See None, Do Some, Teach None: An Analysis of the Contemporary Operative Experience as Nonprimary Surgeon

Alexander R. Cortez, MD,* Leah K. Winer, MD,* Al-Faraaz Kassam, MD,* Dennis J. Hanseman, PhD,* Joshua W. Kuethe, MD,* Ralph Cutler Quillin III, MD,* and John R. Potts III, MD†

*Cincinnati Research on Education in Surgical Training (CREST), Department of Surgery, University of Cincinnati, Cincinnati, Ohio; and †Accreditation Council for Graduate Medical Education, Chicago, Illinois

OBJECTIVE: The operative experience of today's general surgery resident has changed, but little is known about the modern experience as nonprimary surgeon. We set out to explore changes in the operative experience of general surgery residents as first assistant (FA) and teaching assistant (TA).

DESIGN, SETTING, AND PARTICIPANTS: This is a review of ACGME national operative log reports from 1990 to 2018. TA and FA cases were analyzed. Statistical analysis was performed using polynomial regression analysis and Kruskal-Wallis test. Statistical significance was set at $p < 0.05$.

RESULTS: 30,260 individuals completed general surgery residency during the study period with medians of 951 (interquartile range: 929-974) total major, 63 (31-184) FA, and 32 (25-48) TA cases. As a proportion of total cases completed, FA cases decreased from 21.8% of the total operative experience in 1990 to 2.5% in 2018, and TA cases declined from 7.4% of the total operative experience in 1990 to 3.5% in 2018. Regression modeling demonstrated that both operative roles decreased over time, but at a progressively decreasing rate, with FA cases reaching a "floor" around 2010 and TA cases reaching a "breakpoint" in 2008 at which time operative volume rebounded and began to increase. Among the core general surgery domains of abdomen and alimentary tract, compositional analysis revealed a decrease across each of the 11 operative subcategories (all $p < 0.05$) for FA, and for TA, a decrease in 6 of the 11 operative subcategories (stomach, small intestine, large intestine, anorectal, hernia, and biliary, all $p < 0.05$).

CONCLUSIONS: Over the past 3 decades, the resident operative experience as nonprimary surgeon has decreased dramatically, with today's residents graduating with fewer FA and TA cases. As surgical training has traditionally relied heavily on an apprenticeship model for learning technical skills, it is essential that surgical educators recognize and rectify these trends. (J Surg Ed 76:e92−e101. © 2019 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: operative volume, first assistant, teaching assistant, case logs, surgical education, ACGME

COMPETENCIES: Practice-Based Learning and Improvement, Patient Care, Medical Knowledge

INTRODUCTION

The commonly recited dictum of surgical training and an important method by which technical learning occurs in surgery is "see one, do one, teach one." This concept highlights the traditional method by which residents develop and demonstrate competency through observing, then performing, and lastly, teaching an operation. Accordingly, the resident experience as first assistant (FA), surgeon junior/chief, and teaching assistant (TA) each play a unique and important role in resident training. These surgeon roles follow the progression of "graded responsibility" that is paramount to one's development toward becoming a capable and autonomous provider and surgeon.[1]

In recent years, however, the traditional model of surgical training has come under enormous strain from a multitude

Presented at the 2019 Association of Program Directors in Surgery Annual Meeting/Surgical Education Week, April 23−27, 2019

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. JRP is a full-time employee of the ACGME but has no role or voting privileges in accreditation decisions made by the RRC-Surgery.

Correspondence: Inquiries to Alexander R. Cortez, MD, University of Cincinnati, Department of Surgery, 231 Albert Sabin Way, ML 0558, Cincinnati, OH 45267-0558; e-mail: cortezar@ucmail.uc.edu

  1931-7204/$30.00
https://doi.org/10.1016/j.jsurg.2019.05.007

of influences.[2,3] Changes in disease management, the emergence of subspecialty programs, the implementation of duty hour restrictions, rising medicolegal concerns, growing department and faculty sizes, and increasing trainee supervision have reduced resident autonomy in the operating room (OR) compared to years past.[4,5] In an effort to enhance residents' learning of technical skills, simulation has emerged as a viable adjunct for surgical educators[6]; however, simulation is not a replacement for operative experience.[7,8] Whether designing simulation-based techniques or seeking to increase operative experience, educators must closely examine the resident operative experience and better understand today's changing culture of surgical training.[2,9,10]

