GYNECOLOGY

Trainee participation and perioperative complications in benign hysterectomy: the effect of route of surgery

Emma L. Barber, MD; Benjamin Harris, MD; Paola A. Gehrig, MD

BACKGROUND: Intraoperative trainee involvement in hysterectomy is common. However, the effect of intraoperative trainee involvement on perioperative complications depending on surgical approach is unknown.

OBJECTIVE: To estimate the effect of intraoperative trainee involvement on perioperative complication after vaginal, laparoscopic, and abdominal hysterectomy for benign disease.

METHODS: Patients undergoing laparoscopic, vaginal, or abdominal hysterectomy for benign disease from 2010 to 2012 were identified from the American College of Surgeons National Surgical Quality Improvement Program database. Patients with and without trainee involvement were compared with regard to perioperative complications. Complications that occurred from the start of surgery to 30-days postoperatively were included. Perioperative complications were defined via the use of the validated Clavien-Dindo scale with ≥grade 3 complications defined as major and ≤grade 2 complications defined as minor. Major complications included myocardial infarction, pneumonia, venous thromboembolism, deep or organ space surgical-site infection, stroke, fascial dehiscence, unplanned return to the operating room, renal failure, cardiopulmonary arrest, sepsis, intubation greater than 48 hours, and death. Minor complications included urinary tract infection, blood transfusion, and superficial wound infection. To estimate the effect of trainee involvement depending on route of surgery, a stratified analysis was performed. Bivariable analysis and adjusted multivariable logistic regression were used.

RESULTS: We identified 22,499 patients, of whom 42.1% had trainee participation. Surgical approaches were vaginal (22.7%), abdominal (47.1%), and laparoscopic (30.2%). The rate of major complication was 3.2%, and minor complication was 7.2%. In bivariable analysis, trainee involvement was associated with major complications in vaginal hysterectomy (3.3% vs 2.3%, $P = .03$), but not laparoscopic (3.0% vs 2.9%, $P = .78$) or abdominal hysterectomy (4.4% vs 3.6%, $P = .07$). Trainee involvement was also associated with minor complication in vaginal (7.3% vs 5.4%, $P = .007$), laparoscopic (5.9% vs 4.3%, $P < .001$), and abdominal hysterectomy (14.1% vs 9.2%, $P < .001$). In a multivariable analysis in which we adjusted for age, body mass index, medical comorbidity, American Society of Anesthesiologists score, and surgical complexity, the association between trainee involvement in vaginal hysterectomy and major complication persisted (adjusted odds ratio 1.45, 95% confidence interval 1.03−2.04); however, when operative time was added to the model, there was no longer an association between trainee involvement and major complication (adjusted odds ratio 1.26, 95% confidence interval 0.89−1.80).

CONCLUSION: Surgical approach influences the relationship between trainee involvement and perioperative complication. Operative time is a key mediator of the relationship between trainee involvement and complication, and may be a modifiable risk factor.

Key words: hysterectomy, perioperative complication, surgical approach, trainees, vaginal hysterectomy

The top hospitals in national rankings, such as *U.S. News and World Reports*, are large academic institutions with training programs.[1] Large academic institutions are believed to provide high-quality care as the result of expertise of staff, experience with difficult and rare cases, the constant questioning and reevaluation present in a learning environment, and complex patient populations.[2,3] Conversely, patients often perceive trainee involvement in surgery as a potential detriment to high-quality care.[4,5] The evidence, however, regarding trainee participation in medical care, and specifically in surgical procedures, is mixed. Studies across a large number of elective surgical procedures and specialties have found that trainee participation in the operating room is safe, with no changes in major complication rates,[6-8] whereas one study of trainee participation in emergent surgery found an association with major complications.[9]

Gynecologic surgical training may differ from surgical training in other surgical subspecialties; therefore the results from other surgical programs may not be applicable to gynecology. Approximately 500,000 hysterectomies are performed in the United States each year, making it a representative procedure to examine the effect of trainee participation in gynecology.[10] Laparoscopic hysterectomy also is becoming more common, and vaginal hysterectomy is becoming less common.[10,11] Resulting differences in trainee experience may lead to different effects of trainee participation on perioperative complications, depending on the surgical approach.

