Structured Operative Autonomy: An Institutional Approach to Enhancing Surgical Resident Education Without Impacting Patient Outcomes

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BACKGROUND: Although barriers to granting surgical residents autonomy in the operating room are well described, few have proposed practical strategies to overcome these barriers. Our department adopted a multidisciplinary approach to develop a rotation that aimed to grant chief residents structured operative autonomy. In this study, we assess the feasibility of implementation, impact on patient safety, and educational benefit to residents after the program's pilot year.

STUDY DESIGN: During a 1-month rotation, chief residents began cases alone using their own operative block time. The attending surgeon was notified when the critical portion of the operation was reached and supervised its completion. Postoperative complications, intraoperative adverse events, readmissions, operation duration, and length of stay in a subset of patients that underwent a cholecystectomy or appendectomy were compared with patients operated on by standard resident services. Follow-up surveys were administered to residents 1 year after graduation.

RESULTS: One hundred and twenty-four operations, which ranged in complexity, were performed by chief residents. Unadjusted subset analysis comparing the structured operative autonomy (n = 54) and standard resident (n = 718) services outcomes for appendectomies and cholecystectomies revealed no significant differences in 30-day postoperative complications (5.6% vs 4.0%; p = 0.59), major intraoperative adverse events, or readmissions (3.7% vs 3.8%; p = 1.00), respectively. Multivariate analysis performed for 30-day complications (odds ratio 0.8; 95% CI 0.2 to 3.2; p = 0.76) and readmissions (odds ratio 0.4; 95% CI 0.1 to 2.1; p = 0.3) corroborated unadjusted findings. All participants (n = 8) strongly agreed that the rotation eased their transition to fellowship or independent practice.

CONCLUSIONS: Structured operative autonomy overcomes known barriers to granting chief residents autonomy in the operating room. When used for select general surgery cases, resident education is enhanced without impacting patient outcomes. This training model has the potential to improve the surgical independence of graduating residents. (J Am Coll Surg 2017;225:713−724. © 2017 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

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"The Churchill Plan" for resident development, which influenced the restructuring of graduate surgical education in the mid-20th century, sought to ensure the training of a highly skilled surgical workforce that could meet the needs of society.[1-3] Dr Edward Churchill's curriculum centered around a "rectangular surgical residency" and changes in educational philosophy that produced a larger number of fully trained surgeons each year.[1] His fundamental principles have withstood the test of time, but the structure of residency training has inevitably evolved to align with work-hour restrictions, supervision regulations, reimbursement practices, advances in

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technology, and the increase in surgical sub-specialization.[1,4] Although Dr Churchill's system found early success when its graduates responded to our nation's high surgical demands after World War II, the abilities of our current graduating residents to operate independently have been called into question.[5-7] For example, in a survey of fellowship directors in the US, 66% of respondents believed that their incoming fellows could not perform even 30 minutes of a major operation unsupervised.[7] This nationwide phenomenon in surgical education is multifactorial, but the overall decrease in resident operative autonomy is likely a major factor.[4,5,8-10]

Although Dr Churchill disagreed with Dr William Halsted's "pyramidal program," both visionaries espoused the principle of graded responsibility to ensure their graduating chief residents acquired enough operative autonomy to become independent surgeons and educate their successors.[1] Recent studies have shown that the level of intraoperative autonomy given to residents is considerably less than what both faculty and trainees deem appropriate and that the number of teaching cases chief residents perform is decreasing.[11,12] Teman and colleagues[13] surveyed attending surgeons across multiple institutions and found that a greater emphasis on patient outcomes, a desire to increase case efficiency, and both patient and institutional expectations of attending surgeon involvement, were the greatest barriers to granting resident autonomy in the operating room. Despite recognition of these hurdles, there is a paucity of practical strategies that institutions could adopt to enhance resident operative autonomy.

The Massachusetts General Hospital, where Dr Churchill's method was first implemented and refined, is not immune to the pressures of the modern era.[1-3] In response to concerns from its trainees, the Department of Surgery led a multidisciplinary team, including all members of the operating room, to design a rotation that provided surgical residents with structured operative autonomy. This rotation grants chief residents the highest level of independence allowable in our current medicolegal climate for core general surgery operations. In its development, the previously identified barriers to granting autonomy were considered and steps were taken to overcome them. This study describes our pilot-year experience, including both intraoperative and postoperative patient outcomes, and the impact of this rotation on resident education. We hypothesized that there would be an increase in the duration of the procedures but no significant differences in postoperative outcomes between the structured operative autonomy and the standard resident services.

METHODS

Study design and outcomes

The rotation was piloted from September 2014 to June 2015. Operative cases were logged in a database maintained by the residents on service. The primary end point measured was the 30-day postoperative complication rate, as defined by the American College of Surgeons NSQIP.[14] Secondary outcomes included the 30-day mortality rate, 30-day all-cause readmission rate, 30-day procedure-related emergency department visits, operative time, estimated blood loss, major intraoperative adverse events (iAEs), and hospital length of stay. A detailed subset analysis was performed to compare primary and secondary outcomes of the 2 most common intra-abdominal procedures (appendectomy and cholecystectomy) with institutional controls. The institutional control cohort included patients who underwent appendectomy or cholecystectomy by the same group of attending surgeons during the years 2013 to 2015, while operating with a resident on their standard service. These cases were subdivided as laparoscopic or open based on intention to treat. Chief residents who completed the service were administered surveys after their first year of fellowship or independent practice to assess the impact that the structured operative autonomy rotation had on preparing them to operate independently. This study was approved by the IRB of the Massachusetts General Hospital (2015P001836).

