



Research article

What factors impact surgical operative time when teaching a resident in the operating room

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ABSTRACT

Purpose: Resident involvement would likely lead to prolonged operative time of a surgical case performed at academic medical centers. However, little is known about factors beneath this phenomenon. The purpose of this study was to investigate whether factors from case (procedure type, surgical case complexity, and surgical approach), teacher (attending surgeon experience and gender), and learner (resident postgraduate training year and gender) would influence operative time of surgical cases involved teaching a resident (SCT).

Methods: A single-institution retrospective analysis of 3 common general surgery procedures, including cholecystectomies, colectomies, and inguinal hernia, with involvement of general surgery residents between 2016 and 2020 was conducted. Surgical operative time was defined as the "cut-to-close" time from incision to completion of wound closure. Analysis of variance for continuous variables and multivariable linear regression were applied.

Results: A total of 4,417 eligible SCT were included. The average operative time was 114.8 ± 78.7 min. SCT with male resident involvement showed a significantly longer operative time than those with female residents (117 vs. 112, $p = 0.01$). Comparable operative time was observed between male and female attending surgeon cases (115.5 vs. 110.8, $p = 0.15$). SCT operating time decreased with increased resident training level, except for SCT with involvement of Year2 residents. SCT with Year5 residents demonstrated the lowest time to case completion (110.5 min); SCT with major complications took least time to complete (105.7 min). Univariate and multivariate analysis revealed resident training year level, resident gender, and case complexity as factors associated with significant differences in operative time. Attending surgeon experience, surgeon gender, surgical approach, and procedure type did not impact SCT operative time.

Conclusion: Our study findings suggest resident training level, resident gender, and case complexity are factors significantly associated with SCT operative time of cholecystectomies, colectomies, and inguinal hernia. Attending surgeons are recommended to factor them into pre-operative planning.

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1. Introduction

Surgical workforce training, especially in general surgery, remains critical given a rising demand for surgeons to meet population health needs of surgical care. In academic medical centers/teaching hospitals, an attending surgeon has the obligation to teach and train surgery residents in the operating room (OR) but also is responsible for ensuring the surgical case proceeds safely and efficiently. However, multiple studies have consistently demonstrated that resident involvement in a surgical case would commonly lead to a prolonged surgery time length [1–5], which predictively might result in higher expenses of care delivery as well as a decreased operative efficiency and patient outcomes [2,6,7]. Moreover, the coronavirus pandemic exacerbated multiple individual and system pressures (e.g., hospital revenue, relative value unit-based compensation, academic promotion) are placed on contemporary surgeons working in academic medical centers/teaching hospitals. These pressures may push attending surgeons to enhance clinical productivity and operative efficiency by decreasing time spent in teaching a resident in the OR [8,9], which potentially undermines residents' training quality and readiness for independent practice. Surgical resident training geared towards optimizing operative time for both the institution and trainee must meet the demand for skilled, efficient surgeons. To seek a practical solution helping attending surgeons manage such a challenge (of teaching a resident and caring a patient) in the OR, we need to identify what factors contributing to the prolonged operative time of surgical cases involved teaching a resident (SCT) first as part of resolution.

Many studies have been conducted to investigate what patient-related factors (e.g., age, obese) would influence the operative time [10–13] and some institutions have established measures to motivate and reward surgical efficiency/productivity based on tracked metrics of surgery time incurred in the OR. However, it is still unclear what training-related factors, both related and unrelated to the resident, may have the potential to impact the operative time length of a SCT. Such factors may particularly include variables related to “teacher” (i.e., attending surgeon experience, surgeon gender), “learner” (i.e., resident postgraduate training year, resident gender) and “case” (i.e., procedure type, case complexity, and surgical approach). Thus, we conducted this study to investigate whether these factors from teacher, learner, and case would influence operative time of SCT. Findings from this study will help to identify strategies and/or approaches to address the above challenge in aid of achieving high quality intraoperative patient care without scarifying surgical resident training.

2. Methods

2.1. Setting and participants

This is a single-center retrospective analysis conducted at The Ohio State University College of Medicine General Surgery residency, which is a university-based, Accreditation Council for Graduate Medical Education (ACGME) accredited training program. Both categorical and preliminary general surgery residents were eligible for this study. Research residents were excluded. This study was approved by The Ohio State University Institutional Review Board.

