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Gas off, room lights on: Shedding light on the surgical resident's experience in open and laparoscopic surgery

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ABSTRACT

Background: The operative experience of today's surgery residents is different than years past. Although overall volume remains stable, the composition is changing. As such, trends in open versus laparoscopic surgery for general surgery residents were examined.

Methods: The Accreditation Council for Graduate Medical Education national operative log reports from 1994 to 2018 were analyzed for the 15 operations recorded as both open and laparoscopic. Operative volume was examined for total major, surgeon chief, and surgeon junior cases.

Results: From 1994 to 2018, 26,258 residents graduated with 955.2 ± 31.7 total major cases. The 15 identified operations comprised 38.4% of this volume. During the 25-year study period, laparoscopic volume increased (+9.67 cases per year), whereas open volume decreased (−3.25 cases per year, $P < .0001$ for each). Similar trends were seen for both chief and surgeon junior cases ($P < .05$ for both). For 2 of the 4 core general surgery operations examined (hernia and proctocolectomy), the open approach was still the dominant approach, providing residents an opportunity to perform open surgery in an era of increasing minimally invasive approaches.

Conclusion: For select procedures, the frequency of laparoscopy has surpassed open surgery for general surgery residents. These trends raise the concern that when necessary, general surgery graduates may not have adequate experience converting to open.

Introduction

The landscape of general surgery training has changed dramatically during the past 30 years. Evolving patient pathologies, changes in disease management, and shifting practice patterns coupled with reduced resident work hours, decreased resident autonomy, and medicolegal concerns have all shaped the modern culture of surgical training.[1] However, the goal of surgical training today is no different than that of years past: to equip graduates with the requisite skills to function independently in surgical practice.[2] However, achieving this goal in 5 years of clinical training is seemingly more difficult in today's constrained training environment.[3] Recent work by our group has shown a declining breadth of experience among trainees, with greater emphasis on general surgery cases and less focus on subspecialty cases.[4] Moreover, the widespread adoption of minimally invasive surgery and continuing advancements in technology have increased the skillset residents need to acquire during training. Despite laparoscopy being the primary approach for many abdominal operations, residents must still achieve competency in both the open and laparoscopic approach.

The burgeoning field of laparoscopic surgery was incorporated into surgical training shortly after the first laparoscopic procedures were performed.[5] In response, surgical educators have dedicated great effort to help trainees develop competency in minimally invasive surgery and its expanding applications. In the late 1990s, the Society of American Gastrointestinal Endoscopic Surgery (SAGES)

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Table I
Operative volume trends for 15 open and laparoscopic operations

Operative category	Procedure		No. case/y	N	*P* value	R^2
Alimentary tract: esophagus	Anti–reflux procedure	Open	−0.2055	−4.5	<0.0001	0.9017
		Laparoscopic	0.2443	8.7	<0.0001	0.7836
Alimentary tract: stomach	Partial gastrectomy	Open	−0.1348	−5.7	<0.0001	0.6538
		Laparoscopic	0.6405	15.7	<0.0001	0.9340
	Gastrostomy	Open	−0.1731	−4.9	<0.0001	0.7961
		Laparoscopic	0.1292	3.5	<0.0001	0.7478
	Vagotomy, with or without drainage	Open	−0.1873	−4.8	<0.0001	0.7838
		Laparoscopic	−0.0032	−0.1	0.0006	0.4038
Alimentary tract: small intestine	Enterolysis	Open	−0.2155	−5.4	0.0003	0.4354
		Laparoscopic	0.1629	4.5	<0.0001	0.7832
	Enterectomy	Open	0.2575	7.1	<0.0001	0.7878
		Laparoscopic	0.0572	1.0	<0.0001	0.7144
	Ileostomy (not associated with colectomy)	Open	−0.0294	−0.8	0.0033	0.3183
		Laparoscopic	0.0759	1.9	<0.0001	0.6708
Alimentary tract: large intestine	Colectomy or protectomy	Open	−0.4628	−4.4	0.0039	0.3086
		Laparoscopic	1.168	23.5	<0.0001	0.9440
	Appendectomy	Open	−1.231	−26.5	<0.0001	0.8952
		Laparoscopic	2.801	60.5	<0.0001	0.9664
Abdomen: general	Exploratory laparotomy (exclusive of trauma)	Open	0.3502	10.9	0.0003	0.4338
		Laparoscopic	0.4722	14.8	<0.0001	0.8865
Abdomen: biliary	Cholecystectomy	Open	−0.8171	−27.0	<0.0001	0.7269
		Laparoscopic	2.525	75.4	<0.0001	0.8939
	Common bile duct exploration	Open	−0.1787	−5.3	<0.0001	0.8239
		Laparoscopic	−0.0033	0.3	0.4649	0.0235
Abdomen: hernia	Inguinal or femoral hernia repair	Open	−0.1868	−5.9	0.0296	0.1896
		Laparoscopic	1.373	34.6	<0.0001	0.9066
Abdomen: spleen	Splenectomy	Open	−0.1383	−2.9	<0.0001	0.7130
		Laparoscopic	0.05	1.1	<0.0001	0.5159
Trauma	Exploratory laparotomy (trauma)	Open	0.0884	0.5	0.0203	0.2127
		Laparoscopic	−0.0229	0.3	0.0058	0.2867

Operative volume trends for 15 open and laparoscopic operations among general surgery residents from 1994 to 2018. Change represented as change in case per year (Δ case/y) and as net change in total volume from 1994 to 2017 (ΔN). Coefficient of determination (R^2) represents goodness of fit.

developed the Fundamentals of Laparoscopic Surgery (FLS) to provide basic education in laparoscopic surgery.[6] Currently, residents are required to complete 75 complex laparoscopic cases before graduation.[7] Although important for graduates, because laparoscopy will undoubtedly be used in practice, the potential impact of this paradigm shift on resident exposure to open surgery is largely unknown. As such, we sought to evaluate the national open and laparoscopic surgery experience of general surgery residents during the past quarter century. We hypothesize that the overall operative experience of today's graduates is dominated by laparoscopic surgery, with a diminishing open experience for many quintessential operations.