Structured operative autonomy service

The logistics of the structured operative service were determined by a multidisciplinary team composed of members of the Department of Surgery, Department of Anesthesiology, perioperative nursing, and our hospital's legal team. The service was staffed by a rotating chief resident in their fifth post-graduate year (PGY) together with a PGY3 resident who assisted them in the operating room and served as the primary surgeon when the chief resident deemed it to be an appropriate teaching case. The PGY3 resident was also responsible for inpatient orders, documentation, and managing our resident minor surgery outpatient clinic, described previously.[15] Faculty participation in the service was optional. The attending surgeons of record were ultimately composed of a core group of surgeons from the division of general and gastrointestinal surgery with a vested interest in promoting structured resident operative autonomy. The practice of these faculty members included general, oncologic, colorectal, endocrine, thoracic, minimally invasive, and hepatopancreaticobiliary surgery. If there were no operations booked for the structured operative autonomy service on a particular day, both the PGY5 and the PGY3 were separately assigned cases from our standard resident services to augment their educational experience throughout the month (these cases were not considered part of the structured operative autonomy service).

Patients were admitted to the structured operative autonomy service in 1 of 3 ways. First, faculty members identified patients from their elective practices that they thought would be ideal candidates for this service or who would have otherwise had prolonged wait times if scheduled electively in their own operative block. Second, emergency department and inpatient consultations for the division of general and gastrointestinal surgery were directed toward the residents of the structured operative autonomy service. Finally, the contact information for our resident minor surgery clinic was provided to the emergency department and referring providers as a clinic in which patients could be seen for common general surgery problems in an expedited fashion. If the chief resident or attending surgeon believed that the case was too complex for the service, the patient was admitted to the attending surgeon's standard specialty service. In addition to patients who required an operation, the chief resident also admitted cases for nonoperative management (ie small bowel obstructions) or any readmissions of patients who were discharged from the service previously.

The structured operative autonomy service residents were given their own operative block time 2 full days per week, which did not impact the historic case time of the attending surgeon of record, and urgent or semi-elective cases could be added to the waitlist any day during the week. If operations were not scheduled using this block time by the evening before the operative date, the room was opened to other surgeons and waitlisted cases to avoid wasting resources. The chief resident ultimately controlled which patients were added to the operative block time. The attending surgeon of record, along with the chief resident, obtained the informed consent. Through a full disclosure discussion with the patient, they explained the skill level of the chief resident, the importance of allowing them to have structured autonomy in the operating room before graduating, and that although the resident would begin and finish the operation independently, the attending surgeon would be scrubbed to supervise the critical portion of the procedure.[16,17] Before the start of the case, each attending informed the chief resident of the steps they deemed the critical portion of the procedure. Residents began the operations without direct attending supervision. The circulating nurse informed the attending surgeon when the critical portion of the operation was reached, at which time they scrubbed to supervise its completion. The attending surgeon was otherwise immediately available if the residents could not proceed to the critical portion of the procedure themselves, and was not involved in concurrent operations during this time.

Postoperatively, patients were admitted to the structured operative autonomy resident service. The chief resident determined the daily plan, which was discussed with the attending surgeon of record, who later rounded on the patient. The patient's postoperative visit was conducted in the attending surgeon's clinic and residents were encouraged to be present for follow-up visits to maintain continuity of care, if their future service obligations allowed. However, given the complex logistical challenges that must be overcome to maintain high levels of resident continuity of care, this was not a primary goal of our study and was not tracked.[16,18] Any complications were discussed at the weekly departmental morbidity and mortality conference. Finally, the Centers for Medicare and Medicaid Services Manual System states that for a teaching physician to bill for a surgical procedure, they must be responsible for the preoperative, operative, and postoperative care of the beneficiary, present for the critical portion of the procedure, and immediately available throughout the remainder of the operation.[19] These criteria were met, as discussed previously, and all operations were billed under the attending surgeon's name.

Data collection

Demographic, intraoperative, and outcomes data were extracted from clinical databases at our institution and linked through unique patient identifiers to form a deidentified database. Intraoperative data were retrieved from the Anesthesia Information Management System, which includes the following data elements: length of operation (defined as intubation time to extubation time), estimated blood loss, case scheduling status (elective vs non-elective), and preoperative BMI. If estimated blood loss was recorded as minimal, it was entered as 5 mL for the purposes of our analysis. Non-elective cases were those that were added to the operating room waitlist within 24 hours, usually as the result of an inpatient/emergency department consultation. Demographic and outcomes data were derived from billing codes in the Research Patient Data Registry, a centralized clinical data registry that gathers data from hospital legacy systems for research. Key outcomes measures were verified by manual chart review. The severity of pre-procedure comorbid disease was scored and analyzed using the Charlson Comorbidity Index.[20] Postoperative length of stay was defined as the number of days after the operation until discharge or, for complex patients on other inpatient services, the number of days until the surgical problem had resolved and the surgery team signed off.

Operative reports were reviewed manually to determine postoperative diagnosis listed by the surgeon, wound classification, and major iAEs. In terms of cholecystectomy postoperative diagnoses, a pancreaticobiliary complication was defined as a preoperative episode of choledocholithiasis, cholangitis, or gallstone pancreatitis. An iAE is defined as an injury that occurs during an operation, and they are classified per a validated classification system.[21,22] Major iAEs have been associated with a substantially increased rate of postoperative morbidity and mortality, and are defined as class 3, 4, or 5, for which repair necessitated tissue/organ resection, reconstruction, or reoperation within 7 days.[23]

Electronic surveys were administered to chief residents who had completed the service to gauge the impact it had on preparing them to operate independently. Surveys were administered immediately after completion of their first year of fellowship or independent practice. Completion was voluntary and questions were answered using a 4-point Likert scale.

Statistical analysis

Unadjusted comparisons were made using chi-square test for categorical data and Student's *t*-test for continuous data. Unless otherwise noted, results are reported as median (interquartile range [IQR]) and frequency (percent). An adjusted analysis was performed with logistic and linear regression for categorical and continuous outcomes variables, respectively. Regression models were adjusted for having the operation performed by the structured operative autonomy service, age, sex, race, BMI, Charlson Comorbidity Index, case scheduling status, smoking status, operation type, and wound classification. The impact of receiving care on the structured operative autonomy service is reported for each dependent end point. A random resampling technique, specifically bootstrap bagging, was used to assess the stability and accuracy of our multivariate models, given our limited sample. Bootstrap bagging was performed with repeated samples of 20 to 100 observations, with repeated samples of 100 observations selected with replacement from the original set observations. The 95% CIs for the bootstrap resampling models were reported. Statistical analysis was conducted using Intercooled STATA software, version 13.1 (StataCorp). Statistical significance was accepted at $p < 0.05$.