We examined the effect of trainee participation during hysterectomy performed for benign conditions on perioperative complications and evaluated whether the effect of trainee participation differs by surgical approach.

Materials and Methods

Patients who underwent hysterectomy for benign disease from January 2010 through December 2012 and who were recorded in the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database were included in this study. Primary

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Current Procedural Terminology (CPT) codes were used to identify patients who underwent hysterectomy and to classify patients by route of surgery (Supplemental Table 1). CPT codes that include hysterectomy along with other procedures, such as lymphadenectomy, which would indicate the hysterectomy was being performed as treatment for a malignancy, were not included. Patients also were excluded if an *International Classification of Diseases*, 9th Revision code for malignancy was recorded.

The American College of Surgeons NSQIP database is a national surgical quality improvement program. Participation is voluntary, and participating institutions are able to track their own risk-adjusted outcomes after surgery. Trained clinical reviewers prospectively collect variables such as patient demographics, operative variables, and postoperative outcomes for 30 days after surgery. Periodic auditing ensures high-quality data, including for data points that occur after hospital discharge. Details of methods of data collection and reliability have been reported previously.[12]

Demographic variables abstracted included age, race, and body mass index. Patient-related preoperative variables abstracted included hypertension requiring medication, diabetes mellitus requiring insulin or oral therapy, smoking in the last year, American Society of Anesthesiologists (ASA) score, and major medical comorbidity divided into the categories of neurologic, cardiac, pulmonary, and infectious. Major cardiac comorbidity was defined as congestive heart failure in the month before surgery, myocardial infarction 6 months before surgery, history of peripheral vascular disease, history of percutaneous cardiac intervention, or previous cardiac surgery. Major pulmonary comorbidity was defined as history of severe chronic obstructive pulmonary disease or pneumonia in the last 30 days. Major neurologic comorbidity was defined as history of stroke with or without neurologic deficit or history of transient ischemic attack. Major infectious morbidity was defined as preoperative sepsis, or a preoperative open wound. Definitions of these patient history variables, such as the criteria for history of myocardial infarction or stroke, were per the NSQIP data participant use file.[13]

Operative variables abstracted included operative time, surgical approach, trainee involvement, and surgical complexity. Trainee involvement was defined as trainee intraoperative involvement as coded in the NSQIP database. Trainees were further classified as either residents or fellows on the basis of postgraduate year. Residents were defined as postgraduate year 1−4 and fellows were defined as postgraduate year 5 and greater. Surgical complexity was defined by the work relative value unit (wRVU), which is an estimate of the amount of physician work per CPT code defined by Medicare. The wRVU for each procedure is the sum of the assigned value to each CPT code for the procedure; thus, greater wRVU is associated with increased surgical complexity.

Perioperative surgical complications were defined as complications that occurred from the start of surgery up to 30 days postoperatively. Major complications were defined as grade 3 or greater on the validated Clavien-Dindo grading scale.[14] Minor complications were defined as grade 2 or less. Major complications included myocardial infarction, pneumonia, venous thromboembolism, deep or organ space surgical-site infection, stroke, fascial dehiscence, unplanned return to the operating room, renal failure, cardiopulmonary arrest, sepsis, intubation greater than 48 hours, and death. Minor complications included urinary tract infection, blood transfusion, and superficial wound infection. Intraoperative complications such as accidental puncture or laceration are not recorded in the NSQIP database and thus were not included in the definition of perioperative complication. Specific definitions of the diagnostic criteria for each of these complications can be found in the NSQIP data participant use file.[13]

