Not all operative time is created equal: operative time in relation to 30-day complications in benign laparoscopic hysterectomies

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Keywords: Benign hysterectomy, laparoscopy, operative time, postoperative complications

Abstract

STUDY OBJECTIVE: To assess the relationship between operative time and specific 30-day postoperative complications across different intervals of operation duration in total laparoscopic hysterectomies (TLHs).

DESIGN: A retrospective cohort study.

SETTING: American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database from 2011 to 2020.

PATIENTS: 131,146 TLH cases.

INTERVENTIONS: Eligible cases included benign laparoscopic hysterectomies with operative times between 20 and 499 min. We excluded cases involving disseminated cancer, emergency surgery, supracervical approaches, or concomitant procedures.

MEASUREMENTS: Multivariable logistic regression analysis was used to evaluate the relationship between specific postoperative complications and operative time. Spline regression was used to analyze differences in the association between postoperative complications and operative time across different tertiles of operative duration.

MAIN RESULTS: Multivariable logistic regression analysis demonstrated a significant association between operative time and complication occurrence for each complication type investigated, including unplanned readmission, urinary tract infections, superficial surgical site infections, blood transfusion administration, return to the operating room, and deep organ space infections. Multivariable logistic spline regression demonstrated that operative time contributed more strongly to the odds of a complication for shorter procedures than longer procedures. This relationship was more pronounced for major complications than minor complications.

CONCLUSION: Operative time is a stronger risk factor for developing complications for shorter duration procedures than longer procedures. This is especially evident in major complications such as return to the operating room and deep organ space infections. Our results suggest that longer procedure duration may not affect the likelihood of a complication as much as previously thought, and operative times should not be a primary factor in deciding to convert to laparotomy or alter post-operative management.

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Introduction

Hysterectomies are one of the most common surgeries performed in the United States.[1] A trend towards minimally invasive routes, specifically a laparoscopic approach, has been increasing in incidence over the past two decades.[2-5] One of the advantages of laparoscopic hysterectomies over abdominal hysterectomies is decreased overall complication rates.[6,7] Numerous studies have shown that operative time is an independent risk factor for developing postoperative complications,[6,8-12] and that laparoscopic hysterectomies continued to have lower overall complication rates than abdominal hysterectomies even when laparoscopic operative times exceeded 300 min.[6] Evaluating specific operative times with respect to complication rates has thus been the subject of multiple studies[6,9] with the latest data suggesting that the relationship between operative time and overall complication rate does not significantly change for a laparoscopic approach.[6] However, to our knowledge, studies investigating how the relationship between operative time and specific postoperative complications differ across ranges of procedure duration have not been conducted. Understanding how operative time may affect the odds of specific complications could help guide surgeons' intra-operative and postoperative management. Therefore, in this study, we aim to: (1) determine rates of specific total laparoscopic hysterectomy (TLH) complications in the 30 days following surgery, (2) evaluate the association between operative time and specific complications for complications with a 30-day incidence ≥0.5%, and (3) for complications demonstrating a significant association with operative time, assess the relationship between operative time and complication occurrence across different tertiles of operation duration.

Materials and Methods

This was a retrospective cohort study using data from the multi-institutional American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database from 2011 to 2020. This database contains de-identified, prospectively collected data on surgical characteristics, preoperative morbidity, 30-day outcomes, and more than 200 well-defined clinical variables for patients undergoing major surgical procedures. Clinical data is collected by trained clinical reviewers at over 700 participating hospitals, and the database is routinely audited via an inter-rater reliability audit to ensure data integrity. This involves review of multiple patient charts selected both randomly and based on specific indices.[13-15] Overall, the disagreement rate is <2%.[14,15] As all data used was de-identified, the University of Iowa Institutional Review Board deemed this study exempt from formal review.

Eligible cases included TLH with current procedural terminology (CPT) codes 58570, 58571, 58572, and 58573. Of

note, laparoscopic hysterectomies included both conventional and robotic-assisted procedures due to sharing the same CPT code in the ACS-NSQIP database. Exclusion criteria included operative time less than 20 min, greater than 500 min, or unavailable; diagnosis of disseminated cancer, chemotherapy for malignancy within 30 days, or radiotherapy for malignancy within 90 days; "emergent" classification by surgeon and/or anesthesiologist; supracervical hysterectomy; and additional procedure other than cystoscopy, lysis of adhesions, or adnexal removal performed.