RESULTS

Eight chief residents and 10 PGY3 residents rotated onto the structured operative autonomy service during the 10-month pilot period. A total of 124 operations were performed, spanning multiple organ systems and degrees of complexity (Fig. 1A). The 2 most common operations were cholecystectomies (laparoscopic n = 34, open n = 5) and appendectomies (laparoscopic n = 15, open n = 0). Faculty participation (n = 13) and case volume increased as the study period progressed, with the largest number of operations performed during the eighth month (n = 28) (data not shown). Primary outcomes were determined for the collective group of cases (Fig. 1B). Eleven patients (8.9%) had a postoperative NSQIP complication within 30 days, and there were no 30-day postoperative deaths.

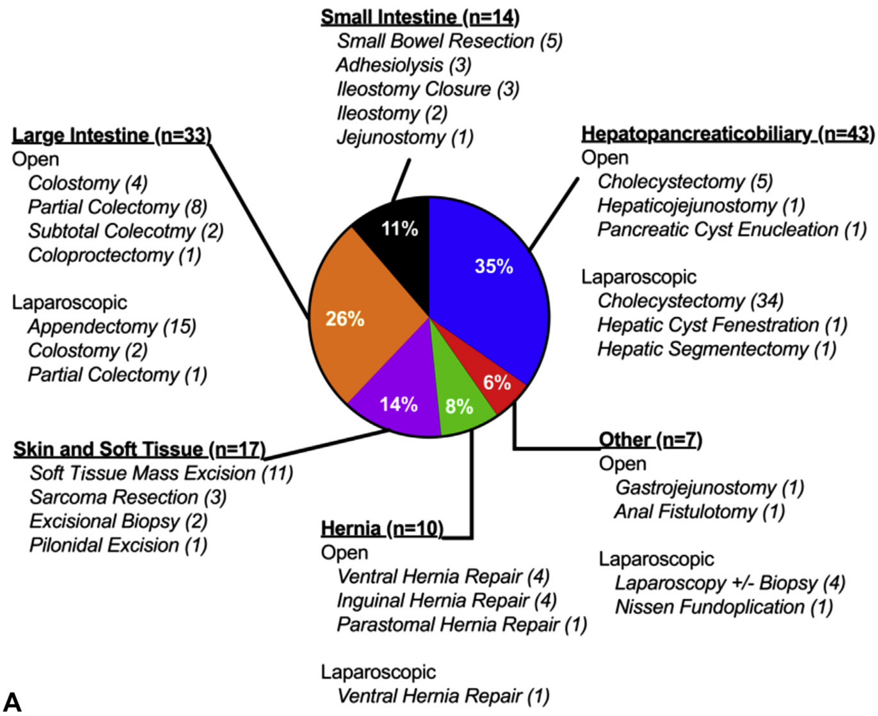
Given the heterogeneity of the operations and differences in their baseline rates of morbidity, a subset analysis of appendectomies and cholecystectomies was performed to assess impact on patient outcomes. This subset (n = 54) was compared with an institutional control cohort (n = 718) of patients operated on by the same group of attending surgeons assisted by a resident on our standard surgical rotations. It is important to remember as the results of the subset analysis are reviewed that although it includes the 2 most common operations, it is only 54 of the 124 operations performed during the entire pilot period. Many of the operations that were excluded from this analysis were more complex and, although they contributed greatly to resident education, the number of similar cases was too low to perform a meaningful outcomes analysis.

Preoperative variables

A comparison of preoperative variables, including demographics, risk factors, and case scheduling status between the structured autonomy and standard service, is presented in Table 1. The number of non-elective cases performed by the structured autonomy service was significantly higher when compared with the standard resident services (79.6% vs 16.7%; $p < 0.001$). Non-elective cases were typically the result of an inpatient or emergency department consultation. There were no significant differences in patient demographics or risk factors between groups.

Intraoperative variables

Intraoperative unadjusted variables were analyzed by intention to treat (Table 2). There were no major iAEs in any of the structured operative autonomy cases. Laparoscopic appendectomy was performed for acute appendicitis most often in both groups (eTable 1). With regard to laparoscopic cholecystectomies, the structured autonomy service operated more often for acute cholecystitis (44.1% vs 11.2%; $p < 0.001$) compared with the standard service (eTable 1). This resulted in a higher percentage of contaminated wound classifications (structured autonomy 58.9% vs standard service 22.7%; $p < 0.001$). The structured autonomy service had a longer median operative time (111 minutes vs 66 minutes; $p < 0.001$) and a slightly higher median blood loss (20 mL vs 5 mL; $p = 0.047$) compared with laparoscopic cholecystectomies performed on the standard



A

Unadjusted Primary Outcome	(n=124), n (%)
30-Day NSQIP Complication	11 (8.9)
30-Day Inpatient Readmission	9 (7.2)
30-Day Emergency Department Visit	7 (5.6)
30-Day Mortality	0 (0)

B

Figure 1. (A) Description of the operations performed on the structured operative autonomy service during the pilot year classified by organ system and (B) overall rates of 30-day NSQIP complications, inpatient readmission, emergency department visits, and 30-day mortality.

services. Three non-urgent conversions occurred on the structured autonomy service after discussion with the attending surgeon, and all were due to poor visibility from inflammation or adhesions. There were no significant differences in the duration of the operation or estimated blood loss between groups for either laparoscopic appendectomy or open cholecystectomy.