This was a secondary analysis cohort study of prospectively collected surgical-quality data. The primary outcome was major perioperative complication and secondary outcome was minor perioperative complication. Patients with intraoperative trainee participation were compared with those without with respect to outcomes. For bivariable analysis, 2-tailed t-tests were used for continuous variables and Pearson χ^2 tests for categorical variables. Stratified analysis was performed by surgical approach, given the association between surgical approach and both trainee involvement and complications. Associations between trainee participation and complications were analyzed by the use of binary logistic regression to examine for potential confounding. Confounders were selected on the basis of known associations with complications in the literature.[15-19] A P value of less than .05 was considered significant for all analyses. SPSS version 20.0 (IBM Corp, Armonk, NY) was used for all analyses. The Institutional Review Board of University of North Carolina at Chapel Hill declared this study exempt from formal review because it does not constitute human subjects research.

Results

We identified 22,499 patients who underwent hysterectomy for benign disease. Demographic and operative characteristics of the overall study population are provided in Table 1. Patients with intraoperative trainee involvement represent a population at greater risk of complication with older age, greater surgical complexity scores based on work relative value units, and greater rates of comorbidities (hypertension, pulmonary and neurologic comorbidities, and ASA score $\geq$3).

Overall, 42.1% (n = 9471) of patients had intraoperative trainee involvement in their hysterectomy. Of the 9471 hysterectomies with trainee participation, 8375 (88.4%) had data available for postgraduate year of the highest-level trainee involved. This was a fellow in 14.5% (n = 1375) and a resident in 73.9% (n = 7000). Surgical approach was 22.7% vaginal (n = 5112), 47.1% abdominal (n = 6803), and 30.2% laparoscopic (n = 10,584). Rates of trainee involvement differed depending on surgical approach with trainee involvement in 45.1% (n = 4272)

of laparoscopic hysterectomies, 32.1% (n = 3038) of open hysterectomies, and 22.8% (n = 2161) of vaginal hysterectomies ($P < .001$).

The overall rate of major perioperative complication was 3.2% (n = 726), and the rate of minor perioperative complication was 7.2% (n = 1616). Rates of complications also differed depending on surgical approach with more complications occurring in the open hysterectomy group. Rates of major perioperative complication were 4.0% for open hysterectomy (n = 270), 3.0% for laparoscopic hysterectomy (n = 316), and 2.7% for vaginal hysterectomy (n = 140). Rates of minor perioperative complication were 11.4% for open hysterectomy (n = 775), 6.2% for vaginal hysterectomy (n = 317), and 5.0% for laparoscopic hysterectomy (n = 524).

Given the observed differences in intraoperative trainee involvement and major perioperative complications depending on surgical approach, a stratified analysis was performed by surgical approach. In bivariable analysis, trainee involvement was associated with major perioperative complication among patients undergoing vaginal hysterectomy, but not abdominal or laparoscopic hysterectomy (Table 2). Trainee involvement also was associated with increased rates of minor complications among patients undergoing vaginal, laparoscopic, and open hysterectomies.

We then compared the association between trainee level and perioperative complication. We found that there was no difference for fellows versus residents in rates of major complications (4.0% vs 3.5%, $P = .33$) or minor complications (9.2% vs 9.0%, $P = .89$). The specific perioperative complications experienced by patients with and without trainee involvement are listed in Table 3.

To address potential confounders, logistic regression was performed in which we adjusted for age, body mass index, hypertension, smoking, cardiac comorbidity, pulmonary comorbidity, neurologic comorbidity, infectious comorbidity, ASA score, and surgical complexity (Table 4). After we adjusted for these confounders, trainee involvement remained associated with major perioperative complications among patients undergoing vaginal hysterectomy. Trainee involvement also remained associated with minor perioperative complications among all 3 surgical approaches.

Operative time is known to be associated with both perioperative complications and trainee involvement. A separate multivariable logistic regression model was performed that also included operative time in addition to the previously adjusted for confounders (Table 5). After operative time was adjusted for, there was no longer an association between trainee involvement and major complication in vaginal hysterectomy. There was also no longer an association between trainee involvement and minor complication in vaginal hysterectomy and laparoscopic hysterectomy.