The primary outcomes were (1) TLH complication rates, stratified by complication type, (2) adjusted odds ratios (aORs) for each complication type per 10-min increase in operative time, controlling for differences in baseline and surgical characteristics, and (3) tertile-specific aORs for each complication type with respect to operative time, controlling for differences in baseline and surgical characteristics. Given that this was an exploratory analysis, tertiles rather than quartiles or quintiles were chosen as this was the minimum number of divisions to show a potential trend across different ranges of operative time. Complications were stratified into major and minor complications according to the scale established by Dindo et al.[16] Grades I and II complications (any deviation from the normal postoperative course, including complications requiring pharmacologic treatments, blood transfusions, and TPN) were categorized as minor complications, while grades III and IV (complications requiring surgical, endoscopic, or radiological interventions; life-threatening complications such as central nervous system [CNS] involvement or intensive care unit admission; single and multi-organ dysfunction; and death) were considered major complications. Minor complications included 30-day readmission, wound infection, postoperative pneumonia, venous thromboembolism, pulmonary embolism, urinary tract infection, and blood transfusion. Major complications included wound dehiscence, reintubation, ventilator use for >48 h, renal insufficiency/failure, return to the operating room, CNS complications, myocardial infarction, cardiac arrest, sepsis/septic shock, and death. Definitions of each complication were based on ACS-NSQIP criteria, as outlined in their user guide.[13] For 30-day readmission, all "NULL" values were assumed to be non-readmission cases.

Baseline demographic characteristics, clinical characteristics, comorbidities, and surgical characteristics were recorded as potential confounders. Variables queried included age, race, body mass index (BMI), American Society of Anesthesiologists (ASA) classification, smoking status, general anesthesia, preoperative hematocrit (Hct), preoperative white blood cell (WBC) count, long-term steroid use, history of diabetes, history of kidney problems, history of congestive heart failure (CHF), history chronic obstructive pulmonary disease (COPD), adhesiolysis during surgery, and uterine weight exceeding 250 g. For this analysis, a history of kidney problems was defined as a preoperative creatinine greater than 1.2 mg/dL, preoperative

dialysis requirement, or preoperative diagnosis of acute renal failure (as outlined by ACS-NSQIP criteria[13]). Adhesiolysis was coded as "Yes" if one of the following CPT codes was listed as an additional procedure in the ACS-NSQIP database: 44005, 44180, 44200, 58660, and 58740. Uterine weight exceeding 250 g was coded based on primary procedure CPT code.

Overall and tertile-specific complication rates and 95% confidence intervals (CIs) were computed for each post-operative complication. Descriptive statistics (median [inter-quartile range] and n [%]) stratified by operative time tertile for all covariates were also computed. For the second study aim, multivariable logistic regression models were used to evaluate the relationship between each complication type and 10-min increase in operative time, adjusting for potential confounders. These confounders were chosen based on clinical relevance and statistical significance in univariate logistic regression analysis (Appendix Table 1). For the third study aim, multivariable logistic regression analysis for the relationship between operative time and each complication was repeated with operative time included as a linear spline term with knots at the 33rd and 67th percentile of TLH operation duration. Statistical analysis was performed using R software (version 3.6.3). Spline regression analysis was performed using the "splines" package.

Results

A total of 192,643 total laparoscopic hysterectomies were recorded in the ACS-NSQIP database from 2011 to 2020. 60,412 cases were excluded due to additional procedures other than cystoscopy, adhesiolysis, and/or adnexal removal; 257 were excluded for operative times <20 or >500 min; 204 were excluded due to emergent classification; and 624 were excluded due to diagnosis of disseminated cancer or recent administration of chemotherapy and/or radiation therapy (Figure 1).

Demographics, comorbidities, and clinical characteristics of patients by hysterectomy route are summarized in Table 1. Overall complication rates and complication rates by type are reported in Table 2. The most common complications were all minor and included unplanned readmission within 30 days, urinary tract infection, superficial surgical site infection, and need for a blood transfusion. The most common major complications were return to the operating room and deep organ space surgical site infections, each of which occurred greater than 1% of the time.