Methods

During the 5 years of general surgery training, all US general surgery residents are required to document their operative experience in a case log system managed by the Accreditation Council for Graduate Medical Education (ACGME). The ACGME aggregates these individual case logs into annual reports containing summary statistics for each graduating class. Case logs from 1994 to 2018 were analyzed to evaluate the operative experiences of graduates, and data was extracted for those operations listed as having both an open and laparoscopic approach ($n = 19$). The case logs from 2000 to 2018 are publicly available (https://www.acgme.org/Data-Collection-Systems/Case-Logs-Statistical-Reports), and case logs before 2000 were used with permission granted by the ACGME.

National mean operative volume was examined for total major, surgeon chief, and junior cases. Among the 19 operations with both an open and laparoscopic approach, 15 operations that represented the core experience of a general surgeon were analyzed. These operations are listed in Table I. Laparoscopic operations were also examined as either basic or complex as defined by the ACGME. The 4 excluded operations were lobectomy or segmental lung resection, wedge lung resection, exploratory thoracotomy, and pediatric antireflux procedure. Of the 15 selected operations, vagotomy with or without drainage and common bile duct exploration were used as an internal reference to assess accuracy of case logs, as the trends for peptic ulcer surgery and operative management of obstructive biliary disease have decreased during the past 30 years. Shifts in overall operative volume relative to the volume of the 15 selected operations was examined. Residual volume was defined as the yearly total major case volume minus the sum of the yearly open and laparoscopic volume for the 15 selected operations.

The ACGME annual reports contain minor year-to-year variation in reporting of operative volumes. For example, colectomy and total or subtotal colectomy with ileostomy were listed separately from 1995 to 2004, although they were listed singularly as colectomy or proctectomy from 2010 to 2018. As such, the mean volume of colectomy and total or subtotal colectomy with ileostomy were combined from 1995 to 2004. Intermittent missing operative volume data was noted in the reports for the following operations: antireflux procedure, partial gastrectomy, vagotomy, enterolysis, ileostomy, colectomy or proctectomy, cholecystectomy, and exploratory laparotomy (for trauma). In total, 52 (6.93%) of the 750 data points were missing and these data points were estimated using linear interpolation techniques.

Time trend analyses were performed using 2 complementary methods. First, year to year changes were examined. Second, yearly data was evenly grouped into 3 time periods: period 1 (1994–2001), period 2 (2002–2010), and period 3 (2011–2018). This analysis facilitated comparison of the early laparoscopic era (period 1) to the late laparoscopic era (period 3).

Statistical analyses were performed using simple linear regression analysis and the Kruskal-Wallis test, with the Steel-Dwass

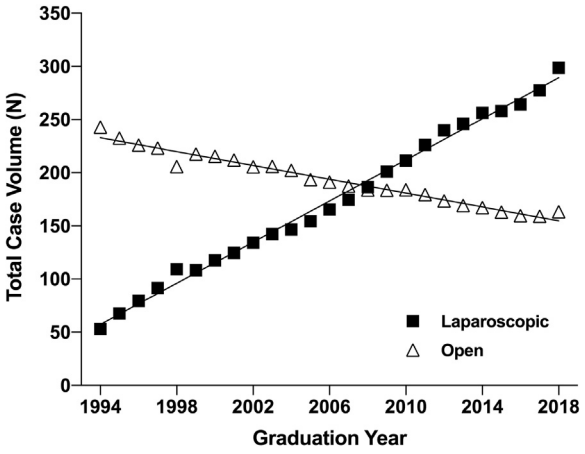

Fig 1. Open and laparoscopic surgery experience of general surgery residents during the past 25 years. For the 15 general surgery operations examined, there was a significant decrease in open operations (−3.25 cases per year, $P \leq .0001$. $R^2 = 0.967$) and concomitant increase in laparoscopic operations (+9.67 cases per year. $P < .0001$, $R^2 = 0.993$).

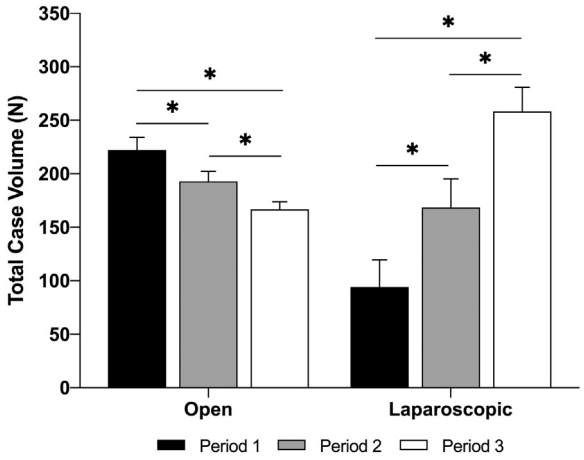

Fig 2. Training in the modern era of laparoscopic surgery is characterized by a predominance of laparoscopic surgery relative to open surgery for the 15 selected operations. During the 3 periods, there was a significant decrease in open surgery volume (−24.9%), which has been replaced by an increase in laparoscopic surgery volume (175%). Period 1 = 1994 to 2001; period 2 = 2001 to 2010; period 3 = 2011 to 2018. *$P < .05$ for comparisons as indicated using the Kruskal-Wallis test with the Steel-Dwass post-hoc test.

post-hoc test for multiple comparisons. For the simple linear regression analysis, the coefficient of determination (R^2) represents goodness of fit. All statistical analyses were performed using JMP Pro Version 13.0 (SAS Institute, Cary, NC). This study was approved by the University of Cincinnati's Institutional Review Board.