Existing work on the contemporary resident operative experience as primary surgeon, that is surgeon junior and/or surgeon chief, has identified a reduction in the chief operative experience with a concomitant increase in surgeon junior operations, as well as a narrowing of the operative composition toward general surgery domains.[11-13] However, the resident operative experience as nonprimary surgeon, that is as FA and TA, has not been fully explored. While prior work indicates a decline in both of these operative roles,[13] the magnitude and composition of such experiences is unknown. Therefore, we set out to examine operative trends among US general surgery residents in their role as nonprimary surgeon. We hypothesized that FA and TA experiences have decreased and narrowed over the past 3 decades of surgical resident training.

MATERIALS AND METHODS

ACGME Case Log Data

During the 5 years of surgical residency all US general surgery residents are required to document their operative experience through entry of case participation into a case log system managed by the Accreditation Council of Graduate Medical Education (ACGME). The ACGME subsequently aggregates these operative data into annual reports containing summary statistics for each graduating resident class. These reports contain the median operative volume for domains (termed "RRC area" for the Residency Review Committee designated operative areas) completed as surgeon chief, surgeon junior, total major, TA, and FA cases, as well as the 10th, 30th, 70th, and 90th percentiles. Case logs from 1990 to 2018 were analyzed to evaluate the operative experience of graduating general surgery residents, with particular focus on the nonprimary surgeon experience, defined as those cases logged as TA or FA. The case logs from 2000 to 2018 are publicly available (https://www.acgme.org/Data-Collection-Systems/Case-Logs-Statistical-Reports), and case logs prior to 2000 have been used with permission granted by the ACGME. This study was approved by the University of Cincinnati Institutional Review Board.

Definitions

Eight domains were evaluated as directly reported in the ACGME summary reports. These included skin/soft tissue, head/neck, breast, endocrine, thoracic, pediatric, plastic, and operative trauma. The alimentary tract domain included subcategories of esophagus, stomach, small intestine, large intestine, and anorectal, while the abdomen domain included subcategories of general, biliary, spleen, liver, pancreas, and hernia. Some subcategories of the vascular domain have changed over time, but aneurysm repair, cerebrovascular, peripheral obstruction, and abdominal obstruction have remained constant and the vascular domain herein is the total of these 4 subcategories. The remaining operative domains (hand, genitourinary, gynecologic, nervous system, organ transplant, and orthopedic) were excluded given the very low frequency of case entries. To quantify the composition of operative role, a category of "total operative experience" was created for purposes of this study and calculated as the sum of surgeon junior, surgeon chief, TA, and FA cases.

Statistical Analysis

All statistical analyses were performed using JMP Pro Version 13.0 and SAS Version 9.4 (both SAS Institute, Cary, North Carolina). Descriptive statistics were reported as median and interquartile range. To evaluate year-to-year trends in operative volume over time, polynomial regression techniques were performed, which identified a quadratic relationship with the observed data. For quadratic models, a prediction model that best fits the observed data is calculated based on a quadratic equation ($x = a + b \times \text{year} + c \times \text{year}^2$). The mathematical symbol associated with the b term indicates an increasing (+ sign) or decreasing trend (− sign) over time, and the mathematical symbol of the c^2 term indicates if the rate of change is increasing (+ sign) or decreasing (− sign). In the case of $-b$ and $+c^2$ terms, this indicates that there is a decreasing trend over time, but at a decreasing rate. The trend may eventually reverse and become positive. Goodness of fit is measured by (1) the coefficient of determination (R^2) which ranges from 0 to 1 with values closer to 1 indicating a "good fit" and values toward 0 indicating a "poor fit"; and (2) inclusion of the all observed data points within the 95% prediction limits. To supplement our time-trend analysis for overall trends, as well as compositional changes in operative experience, annual data was combined into 3 time periods by decade (period 1 = 1990-1999, period 2 = 2000-2009, and period 3 = 2010-2018), representing the relative early, interim, and modern eras of training. Differences between time periods were compared using the Kruskal-Wallis test

with Steel-Dwass test for multiple comparisons. Statistical significance was set at $p < 0.05$.