2.2. Data collection

We included SCT from three most common index surgical procedures that ACGME requires general surgery residents to practice [14], including cholecystectomies, colectomies, and inguinal hernia repairs. Current Procedural Terminology (CPT) codes of the included procedures are listed in the supplement. We extracted following variables from the hospital billing record between July 2016 and June 2020: procedure type, surgical approach, attending surgeon name, case complexity, and operative time. Records from cases without resident involvement were excluded. In this study, surgical approach included two main categories: robotic and non-robotic surgeries (i.e., open and laparoscopy surgery), for robotic surgery is a new surgical approach and attending surgeons' learning curves may influence their teaching in OR. Cases complexity was classified into four groups based on the diagnosis-related group (DRG) information: case with complications, cases with major complications, cases without complications, and day surgery cases. Surgical operative time referred to the “cut-to-close” time that cutting was initiated in the OR to the time of wound closure. Attending surgeon experience (defined by years of practice) and gender as well as resident postgraduate year (PGY) level and gender were obtained from the administrative system and then matched with the hospital billing records.

2.3. Data analysis

Descriptive statistics for continuous variables were presented as means and standard deviation ranges, and descriptive statistics for categorical variables were presented as counts and percentages. The influence of characteristics on operative time was tested using linear regression. The primary outcome measure in this study was total operative time in minutes.

A multivariable linear regression model was developed to identify predictors of operative time. All testing was conducted at 5% Types I error rate, and P-value ≤ 0.05 was considered statistically significant. The statistical analysis was executed using SAS version 9.4 (SAS Institute, Cary, NC) and Stata version 15 (StataCorp, College Station, TX).

3. Results

A total of 4,417 SCT performed by 62 attending surgeons and 75 surgical residents throughout the study time frame were included. Twenty surgeons (32.3%) were female and 42 were male; 48.0% (36 out of 75) of resident participants were female and 52.0% were

male. Cholecystectomies represented the largest procedure group (2078/4417, 47.05%), followed by inguinal hernia and colectomy (Table 1). The overall mean SCT operative time was 114.8 ± 78.7 min across all included procedures.

Univariate analysis revealed resident PGY level and resident gender as factors significantly associated with SCT operative time (Table 2). Female and male residents had a similar number of procedures. Female residents completed SCT cases on average 5 min faster than their male counterparts ($p = 0.0275$). PGY5 residents completed the most procedures (47%) compared to residents in other postgraduate training years. And PGY2 residents had the shortest cut to close times (105.9 min). There was no difference in operative time based on attending surgeon gender or attending surgeon level of experience.

Majority SCT (78.63%) were open surgical cases (Table 3). Overall, day surgery represented most cases (2834/4427, 64.16%); case without complications had 723 cases (16.37%); cases with complications and major complications together had 860 cases (19.47%). Day surgery cases on average took the longest operative time (117.6 min), and the cases with major complications took the least cut-to-close time (105.7 min). The case complexity was also a factor significantly associated with SCT operative time ($p = 0.031$). Procedure type ($p = 0.6337$) and surgical approach ($p = 0.1841$) did not significantly impact the SCT operative time.

Multivariable linear regression also revealed that three factors were significant predictors of SCT operative time amongst the study samples (Table 4): resident PGY level ($p < 0.0001$), case complexity ($p = 0.0026$), and resident gender ($p = 0.0100$).

4. Discussion

4.1. Factors influencing SCT operative time

Intraoperative teaching has become one of common challenges for attending surgeons to manage the balance between training a resident and caring a patient in the OR, which may lead to a prolonged operative time and a decrease in operative efficiency. From education perspective, teacher, learner, and case (i.e., educational content) are three key elements that can influence the teaching/learning progress. Our study findings suggest teacher-related factors do not influence SCT operative time, while two learner-related factors (resident PGY level and resident gender) and one case-related factor (case complexity) significantly impact SCT operative time in the cholecystectomies, colectomies, and inguinal hernia repairs. Particularly, earlier resident postgraduate years of training was associated with longer operative time (except for SCT with a PGY2 resident), which is in line with the literature that junior resident involvement in cases commonly translates into longer operative time compared to senior residents [1–5,15]. This may be due to the novice residents lack technical skills, and thus requires an attending surgeon to “slow down to teach” in the OR [16]. Likewise, finding of decreasing operative time with the increasing PGY level may imply improvement in resident surgical competencies, entrustment, and autonomy leading to enhanced intraoperative efficiency of teaching and operation [17]. Interestingly, we observed a significant decrease in operative time for PGY2 residents compared to all other PGY cohorts in current study samples. One possible reason may be our residency training program’s resident rotation schedule – PGY2 residents primarily participated in cholecystectomies, colectomies, and inguinal hernia cases when they rotated in the trauma surgical care service.