TABLE 1
Patient characteristics and trainee participation

Patient characteristics	Overall n = 22,499	No trainee participation n = 13,028	Trainee participation n = 9471	*P* value
Age, y	47.5 ± 10.8	46.5 ± 10.8	48.59 ± 10.7	<.0001
BMI, kg/m^2	30.1 ± 7.5	30.1 ± 7.3	30.1 ± 7.7	NS
Race				<.0001
White	13,579 (60%)	8583 (66%)	4996 (53%)	
Hispanic	2505 (11%)	2003 (15%)	502 (5.3%)	
Black	2636 (12%)	924 (7.1%)	1712 (18%)	
Asian	371 (1.7%)	160 (1.2%)	211 (2.2%)	
Other	3408 (15%)	1358 (10%)	2050 (22%)	
Hypertension	5740 (26%)	3053 (23%)	2687 (28%)	<.0001
Current smoker	4334 (19%)	2619 (20%)	1715 (18%)	<.0001
Diabetes				NS
Noninsulin	1144 (5.1%)	629 (4.8%)	515 (5.4%)	
Insulin	357 (1.6%)	205 (1.6%)	152 (1.6%)	
Cardiac comorbidity	295 (1.3%)	163 (1.3%)	132 (1.4%)	NS
Pulmonary comorbidity	1024 (4.6%)	659 (5.1%)	365 (3.9%)	<.0001
Neurologic comorbidity	347 (1.5%)	172 (1.3%)	175 (1.9%)	<.002
Infectious comorbidity	156 (0.7%)	81 (0.6%)	75 (0.8%)	NS
ASA score ≥3	3825 (17%)	1892 (15%)	1933 (20%)	<.0001
Surgical complexity (wRVU)	24.3 ± 12.1	23.7 ± 11.9	24.9 ± 12.1	<.0001
Operative time, minutes	122.5 ± 63.7	108.3 ± 58.1	141.8 ± 65.9	<.0001

All data are presented at n (%) for categorical variables and mean (SD) for continuous variables.

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *NS*, not significant; *wRVU*, work relative value unit.

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Comment

Our results agree with other studies that have found that trainee participation in surgical procedures is safe.[6,7,20] We found no association between trainee involvement and major perioperative complication among patients undergoing laparoscopic or abdominal hysterectomy and the increased odds of complication among patients undergoing vaginal hysterectomy was small. This finding is consistent with other literature in gynecology that has shown that trainee participation in total laparoscopic hysterectomy for benign disease is

TABLE 2
Bivariable associations between trainee involvement and 30-day perioperative complications stratified by surgical approach

	No major complication	Major complication	*P* value	No minor complication	Minor complication	*P* value
Vaginal						
No trainee	2,883	68 (2.3%)	.03[a]	2791	160 (5.4%)	.007[a]
Trainee	2,089	72 (3.3%)		2004	157 (7.3%)	
Laparoscopic						
No trainee	6,126	186 (2.9%)	.78	6038	274 (4.3%)	<.001[a]
Trainee	4,142	130 (3.0%)		4022	250 (5.9%)	
Open						
No trainee	3,630	135 (3.6%)	.07	3417	348 (9.2%)	<.001[a]
Trainee	2,903	135 (4.4%)		2611	427 (14.1%)	

Data is presented n or n (%).

[a] Statistical significance with $P < .05$.