RESULTS

Trends in NonPrimary Surgeon Operative Volume

From 1990 to 2018, 30,260 individuals completed general surgery residency with a median of 951 (interquartile range: 929-974) total major, 245 (236-270) surgeon chief, 684 (674-723) surgeon junior, 63 (31-184) FA, and 32 (25-48) TA cases. The proportion of cases performed for each resident operative role relative to total operative experience was first examined as a function of time. Surgeon chief cases remained stable over the study period, comprising 21.4% of the total operative experience in 1990 and 24.8% in 2018. However, surgeon junior cases became more predominant, increasing from 49.4% in 1990 to 69.3% in 2018. Conversely, FA cases decreased from 21.8% of the total operative experience in 1990 to 2.5% in 2018, and TA cases declined from 7.4% of the total operative experience in 1990 to 3.5% in 2018 (Fig. 1A).

Next, year-to-year trends were examined for FA and TA cases using polynomial regression techniques. The trend of both operative roles was found to fit a quadratic model ($p < 0.05$ for both). This demonstrated that for FA cases, operative volume decreased significantly over time, but that the rate of decline from year-to-year also decreased. (Fig. 1B). As an example, the rate of decrease in case volume between graduates of 1996 to 1997 was larger than the decrease between graduates of 2009 and 2010. During the first 5 years of the study period, the average rate of change was −19.9 cases per year, whereas during the last 5 years of the study period, the average rate of change was +1.2 cases per year, suggesting a plateauing of the