Table 1. Demographics, Comorbidities, and Clinical Characteristics

Characteristic	Operative Time			P-value*
	<97 minutes (0-33rd percentile) N = 43,505	97-139 minutes (33rd-67th percentile) N = 43,414	140+ minutes (67th-100th percentile) N = 44,227	
Age Group				<0.001
<45 years	21,182 (49%)	18,935 (44%)	17,370 (39%)	
45+ years	22,318 (51%)	24,477 (56%)	26,854 (61%)	
Race				<0.001
White	33,172 (76%)	30,538 (70%)	22,216 (62%)	
Black	3,995 (9.2%)	5,459 (13%)	8,444 (19%)	
Asian	876 (2.0%)	1,518 (3.5%)	2,084 (4.7%)	
Other or did not disclose	5,462 (13%)	5,899 (14%)	6,483 (15%)	
ASA class				<0.001
1	4,839 (11%)	4,276 (9.9%)	3,575 (8.1%)	
2	29,162 (67%)	27,803 (64%)	27,247 (62%)	
3	9,233 (21%)	11,015 (25%)	12,965 (29%)	
4+	254 (0.6%)	298 (0.7%)	423 (1.0%)	
Body Mass Index (kg/m^2)				<0.001
Underweight (<18.5)	925 (2.2%)	766 (1.9%)	711 (1.7%)	
Normal (18.5-24.99)	9,929 (24%)	8,311 (20%)	6,812 (16%)	
Overweight (25-29.99)	11,494 (28%)	10,637 (26%)	9,804 (23%)	
Obese (≥30)	19,176 (21%)	21,517 (52%)	24,616 (59%)	
Smoker (within 1 year)	7,812 (18%)	6,706 (15%)	6,201 (14%)	<0.001
General anesthesia†	43,437 (100%)	43,331 (100%)	44,150 (100%)	0.282
History of CHF	36 (<0.1%)	53 (0.15%)	60 (0.1%)	0.054
History of COPD	461 (1.1%)	408 (0.9%)	401 (0.9%)	0.052
Diabetes				<0.001
No	40,345 (93%)	39,408 (91%)	39,206 (89%)	
Non-insulin dependent	2,272 (5.2%)	2,887 (6.7%)	3,576 (8.1%)	
Insulin dependent	888 (2.0%)	1,119 (2.6%)	1,445 (3.3%)	
Kidney disease	532 (1.2%)	636 (1.5%)	805 (1.8%)	<0.001
Long-term steroid use	748 (1.7%)	754 (1.7%)	703 (1.6%)	0.179
WBC count >10,500‡	2,923 (7.4%)	3,028 (7.6%)	3,207 (7.8%)	0.128
Hematocrit <35§	4,315 (11%)	5,308 (13%)	7,190 (17%)	<0.001
Uterus >250 grams	3,960 (9.1%)	6,901 (16%)	12,676 (29%)	<0.001
Adhesiolysis performed	1,023 (2.3%)	1,700 (3.9%)	2,668 (6.0%)	<0.001

*Based on Chi-square test of homogeneity
†Number of cases excluded due to missing data was 5, 1, 2 for first, second, third tertiles, respectively
‡Number of cases excluded due to missing data was 3,964, 3,446, 2,954 for first, second, third tertiles, respectively
§Number of cases excluded due to missing data was 3,288, 2,718, 2,424 for first, second, third tertiles, respectively

CHF = congestive heart failure, COPD = chronic obstructive pulmonary disease, WBC = white blood cell