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TABLE 3
Specific perioperative complications among patients without and with trainee involvement in surgery

	No trainee (n = 13,028)	Trainee (n = 9471)	*P* value
Major complication			
MI	5 (0.04%)	3 (0.03%)	NS
PNA	26 (0.2%)	13 (0.1%)	NS
VTE	42 (0.3%)	41 (0.4%)	NS
Deep/organ space SSI	125 (0.2%)	109 (0.2%)	NS
Fascial dehiscence	36 (0.3%)	27 (0.3%)	NS
Return to OR	193 (1.5%)	149 (1.6%)	NS
Stroke	2 (0.02%)	0 (0.0%)	NS
Renal failure	8 (0.06%)	5 (0.05%)	NS
Cardiopulmonary arrest	1 (0.008%)	1 (0.01%)	NS
Sepsis	52 (0.4%)	61 (0.6%)	.02[a]
Prolonged/reintubation	9 (0.1%)	19 (0.1%)	NS
Nerve injury	7 (0.05%)	6 (0.06%)	NS
Minor complication			
Superficial wound infection	164 (1.3%)	160 (1.7%)	.007[a]
Transfusion	329 (2.5%)	404 (4.3%)	<.001[a]
Urinary tract infection	313 (2.4%)	320 (3.4%)	<.001[a]

Postoperative complications are not mutually exclusive. Patients may have experienced more than 1 postoperative complication.

MI, myocardial infarction; *NS*, not significant; *OR*, operating room; *PNA*, pneumonia; *SSI*, surgical-site infection; *VTE*, venous thromboembolism.

[a] Statistical significance with $P < .05$.

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associated with increased operative time and small increases in rates of 30-day readmission, reoperation and transfusion but no association with mortality or severe complications.[21]

Our data suggest that the route of surgery influences the effect of intraoperative trainee participation on perioperative complications. Trainee participation was associated with major complication in vaginal hysterectomy but not in open or laparoscopic hysterectomy. In addition, residents were involved in fewer of the vaginal hysterectomies (23%) compared with open (32%) or laparoscopic hysterectomies (45%). Others have noted that residency training in vaginal hysterectomy has been decreasing, with few residency graduates reporting comfort with their ability to perform the procedure independently.[22-24] Supervision and teaching by an attending physician also may be more difficult in the setting of vaginal hysterectomy, in which visibility of the assistant is limited compared with laparoscopic or open hysterectomy. Although the mechanism of the differential association is unknown, it seems plausible that decreased exposure to vaginal hysterectomy among residents contributes to the increased observed complications. These data identify vaginal hysterectomy as a procedure that may require additional simulation during residency training relative to open and laparoscopic hysterectomy to make up for the decreased training volume.

Operative time also emerged from our analysis as an important mediator of the relationship between trainee participation and complication. Operative time is associated with complication in a variety of surgical settings.[25-27] In our multivariable model, when operative time was adjusted for, many of the relationships between trainee participation and perioperative complication were no longer present and the effect sizes were decreased. Hysterectomies with trainee involvement likely take longer for a variety of reasons, including facility with the procedure, time for intraoperative teaching, and the environment in which the hysterectomy occurs. Large teaching hospital environments with training

programs may not be as production driven as smaller private hospitals without trainees, and this may result in longer operative times. Large teaching hospitals also are likely to have more complex surgeries and medically complex patients as the result of referrals and this may increase operative times, although our adjustment for surgical complexity and medical comorbidities minimizes this bias.

Nevertheless, decreasing operative time among patients undergoing hysterectomy with trainee participation may help to decrease perioperative complication rates. Increased simulation before participation in the operating room has been shown to increase efficiency once trainees enter the operating room.[28] Another potential strategy is to allow the trainee to act as primary surgeon for a defined period of time at which point the attending physician will serve as the primary surgeon. This allows for autonomy and teaching while limiting the potential for increased operative time and resulting complications.

Strengths of the study include a large number of patients recorded in a national quality database, which has been noted to be reliable, accurate, and is widely used across a variety of surgical disciplines to examine perioperative outcomes. Specifically, the NSQIP database has been used to assess the effect of intraoperative trainee participation across a variety of surgical disciplines.[6-9,21,29-31] In addition, the database is focused around the surgical procedure and thus includes detailed comprehensive information regarding preoperative characteristics and perioperative complications.