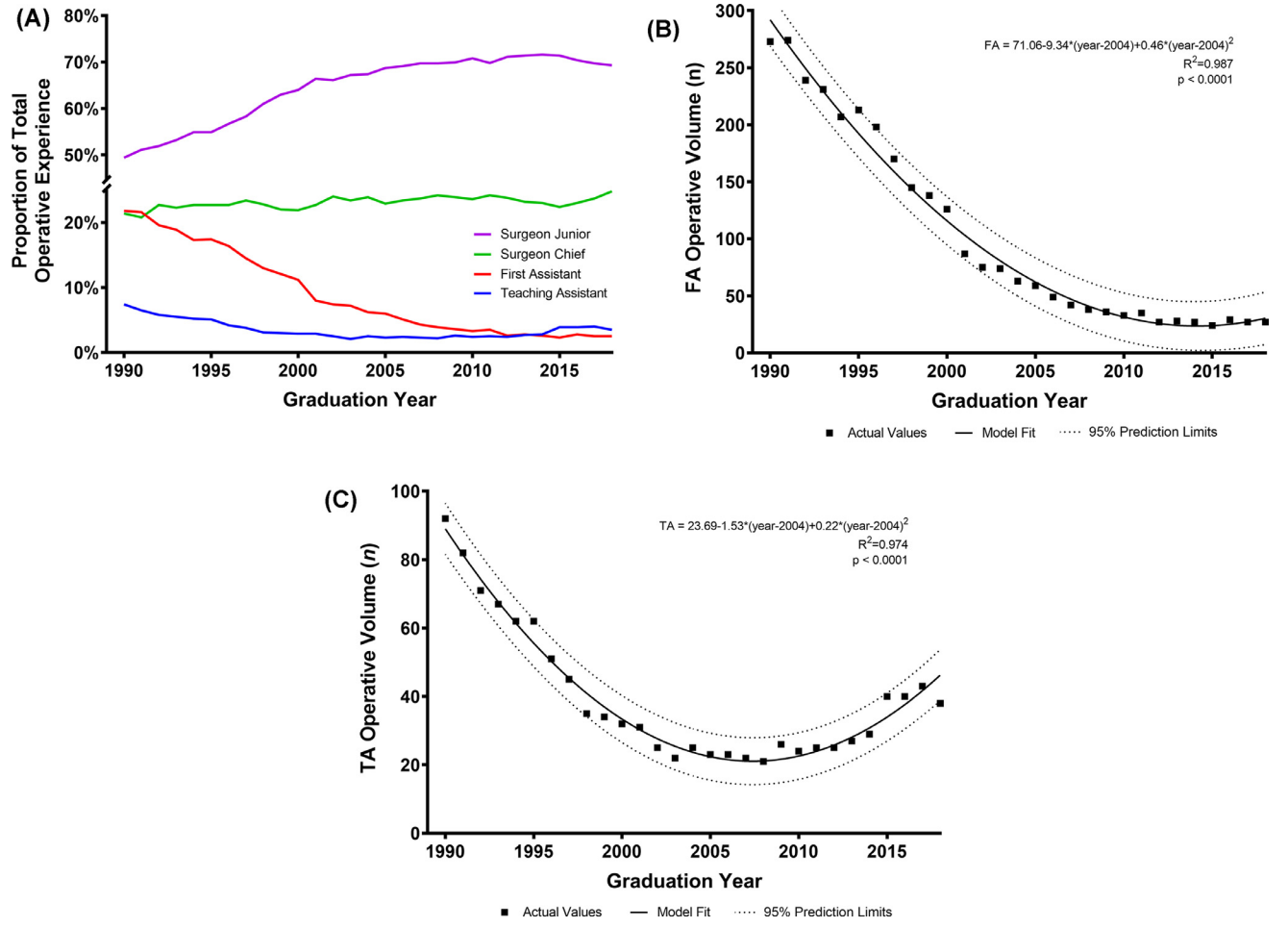

FIGURE 1. The operative experience as nonprimary surgeon has declined dramatically for today's general surgery resident. (**A**) As a proportion of total cases completed, FA cases decreased from 21.8% of the total operative experience in 1990 to 2.5% in 2018, and TA cases declined from 7.4% of the total operative experience in 1990 to 3.5% in 2018. (**B** and **C**) Regression modeling demonstrated that both operative roles of FA and TA decreased over time, but at a progressively decreasing rate, with FA cases reaching a "floor" around 2010 and TA cases reaching a "breakpoint" in 2008 at which time operative volume rebounded and began to increase.

observed trend. Similarly, quadratic modeling demonstrated that TA cases also decreased significantly over time and with a decreasing rate of change year-to-year (Fig. 1C). However, between 2007 and 2008, TA cases began to increase, identifying a "breakpoint" at which the decreasing trend reversed. During the first 5 years of the study period, the average rate of change for graduates was −6.7 cases per year, whereas during the last 5 years of the study period, the average rate of change was +3.6 cases per year. Taken together, graduates in 2018 finished residency training with 246 fewer FA cases and 54 fewer TA cases than graduates in 1990.

To supplement this time-trend analysis, the FA and TA operative experience were next compared by decade to observe changes in era of training. Significant decreases were observed for both nonprimary surgeon roles over time (Fig. 2). The total FA experience decreased significantly by 149 cases between period 1 and period 2 (210 vs 61 cases, $p < 0.01$) and continued to decline by an additional 34 cases between periods 2 and 3 (61 vs 27 cases, $p < 0.01$). Altogether, period 3 graduates completed 183 fewer FA cases than period 1 graduates (210 vs 27 cases, $p < 0.01$). Similarly, the total TA experience in period 2 decreased by 38 cases compared with period 1 (62 vs 24 cases, $p < 0.01$). Period 3 saw a halt in this decrease, with a 5-case increase (24 vs 29 cases), although this did not reach statistical significance. Overall, the TA experience for period 3 graduates compared to period 1 graduates decreased by 33 cases (62 vs 29 cases, $p < 0.01$).

Compositional Analysis of NonPrimary Surgeon Operative Experience

To examine compositional changes to the nonprimary surgeon experience, the operative experience was compared by decade. The FA experience in each of the 11 RRC operative domains is reported in Table 1 and notable for significant differences between time periods for each of the 11 categories (all $p < 0.05$). Among these RRC domains, the largest decrements for the FA experience were in the abdomen and alimentary tract domains, as illustrated in Fig. 3A. To further explore the types of operations in which residents were assisting, the subcategory operations within these 2 domains were explored. There was a decrease in each of these 11 operations for FA cases, as illustrated in Fig. 3B.