Results

From 1994 to 2018, a total of 26,258 general surgery residents graduated from an average of 251 US general surgery residency programs. On average, these residents completed training with 955.2 ± 31.7 total major, 246.5 ± 15.9 surgeon chief, and 701.4 ± 28.1 surgeon junior cases. The 15 open and laparoscopic cases identified represented 38.4% of the total major, 44.0% of the surgeon chief, and 36.9% of the surgeon junior operative volume.

To explore changes in the open and laparoscopic experience over time, operative volume trends were evaluated for the aforementioned 15 general surgery operations. During the study period there was a marked decrease in open total major cases (−3.25 cases per year, $P < .0001$, $R^2 = 0.967$) and a significant increase in laparoscopic total major cases (+9.67 cases per year, $P < .0001$, $R^2 = 0.993$; Fig 1). Stated differently, graduates in 1994 performed 4.57 open operations for every one laparoscopic operation, whereas in 2018, graduates performed 0.55 open for every one laparoscopic operation. The time-trend analysis was supplemented by examining differences in open and laparoscopic surgery volume during 3 time periods. Operative volume for open total major cases decreased by 24.9% ($P = .0018$), whereas laparoscopic total major cases increased by 175% during the 3 periods ($P = .0027$; Fig 2).

Next, we examined changes in open and laparoscopic surgery by resident level. For the 15 operations examined, chief residents graduated on average with 64.2 ± 3.0 open cases in period 1, which decreased by 14.8% (54.7 ± 2.3 cases, $P = .0018$) in period 2 and an additional 9.8% (49.4 ± 1.9 cases, $P = .0018$) in period 3. Conversely, chief residents graduated on average with 31.6 ± 3.6 laparoscopic cases in period 1. This volume increased by 55.8% (49.3 ± 8.6 cases, $P = .0018$) in period 2 and again by 53.1% (75.5 ± 9.3 cases, $P = .0018$) in period 3 (Fig 3, *A*). Similar trends were seen for junior cases, with an average of 157.7 ± 9.8 open cases in period 1. This volume decreased by 12.4% (138.1 ± 7.3 cases, $P = .005$) in period 2 and decreased again by 15.0% (117.4 ± 6.2 cases, $P = .0018$) in period 3. Parallel with these changes, junior residents averaged 62.3 ± 22.1 laparoscopic cases in period 1. This volume nearly doubled in period 2 by 91.6% (119.3 ± 18.5 cases, $P = .0018$) and increased by 53.4% (183.0 ± 14.0 cases, $P = .0018$) in period 3 (Fig 3, *B*).

Next, we examined compositional changes to the operative experience of each of the 15 open and laparoscopic operations during the 25-year study period using simple linear regression analysis. Open operative volume decreased for 12 of the 15 operations ($P < .05$ for each), with increases in open volume observed for enterectomy, exploratory laparotomy exclusive of trauma, and exploratory laparotomy for trauma ($P < .05$ for each). Conversely, there was an increase in laparoscopic volume for 12 of the 15 operations ($P < .05$ for each), with a decrease in laparoscopic vagotomy with or without drainage and exploratory laparotomy for trauma (both $P < .05$; Table I). The 2 reference operations changed as expected, with decreased volume seen for both approaches to vagotomy with or without drainage ($P < .001$ for each) and a decrease in open common bile duct exploration ($P < .0001$).

To supplement the compositional analysis, we explored changes within 4 index general surgery operations: cholecystectomy, appendectomy, inguinal and femoral hernia repair, and colectomy and proctectomy. We selected these 4 operations because they are essential to general surgery training, and collectively, their contribution to trainee education has remained stable during the entire study period (70% of the total volume of the 15 operations in 1994 and 73% of the total volume in 2018). On average, open cholecystectomy volume decreased from 22.2 ± 7.6 cases in period 1 to 9.0 ± 0.8 cases in period 3, whereas laparoscopic cholecystectomy volume markedly increased from 68.5 ± 15.7 cases in period 1 to 110.8 ± 3.6 cases in period 3 ($P < .05$ for both; Fig 4, *A*). There was a slight decrease in open inguinal and femoral hernia volume from period 1 to period 3 (50.7 ± 4.7 to 47.9 ± .6 cases, $P = .036$) with a marked increase in laparoscopic inguinal and femoral hernia volume during the same time period (7.0 ± 4.4 to 30.5 ± 4.6 cases, $P = .0027$; Fig 4, *B*). Similarly, open colectomy and proctectomy volume declined from the early to late period (43.5 ± 4.0 to 35.4 ± 2.7 cases, $P = .0078$), whereas there was a large increase in laparoscopic colectomy and proctectomy volume during the same time interval (1.5 ± 0.4 to 24.5 to 2.3 cases, $P = .0026$; Fig 4, *C*). Finally, we observed a large decrease in open appendectomy volume between periods 1 and 3 (30.7 ± 1.1 to 9.7 ± 5.0 cases) and a substantial increase in

