test.
[c] Student *t* tests.

1314 (16.2%) in the vaginal cohort, and 1953 (16.3%) in the laparoscopic cohort (all $P < 0.001$) (Table 5). Specifically, lower rates of medical, cardiovascular, gastrointestinal, genitourinary, pain, central nervous system, thromboembolic, and respiratory complications were recorded in the robotic-assisted group. The postoperative blood transfusion rate was significantly lower in the robotic-assisted cohort compared with the abdominal and vaginal cohorts, and was lower than in the laparoscopic cohort but this difference was not significant. Significantly lower reoperation rates and hospital readmission rates were observed in the robotic cohort compared with the abdominal cohort. The reoperation and readmission rates were lower in the robotic-assisted cohort than the vaginal and laparoscopic cohorts; however, this difference was not significant (Table 5).

4. Discussion

The results of the present study provide compelling and valuable evidence for the advantages of robotic-assisted hysterectomy for benign disorders when performed by surgeons with high-volume experience compared with laparoscopic, vaginal, or open abdominal hysterectomies performed by high-volume surgeons. Improved clinical outcomes and benefits observed with robotic-assisted hysterectomies included a significantly lower postoperative complication rate compared with abdominal, vaginal, and laparoscopic cohorts, despite the complexity of patients being higher in the robotic-assisted cohort. Reductions in intraoperative and postoperative complications could translate to reductions in the overall economic burden of treatment, with reduced incidence of surgical or medical injury correction, shorter hospitalization, fewer repeat surgeries, shorter recovery with less pain, and less time lost from work or normal activities, with concurrent improvements in quality of life.

The present results contrast with reports of comparable clinical outcomes between robotic-assisted hysterectomy and laparoscopic or vaginal hysterectomy [1,6,10]. Conclusions from these studies could be skewed, with outcomes from surgeons who were relatively inexperienced in robotic-assisted gynecologic surgery being compared with outcomes for established hysterectomy procedures performed by high-volume laparoscopic surgeons. Sarlos et al. [2] and Paraiso et al. [8] reported results from prospective randomized studies comparing robotic-assisted surgery with laparoscopic surgery for benign disease, demonstrating no differences in surgical outcomes and morbidity [2,8]; the surgeons performing these procedures were highly experienced laparoscopic surgeons but were early in their robotic-assisted surgery learning curve.

Previous studies have analyzed surgical outcomes based on results reported in the Premier Perspective database and the Nationwide Inpatient Sample database [1,6,10]. Pasic et al. [1] and Wright et al. [6] reported data from 2007 to 2010, when surgeons were early in their learning curve for robotic-assisted hysterectomy techniques [1,6]; in these studies, the non-robotically trained minimally invasive gynecologic surgeons were proficient in laparoscopic surgery techniques. The results demonstrated no significant differences in perioperative clinical outcomes between robotic-assisted and laparoscopic procedures, although longer operative times were reported for the robotic-assisted procedures.

The statistical difference reported in the present study in terms of intraoperative complications, and postoperative medical, cardiovascular, gastrointestinal, genitourinary, central nervous system, thromboembolic, and respiratory complications favored the robotic approach over the abdominal, laparoscopic, and vaginal approaches; although the difference in intraoperative complication rates between the robotic and laparoscopic approaches did not reach statistical significance. It is hypothesized that the significant reductions in postoperative

Table 4
Intraoperative complications.[a]

Intraoperative events	Robotic hysterectomy (n = 2300)	Premier database hysterectomy procedures		
		Abdominal hysterectomy (n = 9745)	Vaginal hysterectomy (n = 8121)	Laparoscopic hysterectomy (n = 11 952)
Patients experiencing any intraoperative complications[b]	17 (0.7)	174 (1.8)	142 (1.8)	142 (1.2)
P value[c]	Ref.	<0.001	<0.001	0.077
Hemorrhage	0	66 (0.7)	62 (0.8)	43 (0.4)
Laceration/puncture accident during surgery	16 (0.7)	105 (1.1)	79 (1.0)	99 (0.8)
Cautery/thermal injury	1 (0.0)	0	2 (0.0)	1 (0.0)
Nerve injury	0	0	3 (0.0)	0
Foreign body left in peritoneal cavity	0	1 (0.0)	3 (0.0)	2 (0.0)
Mechanical failure	0	0	0	1 (0.0)
Medical accident, not specified	0	66 (0.7)	45 (0.6)	58 (0.5)
Surgical, not specified	0	6 (0.1)	1 (0.0)	2 (0.0)
Patients requiring intraoperative blood transfusion	2 (0.1)	207 (2.1)	61 (0.8)	58 (0.5)
P value[c]	Ref.	<0.001	0.001	0.011

Abbreviation: ICD-9-CM, International Classification of Diseases, 9th Revision, Clinical Modification.
[a] Values are given as number (percentage) unless indicated otherwise.
[b] As defined by ICD-9-CM codes.
[c] χ^2 test.