The TA experience in the 11 RRC operative domains is depicted in Table 2. Of these domains, there were 5 (skin and soft tissue, vascular, endocrine, thoracic, and pediatrics) in which graduates had rare TA experiences at any time period with no changes between groups (all $p > 0.05$). Of the remaining 6 domains (breast, alimentary tract, head and neck, abdomen, operative trauma, and plastics), there was a statistically significant difference between time periods (all $p < 0.05$). Similar to FA, the domains in which the TA experience had the largest decrease were the abdomen and alimentary tract domains as illustrated in Fig. 4A. Finally, within the subcategory operations of these 2 domains, the TA experience was associated with significant differences in 2 of 6 abdomen subcategories (biliary and hernia) and 4 of 5 alimentary tract subcategories (stomach, small intestine, large intestine, and anorectal) between time periods (all $p < 0.05$) (Fig. 4B).

DISCUSSION

In this study, we describe the operative experience for graduating US general surgery residents as nonprimary

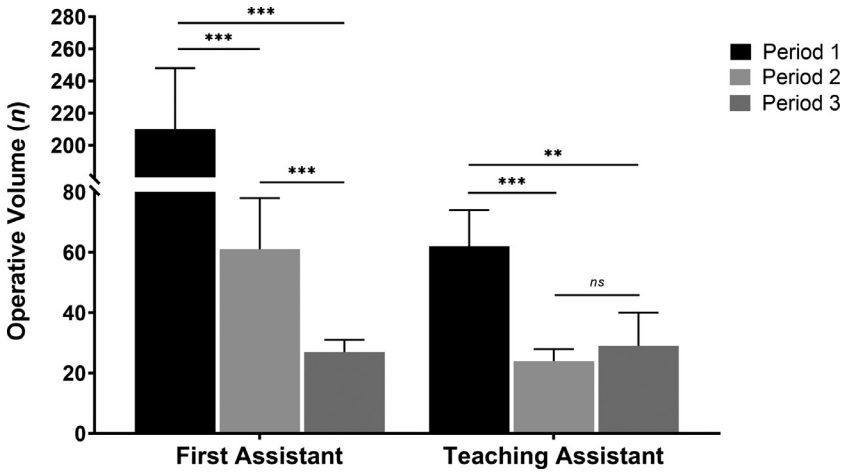

FIGURE 2. Training in the modern era is associated with a markedly reduced operative experience as nonprimary surgeon as evidenced by large decreases in the total first assistant and teaching assistant case volumes over the past 3 decades. Period 1 = 1990 to 1999, Period 2 = 2000 to 2009, and Period 3 = 2010 to 2018; **p < 0.01, ***p < 0.001, *ns* = not significant by Kruskal-Wallis test with Steel-Dwass test for multiple comparisons.

TABLE 1. Changes in First Assistant Operative Volume by Period

Operative Domain	Period 1 (1990-1999)	Period 2 (2000-2009)	Period 3 (2010-2018)	p
	Median (IQR)	Median (IQR)	Median (IQR)	
Skin and soft tissue	2 (2-2)	1 (1-1)	1 (1-1)	<0.01*
Breast	12 (8-14)	3 (2-4)	1 (1-2)	<0.01*
Head and neck	3 (3-4)	1 (1-1)	0 (0-1)	<0.01*
Alimentary tract	28 (21-31)	9 (8-11)	5 (5-7)	<0.01*
Esophagus	3 (2-3)	1 (1-1)	0 (0-1)	<0.01*
Stomach	4 (3-5)	2 (1-2)	1 (1-1)	<0.01*
Small intestine	4 (3-4)	1 (1-1)	1 (1-1)	<0.01*
Large intestine	14 (11-15)	5 (4-6)	3 (3-4)	<0.01*
Anorectal	4 (3-4)	1 (1-1)	0	<0.01*
Abdomen	34 (27-36)	9 (8-13)	6 (6-7)	<0.01*
Biliary	17 (11-17)	4 (4-6)	3 (3-3)	<0.01*
Hernia	10 (8-12)	4 (3-4)	2 (2-3)	<0.01*
Liver	1 (1-1)	0	0	<0.01*
Pancreas	1 (1-2)	0 (0-1)	0	<0.01*
Spleen	1 (1-1)	0	0	<0.01*
General	4 (3-4)	1 (1-2)	1 (1-1)	<0.01*
Vascular	15 (10-18)	3 (1-5)	1 (0-2)	<0.01*
Endocrine	3 (2-4)	1 (1-1)	1 (1-1)	<0.01*
Operative trauma	10 (6-13)	1 (1-2)	1 (1-1)	<0.01*
Thoracic	23 (11-28)	3 (2-5)	2 (1-2)	0.01*
Pediatrics	6 (3-10)	1 (0-1)	0 (0-1)	<0.01*
Plastics	5 (3-7)	1 (0-1)	1 (0-1)	<0.01*