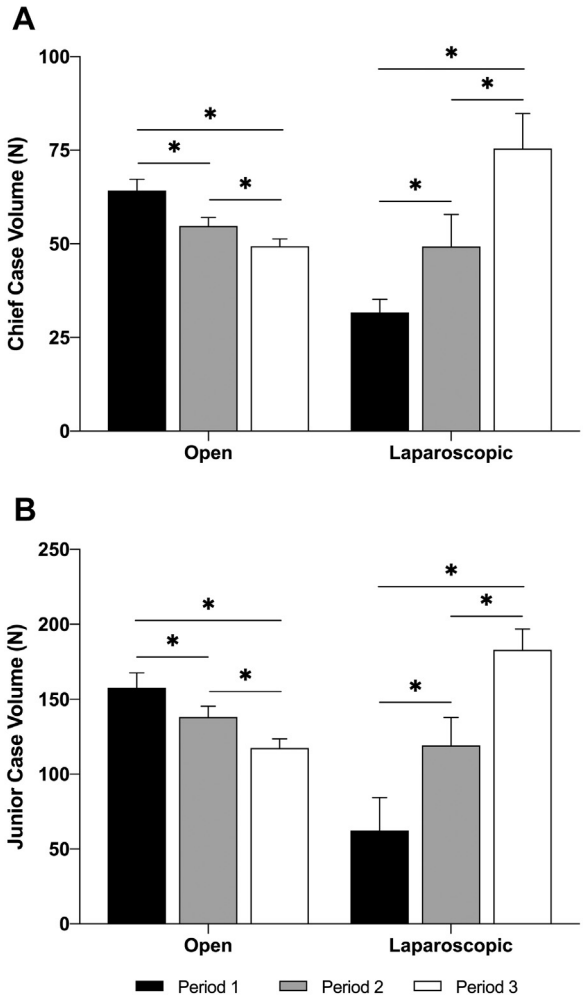

Fig 3. Chief (*A*) and junior (*B*) residents' training in the most recent era of laparoscopic surgery graduate with more laparoscopic than open operations for the 15 identified general surgery operations. Period 1 = 1994 to 2001; Period 2 = 2001 to 2010; Period 3 = 2011 to 2018. *$P < .05$ for comparisons as indicated using the Kruskal-Wallis test with the Steel-Dwass post-hoc test.

laparoscopic appendectomy volume (6.1 ± 2.5 to 54.6 ± 5.3 cases, $P = .0027$ for both; Fig 4, *D*).

Next, we analyzed the trends of both basic and complex laparoscopic operations. During the 25-year study period, surgical residents performed more basic than complex laparoscopic operations; however, there was a near parallel increase of all laparoscopic operations during the study period (Fig 5). Finally, because the rise in laparoscopic volume has outpaced the decline in open volume for the 15 general surgery operations, we examined these changes in the context of overall operative volume. Recent work by our group has shown that overall operative volume has remained stable for general surgery residents.[4] Qualitatively, we found a decrement in residual case volume from 1994 to 2005, where the residual volume reached a floor and leveled off for remainder of the study period (Fig 6).

Discussion

In this study, we evaluated the national open and laparoscopic operative experience of graduating general surgery residents during the past 25 years. For the examined operative domains, laparoscopic surgery surpassed open surgery and comprised a large portion of general surgery residents' training. These trends were also observed for junior and chief residents. Of the 4 core general surgery operations, the open approach remained predominant for hernia repair and colectomy or proctectomy, identifying an opportunity for residents to continue to gain familiarity with open surgery in an era of increasing prevalence of minimally invasive approaches.

Improving medical therapies and technological advancements have led to a rapid increase in nonoperative management and the introduction of minimally invasive modalities, including endovascular, endoscopic, and percutaneous approaches, to address what were traditionally operative diseases and complications. The first laparoscopic appendectomy was performed in 1983, followed by the first laparoscopic cholecystectomy in 1985, with the introduction of laparoscopic surgery into general surgery residency training shortly thereafter.[5,8,9] However, it was not until 1994 that the ACGME started to distinguish operations as either laparoscopic or open in general surgery operative logs. Because the field has evolved and expanded during the past 30 years, so too has the number of requirements issued by various accrediting bodies. First, in 2008, the ACGME's Residency Review Committee for surgery placed increased emphasis on a broader laparoscopic experience, with graduates required to complete 60 basic laparoscopic cases (up from 34) and 25 complex laparoscopic cases (up from 0).[10] Although some educators initially worried about meeting this requirement, the Residency Review Committee recently increased the requirement to 75 complex laparoscopic cases for 2018 graduates.[7] Our findings support that graduates are achieving this goal nationally, completing an average of 100.7 complex laparoscopic operations in 2018. Second, the FLS curriculum was developed in the late 1990s to increase medical knowledge and technical skillset. The successful completion of FLS is now a mandatory requirement of the American Board of Surgery for graduates to sit for the qualifying exam.[6] Although the benefits of minimally invasive techniques on patient morbidity and mortality are compelling, it is important to consider their potential impact on the holistic abilities and experience of surgical trainees.

Our findings of an increased laparoscopic experience and concomitant decreased open experience are complementary to and expand on the existing literature. In 2008, Carson et al found that minimally invasive procedures accounted for 11.1% of all cases performed in 2008 compared to 3.7% in 1999, with a proportional decrease in open cases.[11] Additionally, 3 other studies of ACGME cases logs, all of a similar time frame (1997–2010), found that the number of laparoscopic cases is increasing with an associated decrease in open operations.[12–14] Conversely, one previous study of ACGME case logs from 1994 to 2012 found that the open approach was more common than the laparoscopic approach during this more limited time frame.[15] Similarly, our analysis of the 4 index general surgery operations, inguinal and femoral hernia repair and colectomy or proctectomy were more likely to be performed open, although cholecystectomy and appendectomy were predominantly performed laparoscopically. This suggests that for certain operations, residents may be more comfortable with the open rather than the laparoscopic approach at graduation. Finally, these trends are not limited to operations or hospitals involving surgical residents. A study of the National Inpatient Sample data from 1993 to 2007 revealed a major increase in percutaneous, angiographic, and endovascular interventions with sharp decline in open biliary, gastric, colon, aortic, and trauma cases.[16] As noted, prior studies have examined the open and laparoscopic of experience of general surgery residents. However, these works are more limited in both scope and years examined and do not specifically address core general surgery operations as does the present work.