Table 5
Postoperative complications during 30-day follow-up.[a]

Events	Robotic hysterectomy (n = 2095)[b]	Premier database hysterectomy procedures		
		Abdominal hysterectomy (n = 9745)	Vaginal hysterectomy (n = 8121)	Laparoscopic hysterectomy (n = 11 952)
Patients experiencing at least one postoperative complication	131 (6.3)	2047 (21.0)	1314 (16.2)	1953 (16.3)
P value[c]	Ref.	<0.001	<0.001	<0.001
Surgical	72 (3.4)	751 (7.7)	318 (3.9)	371 (3.1)
Medical	8 (0.4)	684 (7.0)	296 (3.6)	337 (2.8)
Cardiovascular	2 (0.1)	151 (1.5)	126 (1.6)	166 (1.4)
Gastrointestinal	18 (0.9)	598 (6.1)	293 (3.6)	311 (2.6)
Genitourinary	37 (1.8)	384 (3.9)	402 (5.0)	479 (4.0)
Pain	9 (0.4)	354 (3.6)	241 (3.0)	647 (5.4)
Central nervous system	4 (0.2)	34 (0.3)	24 (0.3)	45 (0.4)
Thromboembolic	0	46 (0.5)	12 (0.1)	25 (0.2)
Respiratory	9 (0.4)	266 (2.7)	86 (1.1)	90 (0.8)
Patients requiring a postoperative blood transfusion	5 (0.2)	229 (2.3)	64 (0.8)	46 (0.4)
P value[c]	Ref.	<0.001	0.005	0.298
Patients requiring hospital readmission related to index surgery	28 (1.3)	340 (3.5)	130 (1.6)	186 (1.6)
P value[c]	Ref.	<0.001	0.218	0.259
Patients requiring reoperation related to index surgery	17 (0.8)	187 (1.9)	84 (1.0)	118 (1.0)
P value[c]	Ref.	<0.001	0.248	0.314

[a] Values are given as number (percentage) unless indicated otherwise.
[b] 205 patients from the robotic-assisted cohort did not have complete 30-day follow-up data available and were excluded from the analysis.
[c] χ^2 test.

gastrointestinal, genitourinary, thromboembolic, and respiratory complications are attributable to the combination of the robotic technology with surgical experience and proficiency in this approach. Rosero et al. [10] reported a higher incidence of pneumonia among patients treated with robotic surgery when conducted by surgeons with varying levels of proficiency [10]. Inexperience can lead to prolonged operative times, resulting in increased postoperative complications [16]. The present study demonstrated a lower rate of respiratory complications and this could be attributed, in part, to a mean operative (skin-to-skin) time of 1.7 ± 0.7 h. This compares favorably to operative times reported in the literature for vaginal, total laparoscopic, and laparoscopic-assisted vaginal hysterectomies [17,18]. Skin-to-skin times were not available from the Premier database, which only reported the time from when the patient entered the operating room to when they exited. The times reported were 2.5 ± 1.2 h, 2.2 ± 1.0 h, and 2.7 ± 1.2 h in the abdominal, vaginal, and laparoscopic cohorts, respectively. Although it is not possible to compare the surgical time and operating-room time directly, the mean difference between the robotic-assisted cohort and the laparoscopic cohort was 1.0 h. Inefficiencies in the operating room and differences in preparation times could have contributed to this difference.

The effect of surgical volume on clinical outcomes is highly relevant to the interpretation of the present study data. Significantly improved clinical outcomes can be expected from surgeons with high-volume experience. Lenihan et al. [14] reported that a learning curve of 50 surgical cases was necessary to stabilize the operating time for robotic-assisted hysterectomies [14]. According to Woelk et al. [15], reduced intraoperative morbidity is the primary factor defining surgical proficiency, which—in their study comparing robotic-assisted hysterectomy to abdominal hysterectomy—was reached after completing 91 procedures [15].

The robotic-assisted cohort in the present study experienced fewer intraoperative complications and significantly fewer postoperative complications compared with the non-robotic surgery groups. These results are similar, especially the postoperative complication rates, to those reported by Lönnerfors et al. [19] in a randomized, controlled trial that evaluated the outcomes from high-volume surgeons performing robotic-assisted, laparoscopic, and vaginal hysterectomy [19].

The strengths of the present study included the rigorous, methodical, and detailed analyses of 2300 consecutive patients who underwent robotic-assisted hysterectomy in nine hospitals within the USA. Most published studies of robotic-assisted hysterectomy outcomes involve smaller numbers of patients or are single-center studies [20–22]. The present analysis included granularity regarding intraoperative and postoperative complications. That the present study included only high-volume gynecologic surgeons across all cohorts speaks to the favorable outcomes that are possible with proficiency in robotic-assisted techniques.

The retrospective nature of these comparisons is a limitation. Additionally, the Premier database relies on ICD-9-CM diagnostic and procedure codes, with potential for miscoding. Readmission data could have been lost for patients if they were readmitted to non-Premier member hospitals, resulting in potential under-reporting. The designation of high-volume experience in Premier could be conservative; Premier surgeons could have had a greater degree of experience than 60 procedures if they had performed surgeries at non-Premier hospitals or they performed more procedures prior to the period analyzed. Additionally, postoperative follow-up information following discharge was missing for 205 patients treated by one surgeon using the robotic-assisted approach; missing data is a common inherent limitation of retrospective data collection. Finally, the length of stay for outpatients was not available in the Premier database. Patients in the robotic-assisted cohort were categorized as outpatients if they were hospitalized for less than 24 h; however, patients in the other cohorts could have been observed in the hospital for up to 72 h and still been designated as outpatients.

The present study contains a detailed examination of clinical outcomes from the largest series of robotic-assisted benign hysterectomy patients reported in the literature. The costliness of robotic-assisted hysterectomy has previously been reported [1] without consideration of the perioperative outcomes from procedures performed by surgeons with comparable levels of experience. Consequently, an economic analysis is currently underway. Gynecologic surgeons with high-volume experience with robotic-assisted hysterectomies could offer patients clear benefits and potentially achieve significantly improved perioperative clinical outcomes compared with gynecologic surgeons who have high-volume experience of performing open, laparoscopic, or vaginal hysterectomies.

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Conflicts of Interest

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