Case complexity is another factor that has a significant impact on the SCT operative time. Although we do not include patient-related factors (e.g., age, previous surgical history) in current study, results suggest both attending surgeons and residents value patient safety, which is consistent with the literature [10–13]. It is thus not a surprise that an attending surgeon would take more control and do more in a SCT with major complications [18]. This finding also aligns with the nature of academic medical centers/teaching hospitals, which provides excellent patient care while educating the next generation of surgeons simultaneously.

Our study also shows an association of female residents to shorter operative time, irrespective of attending surgeon gender. Although the difference (5.2 min) is not clinically significant, this finding may bring in two possible interpretations: 1) female residents are more efficient than their male counterparts at completing index surgical operations of colectomies, cholecystectomies, and inguinal hernia, and 2) female residents are permitted less opportunities to practice autonomy from the attending surgeon in the OR, resulting in shorter operative time. Future investigation about this finding is needed to further explore this finding including whether a possible gender effect [19] exists in resident intraoperative surgical training.

4.2. Potential implication of findings

One fundamental function of surgical residency training is to allow surgery residents to develop clinical acumen, acquire technical skills, and attain proficiency that scaffolds their progressive independence upon graduation while maintaining excellent intraoperative surgical care quality and efficiency. Through training in the OR, surgical residents acquire skills. With improved skills, residents would

Table 1
Procedure type summary.

Procedure type	Surgical Approach		Total
	Non-Robotic*	Robotic	
Cholecystectomy	1725	353	2078
Colectomy	984	40	1024
Inguinal Hernia	764	551	1315
Total	3473	944	4417

Note: *Non-Robotic = open and laparoscopy surgery.

Table 2
Operative time by resident and attending surgeon characteristics.

Variable	N (%)	Time (Mean \pm SD [^])	P-Value
Resident Gender			0.0275
Female	2132 (48.37%)	112 \pm 78.5	
Male	2276 (51.63%)	117.2 \pm 78.9	
Resident Training Year			<0.0001
1	164 (3.71%)	127.7 \pm 72	
2	814 (18.43%)	105.9 \pm 60.4	
3	681 (15.42%)	125.2 \pm 82.9	
4	691 (15.64%)	124.8 \pm 94.4	
5	2067 (46.8%)	110.5 \pm 77.7	
Surgeon Gender			0.1471
Female	704 (15.94%)	110.8 \pm 69.2	
Male	3713 (84.06%)	115.5 \pm 80.4	
Surgeon Experience Level*			0.6462
1	126 (2.86%)	113.6 \pm 67.7	
2	771 (17.48%)	114.5 \pm 81.7	
3	1084 (24.57%)	112.4 \pm 73.7	
4	2430 (55.09%)	116 \pm 80.5	

Notes: * Experience Level 1 = Practice year 0–1; Level 2 = Practice year 1–5; Level 3 = Practice year 5–10; Level 4 = Practice year >10. [^]SD = Standard Deviation.

Table 3
Operative time by surgical case attributes.

Variable	N (%)	Time (Mean \pm SD [^])	P-Value
Total	4417	114.8 \pm 78.7	N/A
Procedure Type			0.6337
Cholecystectomy	2078 (47%)	113.6 \pm 75.9	
Colectomy	1024 (23.2%)	116.2 \pm 77.5	
Inguinal Hernia	1315 (29.8%)	115.5 \pm 83.9	
Surgical Approach			0.1841
Non-Robotic*	3473 (78.63%)	115.6 \pm 79.5	
Robotic	944 (21.37%)	111.8 \pm 75.6	
Case Complexity			0.0031
Case with Complication	602 (13.63%)	114.4 \pm 80.6	
Case with Major Complication	258 (5.84%)	105.7 \pm 70.6	
Case without Complication	723 (16.37%)	107.2 \pm 69.1	
Day Surgery case	2834 (64.16%)	117.6 \pm 81.1	

Notes: * Non-Robotic including laparoscopy and open surgery; [^]SD = Standard Deviation.