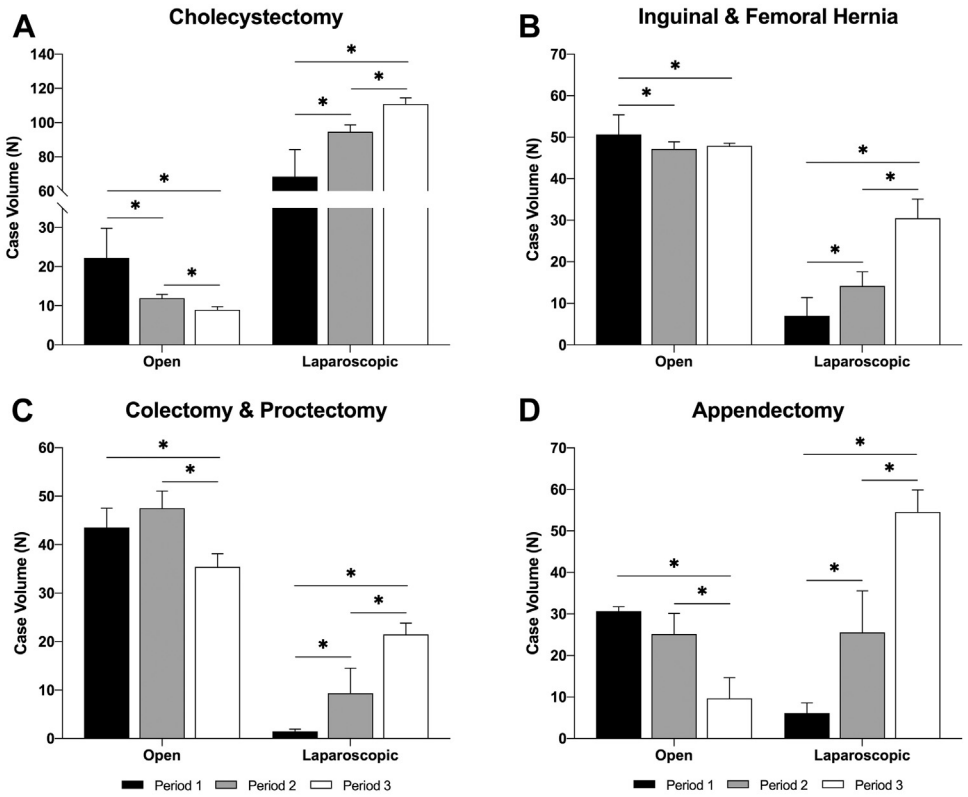

Fig 4. In today's era of laparoscopic surgery, the open approach is still the predominant approach done by surgical residents for inguinal or femoral hernia repair (*B*) and colectomy or proctectomy (*C*), whereas cholecystectomy (*A*) and appendectomy (D) are predominantly performed laparoscopically. Period 1 = 1994 to 2001; period 2 = 2001 to 2010; period 3 = 2011 to 2018. $^{*}P < .05$ for comparisons as indicated using the Kruskal-Wallis test with the Steel-Dwass post-hoc test.

The earliest perceptions of laparoscopy among general surgery residents was clouded by angst, because operations once performed by junior residents were shifted to senior residents given the novelty and complexity of this technological innovation. This shifting experience caused speculation as to whether laparoscopy would delay acquisition of operative skills among junior residents or stifle the independence of senior residents who were no longer taking juniors through cases or were performing laparoscopic surgeries later in training.[17] When asked about their comfort with laparoscopic surgery at the time of graduation, the majority of residents felt they could perform basic laparoscopic operations, but only a minority were comfortable performing advanced procedures.[18] We found that junior residents were doing an increasing amount of laparoscopic cases over time, with their volume increasing by 91.6% from period 1 to 2, whereas the chief resident volume only increased by 55.8% during the same time period. This suggests that early misgivings about laparoscopy in surgical training were short lived. However, an inherent question of these findings is whether today's graduates are suitably comfortable with open surgery because complex open operations previously done by general surgery residents have not been replaced by laparoscopic operations of equal complexity.[19]

So, the question remains unanswered—can today's general surgery residency graduates go open? There are many reasons they may choose not to: first, they have inadequate knowledge about open techniques for certain operations; second, in certain practice settings, senior assistance may not be available to help one convert in a complex operation; and third, and worse yet, pride may delay one from converting, as if converting were an affront on their surgical skills. It is hard to ignore the obvious: as trainees' experiences with open surgery decrease and their experiences with minimally invasive techniques increase, they will be less prepared to perform open surgery. In 2018, only 6.7% of all cholecystectomies and 8.2% of all appendectomies were performed open. In fact, multiple authors have questioned whether general surgery residents today have enough experience with open cholecystectomies to make them safe practitioners with the procedure.[20,21] A study of residents from one general surgery program reported reduced confidence in the management of unexpected events during laparoscopic operations and they maybe disadvantaged should unexpected events arise in an otherwise routine laparoscopic operation.[20] Thus, for the experienced surgeon, the decision to convert represents a retreat to common ground, whereas the decision for those with less experience only adds unfamiliarity to an already hazardous situation that is often relegated to a procedure of last resort.[2,22] Although the presented data does not answer the question at hand, the findings support a reduced experience in open surgery over time.