Postoperative outcomes

Univariate postoperative outcomes are presented in Table 3. There was no significant difference in the rate of 30-day postoperative complications between the groups (5.6% structured autonomy vs 4.0% standard service; $p = 0.59$). The rates of 30-day inpatient readmission (3.7% vs 3.8%; $p = 1.00$), 30-day emergency department visits (5.6% vs 6.6%; $p = 0.78$), and 30-day mortality (0.0% vs 0.1%) were also similar between the structured operative autonomy service and the standard services, respectively. With regard to complications that could result specifically from a cholecystectomy, there were no retained common bile duct stones, bile leaks requiring endoscopic intervention, or bile duct injuries requiring operation during the first 90 days for patients operated on by the structured autonomy service (eTable 2). Finally, postoperative length of stay was similar between the structured autonomy and standard services for elective laparoscopic cases (median 0 [IQR 0 to 1] days vs median 0 [IQR 0 to 0] days; $p = 0.27$) and non-elective laparoscopic cases (median 1 [IQR 1 to 1] days vs median 1 [IQR 0 to 1] days; $p = 0.37$), respectively (eTable 3). However, the length of stay was significantly longer for patients who had an open cholecystectomy performed on the structured autonomy service (median 4 [IQR 3 to 5] days vs median 2 [IQR 2 to 4] days; $p < 0.01$) (eTable 3).

Results of an adjusted analysis to determine the impact on outcomes of having a procedure performed on the structured operative autonomy service are presented in

Table 1. Preoperative Patient Variables for Cholecystectomy and Appendectomy Subset Analysis

Preoperative variable	Structured autonomy (n = 54)	Standard service (n = 718)	p Value
Demographic			
Age, y, median (IQR)	47.2 (33.9–60.1)	53.3 (40.7–65.9)	0.06
Sex, female, n (%)	31 (57.4)	475 (66.2)	0.19
Race, n (%)			0.64
White	38 (82.6)	545 (84.8)	
Black	2 (4.4)	18 (2.9)	
Hispanic	1 (2.2)	20 (3.1)	
Asian	1 (2.2)	30 (4.7)	
Other	4 (8.7)	30 (4.7)	
Insurance status, n (%)			0.84
Private	40 (74.1)	494 (68.9)	
Medicare	10 (18.5)	173 (24.1)	
Medicaid	4 (7.4)	44 (6.1)	
Self-pay	0 (0)	3 (0.42)	
Other	0 (0)	3 (0.42)	
Risk factor			
Charlson Comorbidity Index, median (IQR)	3 (3–6)	3 (3–5)	0.94
BMI, kg/m^2, median (IQR)	27.5 (23.7–31.5)	27.7 (24.3–32.1)	0.96
Smoking status, n (%)			0.38
Current	4 (7.4)	53 (7.4)	
Former	12 (22.2)	222 (31.0)	
Never	38 (70.4)	442 (61.6)	
Case scheduling, n (%)			
Non-elective	43 (79.6)	120 (16.7)	<0.001

IQR, interquartile range.

Tables 4 and 5. This analysis confirmed our unadjusted findings showing no significant differences in postoperative morbidity and mortality. Operative time remained significantly higher with structured autonomy; however, this difference decreased to 22 minutes after adjustment ($p < 0.001$). Additionally, patients remained in the hospital 0.8 days longer compared with the standard services ($p = 0.001$). There was no significant difference in estimated blood loss after adjustment. A bootstrap analysis was performed that validated all multivariate findings, except postoperative length of stay, in which significance was lost.

One-year follow-up survey

Survey results are presented in Table 6. Overall response rate was 100% (n = 8), 12.5% of respondents were female, and mean age was 36 years. Seventy-five percent of respondents planned to have a future practice that included general surgery operations when they participated in the service, and 75% of respondents still performed general surgery operations after their first year of fellowship or independent practice (data not shown). Participants believed that the rotation eased their transition to practice by increasing their self-awareness of technical strengths and weaknesses, confidence in performing operations, ability to lead an operating room team, and effectiveness of intraoperative teaching to trainees. Representative optional comments included that "the autonomy was priceless" and that the experience "is essential to training."

DISCUSSION

The modern-day landscape of healthcare and graduate surgical education precludes chief residents from attaining the same level of operative autonomy that was granted by Dr Churchill and his contemporaries. Previous studies have identified important barriers to operative autonomy, as well as the factors that lead to progressive entrustment by faculty.[13,24] However, steps must be taken at an institutional level to provide chief residents with an autonomous experience that is acceptable within the confines of our current system. Kantor and colleagues[25] recently described a resident acute care surgery service that increased resident operative autonomy and the number of teaching cases logged by chief residents, but patient outcomes were not assessed. In the current study, we have demonstrated the successful implementation of a service that provides

Table 2. Unadjusted Intraoperative Variables by Intention-to-Treat Subset Analysis

Operation	Structured autonomy	Standard service	p Value
Laparoscopic appendectomy, n	15	52	
Conversion, n (%)	0 (0)	0 (0)	
Major iAE, n (%)	0 (0)	0 (0)	
Operation duration, min, median (IQR)	68 (58−81)	61 (49−75)	0.27
Estimated blood loss, mL, median (IQR)	5 (5−20)	5 (5−10)	0.79
Wound class, n (%)			0.23
Clean-contaminated	2 (13.3)	17 (32.7)	
Contaminated	12 (80)	29 (55.8)	
Dirty	1 (6.7)	6 (11.5)	
Laparoscopic cholecystectomy, n	34	631	
Conversion, n (%)	3 (8.8)	22 (3.5)	0.11
Intraoperative reason for conversion, n (%)			0.71
Poor visibility	3 (100)	21 (95.5)	
Vascular injury	0 (0)	0 (0)	
Gastrointestinal tract injury	0 (0)	1 (4.6)	
Hepatobiliary injury	0 (0)	0 (0)	
Major iAE, n (%)	0 (0)	2 (0.3)	0.74
Operation duration, min, median (IQR)	111 (82−134)	66 (49−86)	<0.001
Estimated blood loss, mL, median (IQR)	20 (5−50)	5 (5−10)	0.047
Wound class, n (%)			<0.001
Clean-contaminated	13 (38.2)	485 (76.8)	
Contaminated	20 (58.9)	143 (22.7)	
Dirty	1 (2.9)	3 (0.5)	
Intraoperative cholangiogram, n (%)	2 (5.9)	27 (4.3)	0.66
Open cholecystectomy, n	5	35	
Major iAE, n (%)	0 (0)	0 (0)	
Operation duration, min, median (IQR)	103 (70−104)	60 (50−96)	0.27
Estimated blood loss, mL, median (IQR)	300 (100−500)	100 (25−300)	0.47
Wound class, n (%)			0.04
Clean-contaminated	0 (0)	17 (48.6)	
Contaminated	5 (100)	18 (51.4)	
Dirty	0 (0)	0 (0)	
Intraoperative cholangiogram, n (%)	0 (0)	0 (0)	