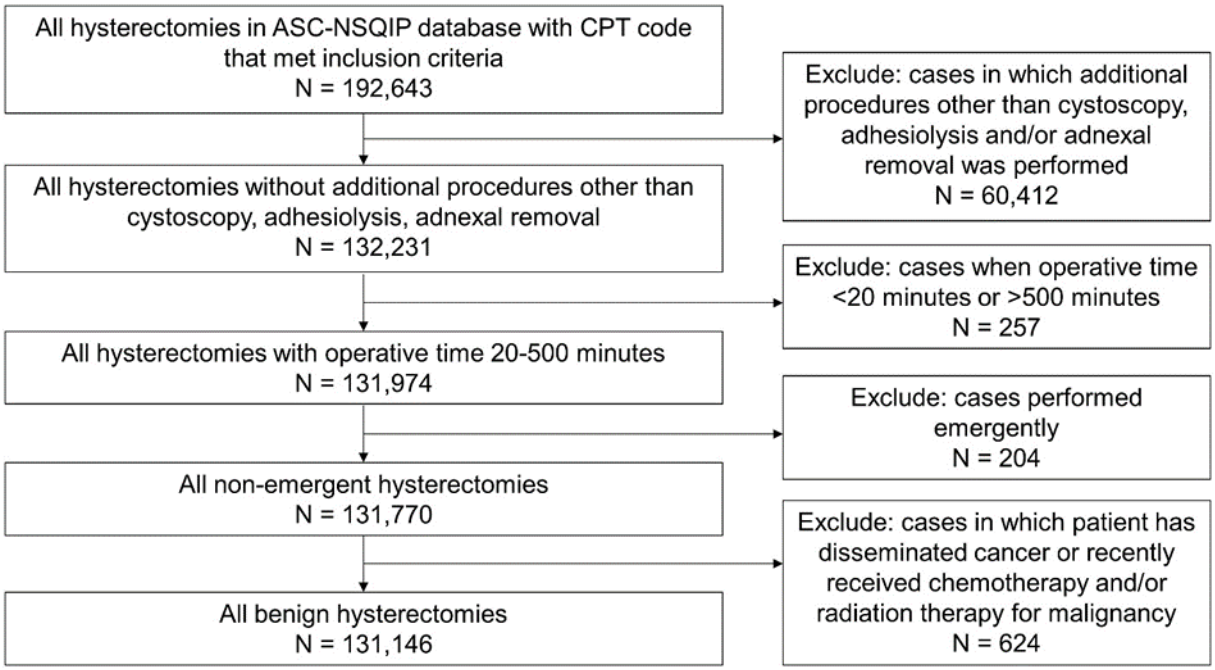

Figure 1. Excluded Cases

Table 2. Total Laparoscopic Hysterectomy Complication Rates

Complication Type	Complication Occurrence	
	Number	Rate
Overall (any complication)	9,006	6.87%
Any minor complication	7,731	5.90%
Unplanned readmission within 30 days	3,055	2.37%
Urinary tract infection	2,659	2.03%
Superficial surgical site infection	1,454	1.11%
Blood transfusion	1,265	0.96%
Any major complication	3,061	2.33%
Return to the operating room	1,515	1.16%
Deep organ space surgical site infection	1,466	1.12%

A histogram for the distribution of operative duration, shown in Figure 2, demonstrated an appreciable positive skew. Operative time tertiles, determined by the operative time points that divided the population into three equal groups, were defined as follows: first tertile <97 min, second tertile 97–139 min, and third tertile ≥140 min.