Table 4
Predictor of operative time.

Predictors	P-Value
Patient Type	0.1676
Procedure Type	0.1814
Attending Experience Level	0.4975
Resident PGY* Level	<0.0001
Surgical Approach	0.4439
Attending Surgeon Gender	0.1940
Resident Gender	0.0100
Case Complexity	0.0026

Note: *PGY=Postgraduate Year.

likely gain increased entrustment and responsibility that affords autonomy in the OR. More opportunities of autonomy then accelerate residents' proficiency development through applications of the skills he/she was entrusted to practice independently with minimal supervision from the attending surgeon. Lastly, operative efficiency (time) naturally emanates from proficiency. The acquisition of skills, entrustment, autonomy, proficiency, and efficiency are essential components that form the training wheel paradigm of residency (Fig. 1). These interdependent factors are recommended be individually maximized during residency training to supply competent independent surgeons who is ready to enter the practice to serve population health needs. The weakening of any one of these factors leads to a collapse of the foundation of the surgical resident training, leading to residents' unpreparedness for independent practice [20–23]. In addition, our study findings also encourage attending surgeons to factor resident PGY level, gender, and case complexity into their pre-operative planning of a SCT including both intraoperative teaching plan and caring plan to optimize the efficiency and

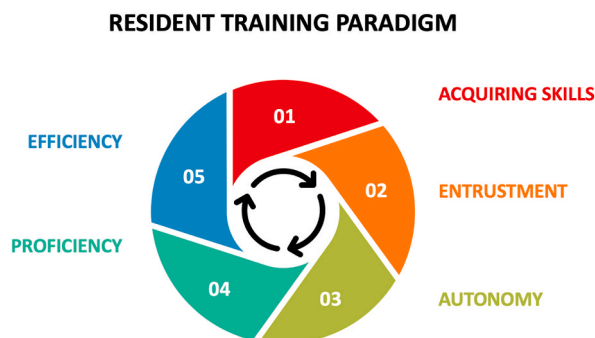


Fig. 1. Resident training paradigm.

quality of patient care and teaching in the OR.

4.3. Strengths and limitations

The strengths of this study include 1) a multi-year large sample size with matched operative time and cost data, and 2) articulated resident training levels and genders in each surgical case. Especially most current electronic medical record systems (EMR) do not capture resident training levels leading to a substantial effort required for data matching and processing, though such a detailed data set enable us to conduct an in-depth analysis to examine our study hypothesis. Several limitations, however, ought to be considered in the interpretation of this study. As a single institutional database review, we were limited by the size of the available cohort. This prevented detailed subgroup analysis, and further studies are indicated to strengthen and expand upon our conclusions. Despite this limitation, significance was attained for the variable studied. The practice niche was likewise narrowed to general surgery, and repeated studies evaluating additional subspecialties will need to be conducted. Only cholecystectomies, colectomies, and inguinal hernia repairs were evaluated, and the study would benefit from further subgroup analysis. Moreover, we were not able to include patient-related factors, detailed case factors (e.g., right vs left vs sigmoidoscopy), and residents' case-based intraoperative autonomy in data analysis, which may be large confounders potentially influences the results. Future studies with detailed patient and case data as well as resident intraoperative autonomy data are needed to further validate this study findings.

5. Conclusion

Our study suggests that resident training year, case complexity, and resident gender are three factors significantly associated with surgical operative time when teaching a resident in a surgical case of cholecystectomies, colectomies, and inguinal hernia at academic medical centers and/or teaching hospitals. Attending surgeons are recommended to include these three factors into their pre-operative planning of a SCT in order to optimize the efficiency of intraoperative management of patient care and teaching.

Author contribution statement

Dathe Z. Benissan-Messan: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Robert Tamer: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Heidi Pieper: Michael Meara: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Xiaodong (Phoenix) Chen: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

The authors do not have permission to share data.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Robert Tamer reports financial support was provided by Intuitive Foundation. Michael Meara reports a relationship with Intuitive Surgical Inc that includes: consulting or advisory.

Abbreviations

SCT	Surgical Cases involved Teaching (a Resident)
OR	Operating Room
PGY	Postgraduate Year
IRB	Institutional Review Board

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.heliyon.2023.e16554>.

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