Most simulation training in general surgery residency focuses on minimally invasive surgery with the intent on diminishing the learning curve in the operating room. However, accrediting bodies have not focused on maintaining adequate training in open procedures, with a potential consequence of introducing a learning curve to the traditional approach. Increased simulation in open surgery can be utilized, using the American College of Surgeons Advanced Surgical Skills for Exposure in Trauma course as a model example. To increase experience in open surgery, some have suggested that residents rotate in other disciplines, where open surgery is more common, and participate in multiorgan procurements.[13] Additionally, for training programs with limited open surgery opportunities, relationships can be established with other programs with a greater open experience, similar to what has

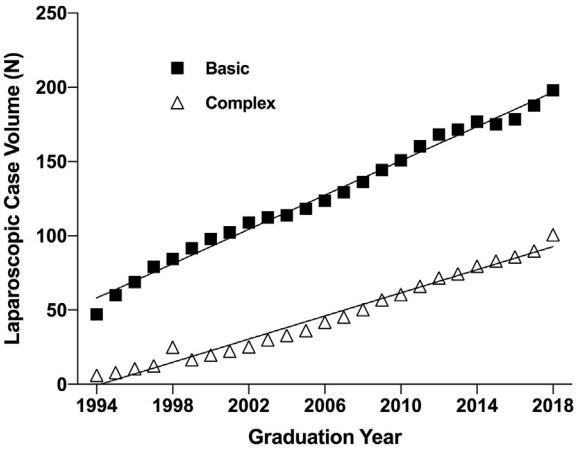

Fig 5. Surgical residents perform more basic than complex laparoscopic surgery cases; however, there has been a near parallel increase in both domains during the past 25 years. Basic laparoscopic cases have increased by 5.77 cases per year ($P < .0001$, $R^2 = 0.990$), whereas complex laparoscopic cases have increased by 3.89 cases per year ($P < .0001$, $R^2 = 0.977$).

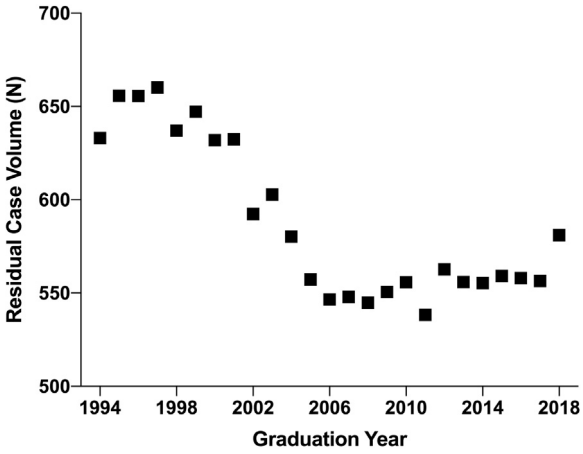

Fig 6. The increase in laparoscopic surgery parallels a decrease in the remainder of the surgical resident's operative experience until 2005, where the residual volume levels off. Residual case volume = total major case volume − (open + laparoscopic volume for the 15 examined operations).

been required of some programs to obtain an experience in transplantation.[23] However, many did not have a transplantation program at their home institution but rather relied on relationships with nonintegrated hospitals to provide this experience Trainees and educators should also maximize the educational opportunities afforded by today's most common indication for an open cholecystectomy—that which is performed in conjunction with another procedure.[24] Basic open operations aside, the greater challenge is training residents to become competent in operations that have only occasionally performed in practice and rarely if never experienced in residency training.[25] And holistically, we as a surgical community need to consider how privileges are granted to new graduates in both laparoscopic and open operations.

The widespread adoption of laparoscopic surgery has caused many established surgeons to retool, with SAGES providing guidelines for privileging committees. The ideal privileging process should result in granting surgical privileges to properly trained, competent surgeons. Minimum requirements include formal residency training plus program director documentation of sufficient laparoscopic experience. Those surgeons lacking laparoscopic experience during training are required to participate in a structured training curriculum along with practical experience to decrease the learning curve required to achieve competence.[26,27] Our findings suggest that the current guidelines may warrant modification. First, given the considerable laparoscopic surgery experience of today's general surgery graduates, it may be unnecessary to require program director documentation of a laparoscopic experience. Second, consideration should be given to limiting the open privileges to new surgical resident graduates. Open surgery, which at one point comprised the comprehensive training experience of general surgery graduates, is now attenuated by a variety of minimally invasive techniques, such that many graduates may not be competent to independently perform some open operations.

The overall operative experience of today's general surgery residents is markedly different than that of years past. Although overall operative volume has remained stable during the past quarter century, the experience is shifting to one with a greater emphasis on general surgery cases and diminished subspecialty operative experience.[4,28] Our analysis of residual case volume supports a shift in the surgical resident operative experience. In this analysis, the increase in laparoscopic surgery outpaced the decrement in open surgery for the 15 operations examined. For example, in 1994, the total laparoscopic and open volume for these operations was 296, whereas it was 462 in 2018. The decrease in residual case volume paralleling the overall volume increase for the 15 open and laparoscopic general surgery operations implies a concurrent decrease in volume occurring for other operative domains not analyzed in this work. Our group has recently demonstrated a more narrowed operative experience for graduating general surgery residents, with greater emphasis on general surgery cases and less focus subspecialty cases.[4] Specifically, others have reported a decrease in vascular, pediatrics, and trauma operative.[29–31] Additional work should be focus on better characterizing these shifts and evaluating the potential impact of the reduction in broad-based nature of general surgery training.