iAE, intraoperative adverse event; IQR, interquartile range.

chief residents with structured operative autonomy without negatively impacting patient outcomes. After reflecting on their first year of fellowship or practice, our graduates overwhelmingly confirmed the value of this autonomous experience in preparing them to function independently in an operating room. The success of our program was contingent on a multidisciplinary institutional approach to overcoming previously

Table 3. Unadjusted Postoperative 30-Day Outcomes for Cholecystectomy and Appendectomy Subset Analysis

	Structured autonomy (n = 54)		Standard service (n = 718)		
Postoperative outcomes	n	%	n	%	p Value
30-day NSQIP complication	3	5.6	29	4	0.59
30-day inpatient readmission	2	3.7	27	3.8	1.00
30-day emergency department visit	3	5.6	47	6.6	0.78
30-day mortality	0	0	1	0.1	—

Table 4. Adjusted Outcomes for Categorical Dependent Postoperative Outcomes

Dependent categorical outcomes*	Odds ratio	95% CI	p Value†	Bootstrapped 95% CI‡
30-day NSQIP complication	0.8	0.2−3.2	0.76	0.1−4.5
30-day inpatient readmission	0.4	0.1−2.1	0.30	0.1−1.5
30-day emergency department visit	0.7	0.2−2.4	0.52	0.2−2.3

*Adjusted by resident case, age, sex, race, BMI, Charlson Comorbidity Index, non-elective case status, smoking status, operation type, and wound class.
†p Values displayed are associated with the independent multivariate analysis (not the subsequent bootstrap analysis).
‡CI values from adjusted categorical bootstrap analysis were not statistically significant.

recognized barriers to granting operative autonomy to residents, in addition to faculty support through endorsement and participation of our department chair and program director.

The concern for patient safety has been the major impetus for decreasing resident autonomy across all graduate medical education and has been identified as one of the greatest barriers to granting operative autonomy to surgical residents.[9,26-29] A review of the literature shows conflicting evidence on patient outcomes when residents are involved in operations.[30-37] However, the vast majority of these studies are not able to determine the level of autonomy that residents are given during the operation. In our study, the level of operative autonomy is clearly defined. Although we were unable to perform a detailed analysis of all procedures, given their heterogeneity, the overall mortality, complication, and readmission rates appeared to be consistent with predicted ranges, considering the case mix.[38] Subset analyses showed no significant differences in mortality, morbidity, readmission rates, or estimated blood loss for those procedures performed on the structured operative autonomy service compared with those performed on the standard resident services. These findings are consistent with our initial hypothesis, and we attribute this to the fact that chief residents are highly trained as they enter their final year of residency, the attending surgeon is always present and scrubbed for the critical portions of each case, and appropriate cases are selected for the rotation.

Although morbidity and mortality were unchanged between the structured autonomy and standard resident services, we did observe increased operative times in patients operated on by the structured autonomy service. Resident involvement has been associated with increased operative times in multiple studies, and we hypothesized that the high level of resident operative autonomy on this service would undoubtedly lead to similar outcomes.[39-41] The unadjusted difference was significant with the laparoscopic cholecystectomies and is likely due to the chief resident leading the PGY3 through the case and having them perform a careful dissection. In addition, resident cases were more likely to be non-elective due to acute cholecystitis, which might have resulted in a more difficult dissection. Despite this difference, however, laparoscopic cholecystectomies were still completed in less than 2 hours from intubation to extubation and, after adjustment, the structured operative autonomy cases were only 22 minutes longer in duration compared with those performed on the standard resident services. This short increase in operative time likely does not have a significant clinical impact on the patient and is justified by the overwhelming educational benefit noted by residents, given that there were no major iAEs or differences in postoperative outcomes.

Hospital length of stay was also increased in patients who underwent operations on the structured operative autonomy service. Although this was most pronounced in the open cholecystectomy group, adjusted analysis of the entire subset showed that patients stayed, on average, 0.8 days longer in the hospital compared with our standard surgical service. However, the significance of this difference was lost on bootstrap analysis, suggesting that the length of stay might be closer than our data alone can predict. Increased length of stay is explained partially by the fact that the structured operative autonomy service had a larger number of non-elective operations. As the patient was not anticipating a day operation, this likely prolonged discharge due to the time of day the operation began or

Table 5. Adjusted Outcomes for Continuous Intraoperative and Postoperative Variables

Dependent continuous outcomes*	Adjusted difference	95% CI	p Value†	Bootstrapped 95% CI
Length of hospital stay, d	+0.8	0.4 to 1.3	0.001	−0.7 to 2.3
Operation duration, min	+21.6	12.9 to 30.3	<0.001	6.0 to 37.1‡
Estimated blood loss, mL	+8.1	−26.5 to 42.8	0.65	−55.0 to 71.3

*Adjusted by resident case, age, sex, race, BMI, Charlson Comorbidity Index, non-elective case status, smoking status, operation type, and wound class.
†p Values displayed are associated with the independent multivariate analysis (not the subsequent bootstrap analysis).
‡Statistically significant.