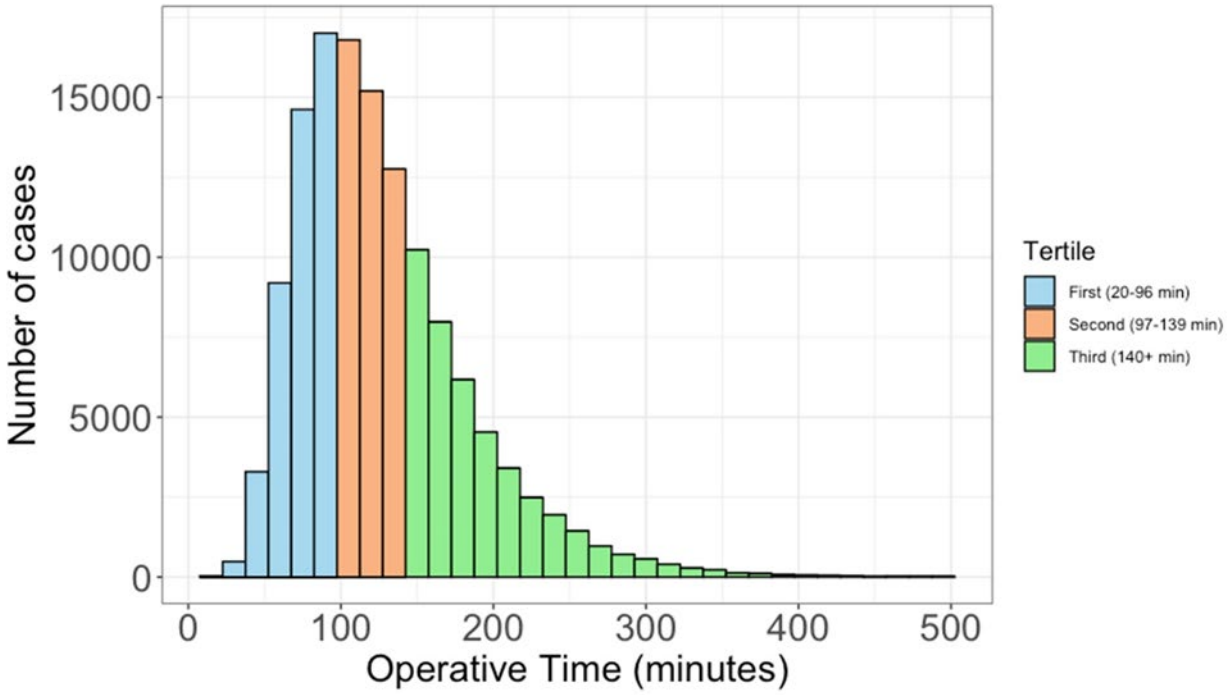

Figure 2. Histogram of Tertiles

Multivariable logistic regression demonstrated a significant association between operative time and each complication type investigated (Table 3). Most complications had a moderate association with operation duration with an adjusted odds ratio per 10-min increase in operative time around 1.04. Blood transfusion was more strongly associated with operative time than other complications.

Multivariable logistic spline regression demonstrated differences in the association between complications and operative time across operative time tertiles (Table 4, Figure 3). In general, operative time was more strongly associated with the odds of a complication during the first tertile of operative time (0–97 min) as compared to the second or third tertiles, although this pattern was more pronounced for major complications than minor complications. The exception to this trend was need for a blood transfusion, which showed the strongest association with operative time in the middle tertile (98–139 min) and the weakest association in the first tertile.

Table 3. Adjusted Odds Ratios for Complications

Complication Type	aOR (95% CI)
Overall (any complication)	1.04 (1.04-1.05)
Any minor complication	1.05 (1.04-1.05)
Unplanned readmission within 30d	1.04 (1.04-1.05)
Urinary tract infection	1.03 (1.02-1.04)
Superficial surgical site infection	1.03 (1.03-1.04)
Blood transfusion	1.08 (1.07-1.09)
Any major complication	1.04 (1.03-1.04)
Return to the operating room	1.03 (1.02-1.04)
Deep organ space surgical site infection	1.04 (1.04-1.05)

aOR = adjusted odds ratio, CI = confidence interval, d = days

Table 4. Adjusted Odds Ratios for Complications by Operative Time Tertile

Complication Type	aOR (95% CI)		
	<97 minutes (0-33rd percentile)	97-139 minutes (33rd-67th percentile)	140+ minutes (67th-100th percentile)
Overall (any complication)	1.06 (1.04-1.09)	1.05 (1.03-1.07)	1.04 (1.03-1.04)
Any minor complication	1.06 (1.03-1.09)	1.05 (1.03-1.07)	1.04 (1.03-1.05)
Unplanned readmission within 30d	1.09 (1.04-1.14)	1.05 (1.02-1.08)	1.03 (1.02-1.04)
Urinary tract infection	1.05 (1.01-1.10)	1.05 (1.01-1.08)	1.02 (1.01-1.03)
Superficial surgical site infection	1.08 (1.01-1.15)	1.04 (0.99-1.08)	1.03 (1.01-1.04)
Blood transfusion	1.02 (0.95-1.11)	1.11 (1.06-1.17)	1.08 (1.06-1.09)
Any major complication	1.10 (1.05-1.15)	1.05 (1.02-1.08)	1.02 (1.01-1.03)
Return to the operating room	1.06 (1.00-1.12)	1.05 (1.01-1.09)	1.02 (1.01-1.04)
Deep organ space surgical site infection	1.17 (1.09-1.25)	1.08 (1.03-1.12)	1.02 (1.01-1.03)