Limitations of this study include the potential for unmeasured factor bias. It may be that hysterectomies with trainees are more prone to complications than hysterectomies without trainees because of population or system factors. We were able to adjust for both surgical complexity and diverse patient comorbidities to minimize these differences; however, it is possible that these cases differ by additional unmeasured factors that we were unable to adjust for. We also are unable to quantify the extent of intraoperative trainee participation as detailed data on whether the trainee was primary surgeon or assistant is not available. Additionally, complications are only recorded for 30-days postoperatively and thus we may have underestimated the true rate of complication.

Intraoperative trainee participation is associated with small increases in major perioperative complications in vaginal hysterectomy and increased minor perioperative complications in all surgical approaches to hysterectomy. Our study suggests that efforts to mitigate the effect of trainee participation on complications should focus on

TABLE 4
Unadjusted and adjusted odds ratios for the association between trainee involvement and perioperative complication

	Unadjusted OR	95% CI	Adjusted OR	95% CI
Major complication				
Vaginal	1.46[a]	1.04–2.04[a]	1.4 [a]	1.03–2.04[a]
Laparoscopic	1.03	0.82–1.30	1.09	0.86–1.37
Open	1.25	0.98–1.60	1.19	0.92–1.53
Minor complication				
Vaginal	1.37[a]	1.09–1.72[a]	1.30[a]	1.03–1.63[a]
Laparoscopic	1.37[a]	1.15–1.63[a]	1.36[a]	1.14–1.63[a]
Open	1.61[a]	1.38–1.87[a]	1.56[a]	1.33–1.82[a]

Binary logistic regression model with adjusted odds ratios adjusted for age, BMI, hypertension, smoking, cardiac comorbidity, pulmonary comorbidity, neurologic comorbidity, infectious comorbidity, ASA score, and surgical complexity.

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *CI*, confidence interval; *OR*, odds ratio.

[a] Statistical significance with $P < .05$.

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TABLE 5
Adjusted odds ratios for the association between trainee involvement and perioperative complication without and with adjustment for operative time

	Model without operative time		Model adjusted for operative time	
	Adjusted OR	95% CI	Adjusted OR	95% CI
Major complication				
Vaginal	1.45[a]	1.03–2.04[a]	1.26	0.89–1.80
Laparoscopic	1.09	0.86–1.37	0.88	0.69–1.12
Open	1.19	0.92–1.53	1.08	0.83–1.40
Minor complication				
Vaginal	1.30[a]	1.03–1.63[a]	1.21	0.95–1.54
Laparoscopic	1.36[a]	1.14–1.63[a]	1.12	0.93–1.35
Open	1.56[a]	1.33–1.82[a]	1.34[a]	1.13–1.57[a]

Both models are adjusted for age, BMI, hypertension, smoking, cardiac comorbidity, pulmonary comorbidity, neurologic comorbidity, infectious comorbidity, ASA score, surgical complexity. In the model on the right, operative time is also adjusted for.

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *CI*, confidence interval; *OR*, odds ratio.

[a] Statistical significance with $P < .05$.

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decreasing operative time and addressing disparities in vaginal hysterectomy complications relative to other surgical approaches. ■

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Author and article information

From the University of North Carolina, Division of Gynecologic Oncology, Department of Obstetrics and Gynecology, Chapel Hill, North Carolina (Drs Barber and Gehrig); Department of Obstetrics and Gynecology, Duke University, Durham, North Carolina (Dr Harris); and Lineberger Clinical Cancer Center, University of North Carolina, Chapel Hill, North Carolina (Dr Gehrig).

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Corresponding author: Emma Barber, MD. embarber@med.unc.edu

SUPPLEMENTAL TABLE 1
CPT codes used to select hysterectomy groups

	CPT codes
Open hysterectomy	58150, 58152, 58180
Laparoscopic hysterectomy	58541–4, 58550–4, 58570–3
Vaginal hysterectomy	58260–3, 58267, 58270, 58290, 58290–4

CPT, Current Procedural Terminology.

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