Table 6. One-Year Follow-Up Survey of Chief Resident Participants

Survey question	Strongly disagree		Somewhat disagree		Somewhat agree		Strongly agree	
	n	%	n	%	n	%	n	%
Compared with other chief level surgical rotations, this rotation…								
Increased my self-awareness of technical strengths and weaknesses	—	—	—	—	—	—	8	100
Increased my confidence to perform operations smoothly and independently	—	—	—	—	—	—	8	100
Increased my ability to lead an operating room team	—	—	—	—	2	25	6	75
Increased my ability to provide effective intraoperative teaching to junior residents	—	—	—	—	1	12.5	7	87.5
Participation improved the way in which I prepared preoperatively for an operation	—	—	—	—	1	12.5	7	87.5
I believe this experience has helped me transition to fellowship or independent practice	—	—	—	—	—	—	8	100

Likert 4-point scale: strongly disagree (1 point), somewhat disagree (2 points), somewhat agree (3 points), strongly agree (4 points).

the comfort level of the patient. Although the median length of stay was similar for non-elective laparoscopic operations, the structured operative autonomy service IQR was wider. Additionally, the timing of discharge was dictated by the chief resident, although ultimately approved by the attending surgeon. Having increased operative autonomy in the patient's case, the chief resident might have been more cautious in discharging patients to ensure that there were no postoperative complications. As we have now shown similar postoperative morbidity and mortality rates compared with the standard surgical services, and as enhanced recovery after surgery (ERAS) protocols are becoming more common at our institution, chief residents are encouraged to discharge patients using a standardized approach.[42]

The barrier of faculty feeling pressure to expedite cases and increase efficiency was overcome by the department granting the structured operative autonomy service their own operative block time and making attending participation in the service voluntary. As operative time is coveted, our department demonstrated its commitment to this educational initiative by allowing residents to fully control 2 elective block days each week and having the ability to add non-elective cases to the waitlist each day of the week. To the best of our knowledge, this level of institutional commitment has not been described in the literature. Attending surgeons were incentivized to work with residents during this operative time, as it allowed the completion of appropriate cases that did not use their own assigned block time, and the length of each operation was not factored into the calculations of their own historic case times. The chief resident ultimately chose which cases were scheduled and with whom to staff non-elective cases, thereby protecting the intended operative autonomy of the service by selecting faculty that truly embraced this educational goal. Kantor and colleagues[25] used attending surgeons from the acute care surgical service, however, this service is led by a PGY4 at our institution. Therefore, chief residents targeted faculty with whom they work closely during their final year of residency so that this fourth-year experience with increased autonomy on our acute care surgery service would be augmented rather than replaced. In addition, the structured operative autonomy service was initiated 3 months after the start of the academic year to ensure established working relationships to enhance autonomy.

Finally, and most importantly, barriers related to institutional expectations for attending surgeon involvement were overcome by using a multidisciplinary committee to determine the logistics of the rotation. The service structure agreed on ensured that all members of the operating room team were comfortable with the level of autonomy given to the chief resident. Specifically, by scheduling cases using the unique block time, it was known well before the time of incision that there would be less attending oversight. However, structure was brought to the autonomy by defining the critical portion of the operation before the start

- ☑ Development of rotation logistics with input from all involved disciplines
- ☑ Endorsement and participation by departmental leadership
- ☑ Distinct operative block time that does not impact attending surgeon efficiency
- ☑ Voluntary trainee and faculty participation to select for motivated individuals
- ☑ Identification of the appropriate breadth and complexity of cases
- ☑ Clearly defined expectations of intraoperative attending surgeon involvement
- ☑ Patient consent through a full disclosure conversation with the attending surgeon
- ☑ Accurate tracking of operations, patient outcomes, and educational benefit

Figure 2. Key components for successful implementation of structured operative autonomy.

of the case and using the circulating nurse to alert the attending surgeon that it was time to scrub in and supervise its completion. The Medicare claims processing manual states that the billing physician must be present for the critical portion of the procedure, but we mandated that the attending surgeon must also be scrubbed to supervise its completion.[19] This requirement provided an extra level of patient safety and also aided in satisfying patient expectations of attending surgeon involvement in the operation during the informed consent. Earlier studies have found that patients are more accepting of a higher level of resident involvement when a personal conversation with the attending surgeon occurs and they can be assured of similar outcomes.[10,16,17]

We hope that this detailed account of our pilot-year experience will help other interested surgical residency programs create similar structured operative autonomy experiences for their residents. This program is currently entering its third year at our institution. One major change made after our second year was to allow residents to opt out of the rotation if they were entering a specialty that did not include general surgery operations. We found that this rotation requires the chief resident to be highly motivated to work with surgical attendings and consultants to ensure that an appropriate volume of general surgery cases are booked. The highest-volume residents typically initiated these discussions in the weeks to months leading up to their assigned time on the service. Therefore, this experience might not be well suited for residents pursuing a career outside the scope of general surgery who would prefer dedicating this month to an elective in a field more germane to their future practice. Although each program is likely to encounter their own unique challenges, it is the purview of the authors that with appropriate foresight and incorporation of several key components, that operative autonomy can be successfully enhanced for motivated residents (Fig. 2).

There are several limitations to our study that must be considered. First, this is the description of our pilot-year experience at a single institution, so we have a limited sample size. We attempted to mitigate this by performing a bootstrap analysis, which aided in our interpretation of the results. Second, although our institutional control cohort is the best comparison group for the purposes of this study, there are inherent differences in the groups that can impact our results. Notably, the structured operative autonomy service accepted many of the inpatient/emergency department consults, leading to a higher percentage of non-elective operations. Although we attempted to adjust for this, there might be variables for which we could not account. Finally, we were not able to record the actual amount of time that the attending surgeon was in the operating room. However, chief residents noted an educational benefit compared with standard services, which suggests that the intended operative autonomy was preserved. After reviewing our pilot-year data, our institution has approved the service for the foreseeable future. We are currently working to increase the volume of elective cases scheduled on the service and will continue to update and analyze our patient outcomes going forward.