aOR = adjusted odds ratio, CI = confidence interval

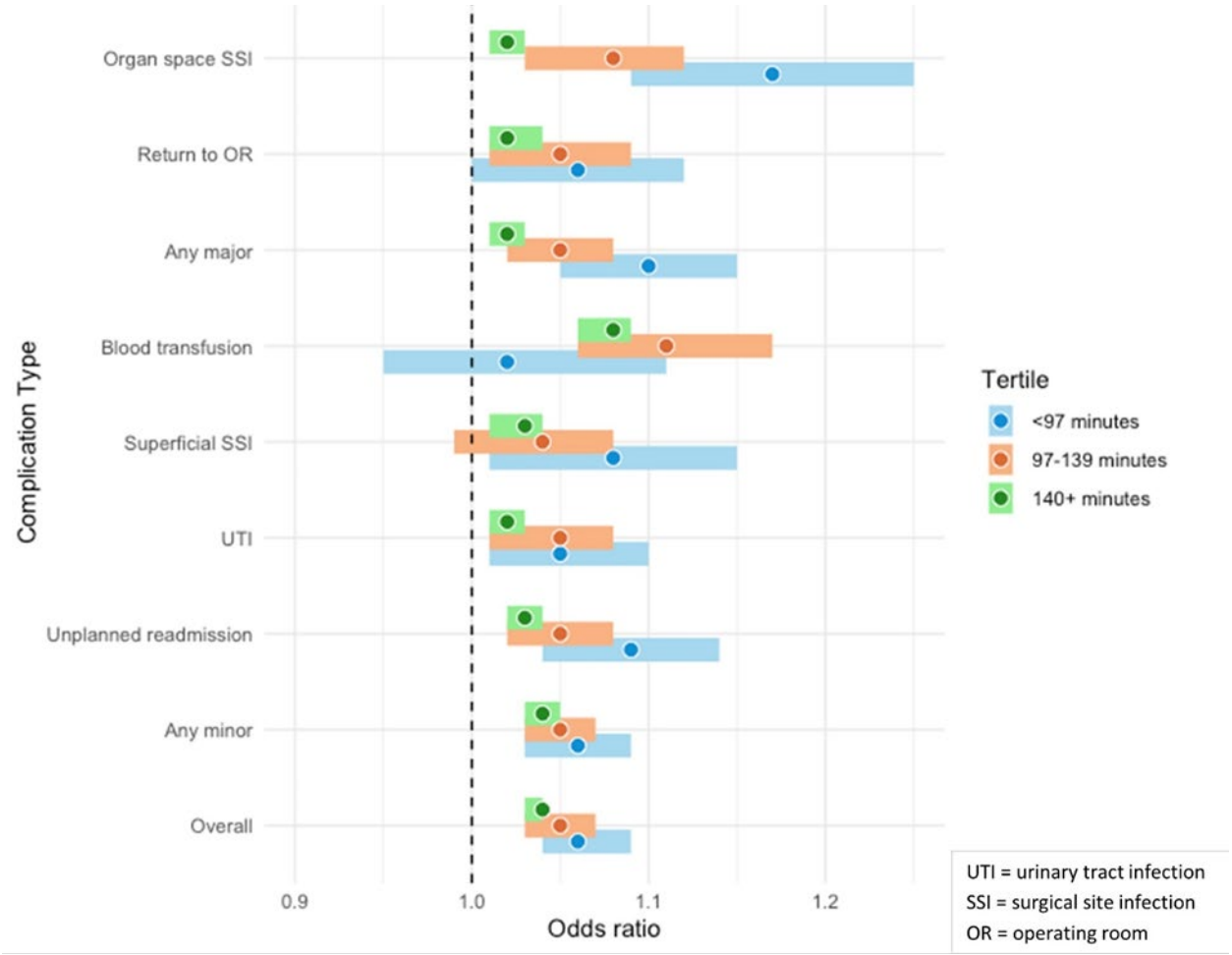

Figure 3. aOR across Tertiles

When assessing complications across tertiles of operative time, a significant difference in aOR was observed between the first tertile of time and the third tertile of time for three specific complications: unplanned readmission within 30 days, any major complication, and deep organ space surgical site infection. The odds of a complication per 10-min increase in operative time decreased from 1.09 (1.04–1.14) to 1.03 (1.02–1.04), 1.10 (1.05–1.15) to 1.02 (1.01–1.03), and 1.17 (1.09–1.25) to 1.02 (1.01–1.03) for unplanned readmission within 30 days, any major complication, and deep organ space surgical site infection, respectively.