There are several potential limitations of our study. First, case logs are self-reported and subject to inaccuracies inherent with that process because ACGME case logs may not accurately reflect the operative experience of residents.[32] In addition, the case logs are subject to heterogeneity from system-based changes in the case logging system, including the implementation of online reporting, permitting 2 residents to log different portions of the same operation, increasing reporting of cases at the end of one's training and changes to operative codes and categorization. However, we did utilize, as an internal reference, 2 operations whose trend is both well-known and reflected in our data to assess the accuracy of case logs. The ACGME case logs represent national aggregate data, and as such we cannot account for institutional or individual factors that could influenced operative experience. In addition, we only examined the 15 operations from the ACGME case log reports that are listed with both an open and laparoscopic approach. As such, we are unable to evaluate the trends of other operations and may underestimate the decrease in open operations overtime as shifting surgical management strategies may contribute to fewer cases overtime for a variety of other open procedures. Finally, the data set contained intermittent missing data, with 6.9% of the total data set being estimated with interpolation techniques.

Our findings suggest that for specified procedures, laparoscopic surgery has surpassed open surgery experiences for general surgery residents. These trends raise the concern that when necessary, today's general surgery graduates may not have an adequate experience with open abdominal surgery and may continue to rely on subspecialists for support. This erosion of the open operative

experience may soon lead to the loss of the skill set that some think constitutes the craft of traditional surgery, although others may argue that the importance of a craft is a durable product, not the approach or tools.[13,25] As such, future work should focus on the assessment of operative competency among graduating surgical residents to ensure technical proficiency. These assessments could affect how new surgeons are credentialed to ensure graduates can safely perform open operations.

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Discussion

Dr Dimitrios Stefanidis (Indianapolis, IN): Thank you very much for the opportunity to discuss this paper. This is an interesting paper by Dr Quillin and his colleagues that was sent to me in advance of today's meeting.

With the advent of laparoscopy now over two 2 decades ago, general surgery has experienced a revolution; numerous new procedures have been introduced into our daily practice that provide several benefits to our patients, less pain, earlier convalescence, but also pose challenges to our training system.

As we have learned from Ericsson's research, expertise is task specific, which means that our trainees are subjected to a new learning curve with every new technique that is introduced in our practice, even if the type of procedure does not change. This issue is further amplified by the fact that open surgery technical skills have little transferability to laparoscopic skills. If you consider the example of inguinal hernia repair, today we can do it open using a variety of techniques: Kugel, PHS, Lichtenstein, tissue repairs, etc; laparoscopically—TAPP, TEP; or robotically. If the number of inguinal hernia repairs our residents were doing 15 to 20 years ago were on average 60 to 70 mostly open and today are 40+ open and 30+ laparoscopic procedures the experience our residents get with each procedure is lower than it used to be. This clearly poses a significant challenge to our training system.

The paper by Dr Quilin and colleagues therefore is timely and relevant.

The authors, as you heard, reviewed ACGME case logs over a 26-year period and have clearly demonstrated that over time open case numbers have decreased significantly, whereas laparoscopic have increased. In the context of my introductory comments, this raises concerns about the ability of our residents to achieve competence in all procedures by graduation.

I have the following questions for the authors:

How do you explain that the total number of cases has remained stable over the study period when the drop of the open cases seems to be less than the rise of the laparoscopic cases for the examined procedures? For example, appendectomy or hernia.

Secondly, could the decrease in open cases be related, at least in part, to other factors besides the introduction of the laparoscopic technique? Could, for example, the increased application of nonoperative trauma management strategies have contributed to the fewer open cases over time? Another example may be axillary node dissection which is used a lot less often than in the past?

Given the dilution of the experience our residents get with a procedure due to multiple techniques used, for example, inguinal hernia is one of the better ones, how do we train everyone in all techniques well, especially since robotic techniques are now on the rise?

Finally, what is the role of simulation in all of this? Based on one of the comments you made in your presentation but was not in your paper, the statement of SAGES about laparoscopic privileges, I tend to be biased because I am a SAGES member, but it's actually very relevant still.

Dr R. Cutler Quillin, III: Thank you, Dr Stefanidis, for your comments and your review. I really appreciate it.

To address your first question, the point that overall operative volume is stable, yet we show that laparoscopic cases are outpacing open cases. So, what exactly is happening to the remainder of this other fraction? We didn't examine it specifically. There's different ways to examine these data sets. You can look at individual operations or you can look at operative categories. There are literally hundreds of operations in these case log reports and we didn't examine them all. But I think it's just reflective of the fact that the surgical resident experience has narrowed in recent years. If you look at Thurston Drake's papers, who has written a lot with these case log reports. He shows there has been a decrease in operative trauma volume and there has been an increase in pediatric experience. Dr Potts presented recently at the American Surgical and showed that open vascular surgery has decreased for surgical residents.

Your second question was, is there some other relation as to why these open cases may be decreasing, and you gave the example of the lymph node dissection. I do not think it is necessarily relevant here because we are only looking at operative volume for specific open and laparoscopic operations. So, the changes are really just a function of what is happening with these specific operations, and changing practice patterns for other operations not examined may not necessarily be implicated here.

Your third question about the dilution of the resident experience and how can you train residents in all these techniques? I think the short answer is we are not. Eighty percent of residents are going into fellowships, and the reason they are going into fellowships is because they are not confident, and they lack confidence in their skills. So, it's a real challenge, and it's a hard one to answer. For the ones that don't go into fellowship, there is the transition of practice program that's available for them. But maybe we don't need to train everybody in all these different skills. Maybe privileges and credentials should be limited for graduating residents depending on where they come from and what the scope of their training is. As we all know, someone in a small community program has a vastly different experience than someone at a tertiary care center.