CONCLUSIONS

A rotation designed to provide senior surgical trainees with structured operative autonomy overcomes previously identified barriers to resident autonomy in the operating room. Key components of this educational initiative include garnering the support of the institutional leadership, allowing residents to control their own operative block time that does not impact faculty historic operative times, and mandating that attending surgeons scrub in to supervise the critical portion of the operation. Structured operative autonomy enhances chief resident education and eases their transition to practice without adversely impacting patient outcomes. To better prepare the next generation of surgeons for independent practice, general surgery training programs should strive to incorporate structured operative autonomy into dedicated chief resident rotations.

Author Contributions

Acquisition of data: Wojcik, Fong, Patel, Long

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REFERENCES

1. Grillo HC. Edward D. Churchill and the "rectangular" surgical residency. Surgery 2004;136:947–952.
2. Wright CD. Historical perspectives of the American Association for Thoracic Surgery: Edward D Churchill (1895–1972). J Thorac Cardiovasc Surg 2012;143:1–3.
3. Baue AE. Edward Delos Churchill (1897–1972). A giant in surgery and surgical education and leadership. Dig Surg 2002;19:71–76; discussion 76–78.
4. Klingensmith ME, Lewis FR. General surgery residency training issues. Adv Surg 2013;47:251–270.
5. Bell RH Jr. Why Johnny cannot operate. Surgery 2009;146:533–542.
6. Bucholz EM, Sue GR, Yeo H, et al. Our trainees' confidence: results from a national survey of 4136 US general surgery residents. Arch Surg 2011;146:907–914.
7. Mattar SG, Alseidi AA, Jones DB, et al. General surgery residency inadequately prepares trainees for fellowship: results of a survey of fellowship program directors. Ann Surg 2013;258:440–449.
8. Malangoni MA, Biester TW, Jones AT, et al. Operative experience of surgery residents: trends and challenges. J Surg Educ 2013;70:783–788.
9. Halpern SD, Detsky AS. Graded autonomy in medical education—managing things that go bump in the night. N Engl J Med 2014;370:1086–1089.
10. Kempenich JW, Willis RE, Rakosi R, et al. How do perceptions of autonomy differ in general surgery training between faculty, senior residents, hospital administrators, and the general public? A multi-institutional study. J Surg Educ 2015;72:e193–e201.
11. Meyerson SL, Teitelbaum EN, George BC, et al. Defining the autonomy gap: when expectations do not meet reality in the operating room. J Surg Educ 2014;71:e64–e72.
12. Sachs TE, Pawlik TM. See one, do one, and teach none: resident experience as a teaching assistant. J Surg Res 2015;195:44–51.
13. Teman NR, Gauger PG, Mullan PB, et al. Entrustment of general surgery residents in the operating room: factors contributing to provision of resident autonomy. J Am Coll Surg 2014;219:778–787.
14. American College of Surgeons NSQIP. User guide for the 2015 ACS-NSQIP participant use data file. Available at: https://www.facs.org/~/media/files/qualityprograms/nsqip/nsqip_puf_user_guide_2015.ashx. Accessed April 1, 2017.
15. Wojcik BM, Fong ZV, Patel MS, et al. The resident-run minor surgery clinic: a pilot study to safely increase operative autonomy. J Surg Educ 2016;73:e142–e149.
16. Wojcik BM, Phitayakorn R, Lillemoe KD, et al. Preoperative disclosure of surgical trainee involvement: Pandora's box or an opportunity for enlightenment? Ann Surg 2017;265:869–870.
17. Sharda RK, Sher JH, Chan BJ, et al. A comparison of techniques: informed consent for resident involvement in cataract surgery. Can J Ophthalmol 2012;47:113–117.
18. Turner JP, Rodriguez HE, Daskin MS, et al. Overcoming obstacles to resident-patient continuity of care. Ann Surg 2012;255:618–622.
19. Centers for Medicare and Medicaid. Pub 100-04 Medicare claims processing; transmittal 2303: teaching physicians services. Available at: https://www.cms.gov/Regulations-and-Guidance/Guidance/Transmittals/downloads/R2303CP.pdf. Accessed July 9, 2017.
20. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373–383.
21. Kaafarani HM, Mavros MN, Hwabejire J, et al. Derivation and validation of a novel severity classification for intraoperative adverse events. J Am Coll Surg 2014;218:1120–1128.
22. Kaafarani HM, Velmahos GC. Intraoperative adverse events: the neglected quality indicator of surgical care? Surgery 2015;157:6–7.
23. Bohnen JD, Mavros MN, Ramly EP, et al. Intraoperative adverse events in abdominal surgery: what happens in the operating room does not stay in the operating room. Ann Surg 2017;265:1119–1125.
24. Sandhu G, Magas CP, Robinson AB, et al. Progressive entrustment to achieve resident autonomy in the operating room: a national qualitative study with general surgery faculty and residents. Ann Surg 2017;265:1134–1140.
25. Kantor O, Schneider AB, Rojnica M, et al. Implementing a resident acute care surgery service: improving resident education and patient care. Surgery 2017;161:876–883.
26. Franzone JM, Kennedy BC, Merritt H, et al. Progressive independence in clinical training: perspectives of a national, multispecialty panel of residents and fellows. J Grad Med Educ 2015;7:700–704.
27. Haber LA, Lau CY, Sharpe BA, et al. Effects of increased overnight supervision on resident education, decision-making, and autonomy. J Hosp Med 2012;7:606–610.
28. Counihan TC, Nye D, Wu JJ. Surgeons' experiences with patients' concerns regarding trainees. J Surg Educ 2015;72:974–978.
29. Flynn TC. Invited comment on: the surgical residency and ACGME reform: steep learning or sleep learning? Am J Surg 2011;202:372–373.
30. Hernandez-Irizarry R, Zendejas B, Ali SM, et al. Impact of resident participation on laparoscopic inguinal hernia repairs: are residents slowing us down? J Surg Educ 2012;69:746–752.
31. Patel SP, Gauger PG, Brown DL, et al. Resident participation does not affect surgical outcomes, despite introduction of new techniques. J Am Coll Surg 2010;211:540–545.
32. Castleberry AW, Clary BM, Migaly J, et al. Resident education in the era of patient safety: a nationwide analysis of outcomes and complications in resident-assisted oncologic surgery. Ann Surg Oncol 2013;20:3715–3724.
33. Schoenfeld AJ, Serrano JA, Waterman BR, et al. The impact of resident involvement on post-operative morbidity and mortality following orthopaedic procedures: a study of 43,343 cases. Arch Orthop Trauma Surg 2013;133:1483–1491.
34. Davis SS Jr, Husain FA, Lin E, et al. Resident participation in index laparoscopic general surgical cases: impact of the learning environment on surgical outcomes. J Am Coll Surg 2013;216:96–104.
35. Scarborough JE, Bennett KM, Pappas TN. Defining the impact of resident participation on outcomes after appendectomy. Ann Surg 2012;255:577–582.
36. Kiran RP, Ahmed Ali U, Coffey JC, et al. Impact of resident participation in surgical operations on postoperative outcomes: National Surgical Quality Improvement Program. Ann Surg 2012;256:469–475.
37. Siam B, Al-Kurd A, Simanovsky N, et al. Comparison of appendectomy outcomes between senior general surgeons and general surgery residents. JAMA Surg 2017;152:679–685.