Discussion

In this study we showed that operative time is a risk factor for the most common minor and major postoperative complications in patients undergoing a total laparoscopic hysterectomy for benign indications. Our study also demonstrated that operative time is a stronger risk factor for major complications during the first 100 min of

a procedure as compared to operative time accrued after 140 min.

Our results also showed a consistent pattern of narrower aOR CIs for the third tertile of operative time (≥140 min) compared to the first two operative time intervals. While the cause of this pattern is unclear, several variables may be contributing to this observation. First, surgeries that take longer than 140 min (third tertile of operative time) likely involve a consistent set of characteristics that make the surgery more complex, such as large uteruses, prior abdominal surgeries, and obesity.[17] Similarly, longer operative times encompass a larger proportion of surgeons who are less experienced or are considered low-volume.[17,18] These specific factors likely represent a more consistent population and complication pattern than those observed in the first and second tertiles. Additionally, those institutions that have the capacity to consistently perform complex hysterectomies laparoscopically are likely fewer in number and proportionally contribute more hysterectomy cases to the NSQIP database for longer operative times, fundamentally decreasing the variability. Lastly, the first 140 min (representing the first and second tertiles of operative time) captures cases at all stages of the hysterectomy, encompassing a wide array of risk factors for postoperative complications, including more risky aspects of the procedure such as initial skin incision and abdominal entry, adhesiolysis, and identification and isolation of the ureters and the blood supply.[19] In contrast, the stage of the hysterectomy after 140 min is likely to be more consistently toward the end of the procedure or after the riskier parts of the surgery have been completed, reducing the variability in odds of a postoperative complication occurring.

Our results are consistent with previously published studies. Our overall complication rate of 6.87% as well as occurrence rates for specific post-operative complications, such as UTI (2.03%), superficial surgical site infection (1.11%), blood transfusion (0.96%), and return to the operating room (1.16%) was similar to prior studies.[6,9,20] Additionally, the aOR of 1.04 per 10-minute increase in operative time for overall complications was consistent with previously published works.[6,12] In the multivariable regression model, the covariates that were most strongly associated with complications, including Black or African American race, ASA class ≥ 2, smoking, and medical comorbidities (e.g. CHF, COPD, poorly controlled diabetes, anemia) are all established as risk factors for surgical complications (Appendix Table 2).[9,11,21,22] Likewise, previous work has demonstrated no statistically significant difference in the aOR for overall complications across different ranges of operative time for TLH.[6] The current study builds on these findings, demonstrating that when complications are disaggregated, the association between major complications and operative time is stronger earlier in a procedure compared to later, however, the same is not true for minor complications.

Our results highlight several clinical notions: (1) that surgical intervention entails an “upfront cost,” reflected in stronger association of operative time

with odds of a complication for minutes 0–97 of the procedure, and (2) longer procedure duration may not affect the likelihood of a complication as much as previously thought.

Future studies could investigate whether prolonged procedure duration for benign hysterectomies is more strongly associated with certain complications for other minimally invasive routes other than laparoscopy, such as vaginal and vaginal natural orifice transluminal endoscopic surgery. Similarly, further studies could explore operative time thresholds among different routes of myomectomies at which the procedure becomes higher risk.

Our study is strengthened by use of a large sample size from the ASC-NSQIP database, which is routinely audited to ensure the incidence of any mis-entered or mis-reported data remains less than 2%.[14,15] Use of a database, on the other hand, contributes to weaknesses in our study such as selection bias where larger institutions are more likely to participate and contribute to the ASC-NSQIP database. As such, the data may not be representative of all healthcare institutions nationwide. Given the fixed categories supplied by the dataset, analysis and interpretation of the data is also limited. For instance, intraoperative events are not recorded, such as anesthesia-related problems, bowel or ureteral injuries, or estimated blood loss. In addition, listed categories are not always consistent across datasets. Trainee involvement, for example, is included in earlier datasets but has not been recorded since 2012. This limited our ability to evaluate the data even further, as only those characteristics present in all datasets from 2011 to 2020 were included in analysis. It is also notable to point out that the ASC-NSQIP database does not distinguish between conventional laparoscopic and robotic approaches. However, a study conducted by Albright et al. that evaluated benign hysterectomies performed via robotic versus conventional laparoscopy showed no difference in complication rates or operative time.[23] In addition, this study was limited by strict inclusion criteria, which strengthened our overall conclusions, but excluded other routes of surgery and common benign gynecologic surgeries, limiting its application in the gynecologic field.