Then your last comment about the implication of simulation and how simulation plays into all of this. I think simulation is only as beneficial as the competing alternative. So, consider that you are a resident and you have the opportunity to do surgery in the operating room, but a simulation laboratory is taking place. You have to go to the simulation lab, but you may not get as much out of it as you would because you are worried about what is going on in the open operation.

I think we should think a little differently about simulation. Obviously, simulation and open surgery has to be more integrated. Trauma has a good model with the American College of Surgeons Advanced Surgical Skills for Exposure in Trauma open exposure course. So, we can follow that lead and introduce cadaver models or porcine models for vascular anastomoses for instances. There are many ways that we can go about doing this. But maybe we should think about simulation differently.

Maybe we should have the residents simulate an open cholecystectomy by taking a gallbladder out during a Whipple or during a liver resection. Or they can simulate the exposure necessary for a right hemicolectomy by doing a multiorgan procurement. There are many different novel ways we can get residents into the operating room and teach them simple open operations by doing components of complex open operations.

Finally, how residents think today about what is beneficial for them is different from how people used to think about it. Consider the operative surgeon in a laparoscopic case and the assistant. The operative surgeon is doing the case while the assistant is providing static retraction, which may be off screen, for much of the operation. This is quite different from the dance that's required for open surgery. The assistant in a laparoscopic operation isn't doing quite as much as the assistant in an open operation. We are going to present data at the Surgical Education Week which will show that residents are not first assisting and not performing teaching assistant in any cases; they are just doing the operation. There has been a paradigm shift where residents don't want to come in and watch operations. They just want to be doing the operation. However, there are probably many opportunities for them to learn the operation by watching someone do the operation.

Dr Gerald Fried (Montreal, QC): We as a profession have responsibility to the public to ensure that the people that we train are safe and appropriately ready for practice, but we also have to recognize that surgery has evolved.

We are doing different procedures now. Although we should be aware of the change in the volume of both open and laparoscopic procedures, I think the most important message here is that volume is not the only surrogate for competence, and we should not rely on that. We should ensure that we take maximum advantage of our educational opportunities and that the cases that residents do reflects their skills. We need to properly evaluate our residents and give them feedback and we must ensure that, at the end of their training, they are ready for practice. When I finished my training, almost 40 years ago, most of the residents did Fellowships. They did different types of Fellowships then than they do now. There is still ample opportunity for our residents to do open surgery whether it be trauma, transplantation, or major hepatobiliary surgery. Each of these operations is a learning opportunity. It may not be reflected in the volume. But, at the end of the day, we have to ensure as a profession that we are turning out surgeons who are safe for the population.

Thank you for bringing this to our attention. I think this is a call to arms for us.

Dr R. Cutler Quillin, III: Thank you for those comments.

Dr Jose Velasco (Chicago, IL): Thank you for bringing this to us. For somebody who was trained in open surgery and then self-taught laparoscopic surgery, initially, at least, conversion to open

was a failure. It was because of the complications. One of the problems in the data that you collected there is no way to know why those open cases were done. Were they done because of the complication, or were they done because of the practical approach to it? So, there is one issue.

Have you looked into your own institution? I know you can answer that question based on the logs, but maybe at your institution you looked at it and it would be interesting to know what the answer is.

Second, I think laparoscopy or open is an issue of process. Do I make a midline incision, transverse, chevron, and I think out of the 5 domains, critical thinking is the one that we haven't really learned how to teach in the technical and nontechnical issues. I would submit that the use of what is called now EPAs, entrustable professional activities, may be a more rational way to certify or credential a surgeon and learn this.

So, the question is, do you have any idea as to whether those open cases mean a changing approach, or a complication? Because those are different issues. Two, is it feasible to address the different competencies that we have in training by using tools such as EPA, entrustable professional activities. Thank you for bringing this important topic.

Dr R. Cutler Quillin, III: The first point, we can't tell from the data set whether an open operation started out as a laparoscopic operation and converted to open. It's simply a limitation in the data set, as you point out, but could be easily addressed by using institutional specific data.

The second, measuring competence is not an easy thing. There are tools available to assess competence, you can start with a couple of operations and then scale it up to multiple operations. The SIMPL app is one easy way that you can do it.

As far as entrustable professional activities are concerned, I agree these will be useful going forward to gauge trainees. Take bringing a patient to the operating room, residents often focus on the big picture items like preoperative workup and indication for the operation, but there's some of these little details that as a new faculty I am really worried about, but I can tell the residents don't even think about it, positioning the patient, necessary equipment for the case and what incision I am going to make. So, there's probably lots of opportunities that we miss in the immediate preoperative phase as an example, that we could take advantage of to both assess and teach residents.

Dr R. Matthew Walsh (Cleveland, OH): I do want to build on this number of cases versus competence equation. Is it our responsibility to report to the ACGME with each individual case how the resident is performing in terms of competence? Because my question is, when do we get to the tipping point that an additional laparoscopic Fellowships is not needed? Maybe even though the number of cases are less than open, they may be competent at doing a laparoscopic colectomy, and thus where are we in terms of how to define that tipping point?

Dr R. Cutler Quillin, III: We are not there yet, certainly. Operative volume is really the only surrogate we have now for competence, and that's the only thing. You can debate it, and it's different for every single person. But we need to continue to try and develop some of these tools to really assess operative competency. I think that's where we need to go in surgical education, competency-based training as opposed to just the sheer volume.