38. American College of Surgeons. American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) surgical risk calculator. Available at: http://riskcalculator.facs.org/RiskCalculator/. Accessed February 15, 2017.
39. Dull MB, Gier CP, Carroll JT, et al. Resident impact on operative duration for elective general surgical procedures. Am J Surg 2017;213:456–459.
40. Allen RW, Pruitt M, Taaffe KM. Effect of resident involvement on operative time and operating room staffing costs. J Surg Educ 2016;73:979–985.
41. Endo K, Kujirai D, Maeda H, et al. Transumbilical laparoscopic appendectomy performed by residents is safe and feasible. Asian J Endosc Surg 2016;9:270–274.
42. Ljungqvist O, Scott M, Fearon KC. Enhanced recovery after surgery: a review. JAMA Surg 2017;152:292–298.

Invited Commentary

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With their work, Wojcik and colleagues demonstrated a method for developing surgical resident operative autonomy while providing safe patient care. The authors and the institution are to be congratulated for this development and the resultant publication. This can serve as a model for other institutions that seek opportunities to improve the quality of the graduates of their surgical residency programs. It is clear from the article that a lot of thought went into the development of the Structured Operative Autonomy Service.

I encourage readers to consider adopting this model at their institutions, while recognizing that some modification may be necessary for a given institution's culture. I also encourage readers to consider developing and sharing other opportunities for safely enhancing resident autonomy so that one day in the future, we may achieve our collective goal: that every graduate of every surgical residency program is well prepared for the practice of surgery. Dr Wojcik and the surgical educators at the Massachusetts General Hospital are to be congratulated for their commitment to producing high quality surgeons at their institution. This commitment appears to be reflected in their institution's pass rates on the American Board of Surgery examinations, as they are 1 of only 4 institutions in the northeastern United States that have more than 90% of their graduates pass both the qualifying and certifying examinations on the first attempt. It is not surprising to me that this is the case at an institution that takes significant deliberate steps to enhance resident autonomy.

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eTable 1. Postoperative Diagnosis Listed by Operation Type

Indication for operation	Structured autonomy	Standard service	p Value
Laparoscopic appendectomy, n	15	52	—
Acute appendicitis	15 (100)	42 (80.8)	0.07
Appendiceal tumor	0 (0)	10 (19.2)	0.07
Laparoscopic cholecystectomy, n	34	631	—
Symptomatic cholelithiasis	14 (41.1)	435 (68.9)	0.001
Acute cholecystitis	15 (44.1)	71 (11.2)	<0.001
Chronic cholecystitis	3 (8.8)	65 (10.3)	0.78
Gallbladder polyp/tumor	0 (0)	19 (3.0)	0.69
Pancreaticobiliary complication	2 (5.9)	41 (6.5)	0.89
Open cholecystectomy, n	5	35	—
Symptomatic cholelithiasis	0 (0)	4 (11.4)	0.43
Acute cholecystitis	3 (60)	18 (51.4)	0.72
Chronic cholecystitis	2 (40)	9 (25.7)	0.50
Gallbladder polyp/tumor	0 (0)	0 (0)	—
Pancreaticobiliary complication	0 (0)	4 (11.4)	0.43

Values are n (%) unless otherwise noted.

eTable 2. 90-Day Cholecystectomy Biliary Complications

	Structured autonomy (n = 39)		Standard service (n = 666)		
90-day cholecystectomy biliary complication	n	%	n	%	p Value
Retained common bile duct stone requiring endoscopic procedure	0	0	5	0.8	0.59
Biliary leak requiring endoscopy procedure	0	0	3	0.5	0.67
Bile duct injury requiring operation	0	0	0	0	—

eTable 3. Unadjusted Postoperative Length of Stay Classified as Elective Laparoscopic, Non-Elective Laparoscopic, and Open Operations

	Structured autonomy		Standard service		
Procedure	**n**	**LOS, d, median (IQR)**	**n**	**LOS, d, median (IQR)**	**p Value**
Elective laparoscopic	11	0 (0–1)	577	0 (0–0)	0.27
Non-elective laparoscopic	38	1 (1–1)	106	1 (0–1)	0.37
Open cholecystectomy	5	4 (3–5)	35	2 (2–4)	<0.01

No open appendectomies were performed.
IQR, interquartile range; LOS, length of stay.