To our knowledge, this is the first study to assess the relationship between operative time and specific postoperative complications across various operative time intervals for benign laparoscopic hysterectomies. Our study demonstrates that the most common postoperative complications are significantly associated with operative time; however, the strength of this relationship varies by complication and time interval.

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Appendix Table 1. Covariates for multivariable logistic regression models

Any complication	Minor complication	Unplanned readmission	Urinary tract infection	Superficial SSI
Age Race ASA class BMI group Smoker Hx of CHF Hx of COPD Diabetes Kidney disease Long-term steroids WBC count > 10.5k Hct < 35 Uterus > 250 grams Adhesiolysis	Age Race ASA class BMI group Smoker Hx of CHF Hx of COPD Diabetes Kidney disease Long-term steroids WBC count > 10.5k Hct < 35 Uterus > 250 grams Adhesiolysis	Age Race ASA class Smoker Hx of CHF Hx of COPD Diabetes Kidney disease Long-term steroids WBC count > 10.5k Hct < 35 Adhesiolysis	Age Race ASA class BMI group Smoker Diabetes WBC count > 10.5k Adhesiolysis	Age Race ASA class BMI group Smoker Hx of COPD Diabetes Kidney disease WBC count > 10.5k
Blood transfusion	**Major complication**	**Return to operating room**	**Deep organ space SSI**	
Race ASA class Hx of CHF Diabetes Kidney disease WBC count > 10.5k Hct < 35 Uterus > 250 grams Adhesiolysis	Age Race ASA class Smoker Hx of CHF Diabetes Long-term steroids WBC count > 10.5k Hct < 35 Uterus > 250 grams Adhesiolysis	Age Race BMI group Hx of CHF	Age Race ASA class Smoker Long-term steroids WBC count > 10.5k Adhesiolysis	

SSI = surgical site infection, BMI = body mass index, Hx = history, CHF = congestive heart failure, COPD = chronic obstructive pulmonary disease, WBC = white blood cell, Hct = hematocrit

Appendix Table 2. Multivariable regression model for overall complications

Covariate	aOR[1]	95% CI[1]
Operative time (per 10 min)	1.04	(1.04-1.05)
Age		
<45	—	—
45+	0.76	(0.73-0.80)
Race		
White	—	—
Black or African American	1.08	(1.01-1.15)
Asian	1.04	(0.91-1.18)
Other or unknown	1.1	(1.03-1.18)
ASA class		
1	—	—
2	1.19	(1.09-1.30)
3	1.54	(1.40-1.71)
4+	2.3	(1.84-2.87)
BMI		
Normal	—	—
Overweight	0.94	(0.88-1.01)
Obese	0.89	(0.83-0.95)
Underweight	0.84	(0.70-1.01)
Smoker (within 1 year)		
No	—	—
Yes	1.15	(1.08-1.23)
History of CHF		
No	—	—
Yes	2.37	(1.53-3.57)
History of COPD		
No	—	—
Yes	1.18	(0.96-1.44)
Diabetes		
No	—	—
Non-insulin	0.99	(0.90-1.08)
Insulin	1.34	(1.18-1.51)
Kidney disease		
No	—	—

Yes	1.12	(0.95-1.31)
Long-term steroid use		
No	—	—
Yes	1.23	(1.05-1.43)
WBC count >10,500		
No	—	—
Yes	1.16	(1.07-1.26)
Hct < 35		
No	—	—
Yes	1.62	(1.52-1.71)
Uterus > 250 grams		
No	—	—
Yes	1.01	(0.95-1.07)
Adhesiolysis		
No	—	—
Yes	1.13	(1.02-1.26)

aOR = Adjusted Odds Ratio, CI = Confidence Interval, min = minutes, BMI = body mass index, CHF = congestive heart failure, COPD = chronic obstructive pulmonary disease, WBC = white blood cell, Hct = hematocrit