*p < 0.05 by Kruskal-Wallis test among the 3 groups.

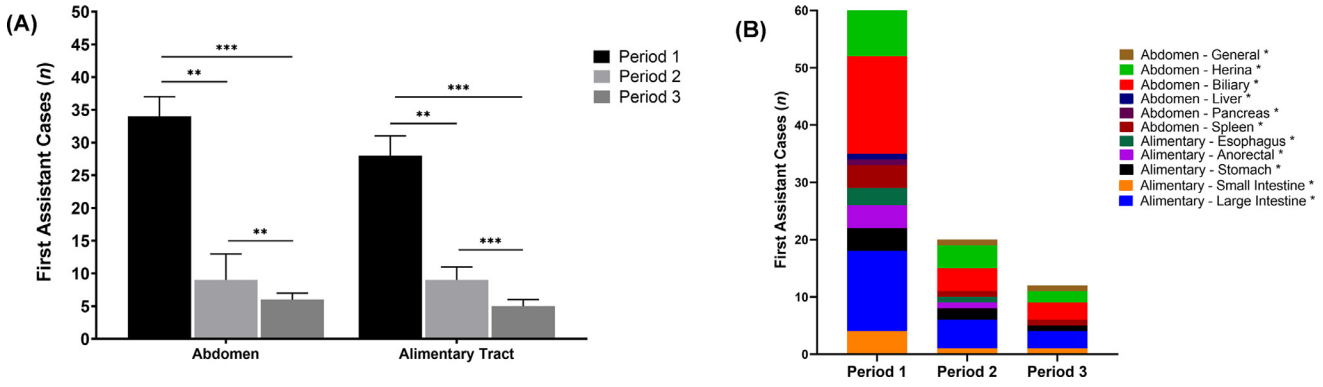

FIGURE 3. The operative experience as first assistant within the "core" general surgery domains has decreased markedly. (**A**) Total abdomen and alimentary tract cases as first assistant have declined over the past 3-decades and (**B**) within these domains, these decreases have impacted each of the 11 operative subcategories. Period 1 = 1990 to 1999, Period 2 = 2000 to 2009, and Period 3 = 2010 to 2018; **p < 0.01, ***p < 0.001, *ns* = not significant by Kruskal–Wallis test with Steel-Dwass test for multiple comparisons.

surgeon and report ongoing and significant decreases in FA and TA cases over the past 3 decades, with a recent rebound occurring among the TA case trend. What is of greater concern is the magnitude of these decreases, particularly for FA cases. Moreover, the areas most impacted by these vanishing experiences are within the core general surgery domains of abdomen and alimentary tract. Given the inherent apprenticeship model that exists in surgical training for learning technical skills, it is essential that surgical educators recognize these trends.

Surgical training is unique compared with other medical specialties in that, in addition to a fund of clinical knowledge, residents must also acquire a technical skill set. Consequently, the OR serves as a "classroom" for trainees,[14] and the resulting task of coaching residents toward competency remains a complex undertaking for educators. In the modern era, "learning" in the OR has been scrutinized and therefore adjuncts that optimize resident preparation for the OR are important.[15] While recent work in surgical education has identified quality methods for teaching

TABLE 2. Changes in Teaching Assistant Operative Volume by Period

Operative Domain	Period 1 (1990-1999)	Period 2 (2000-2009)	Period 3 (2010-2018)	p
	Median (IQR)	Median (IQR)	Median (IQR)	
Skin and soft tissue	1 (1-1)	1 (1-1)	2 (1-3)	0.07
Breast	5 (4-7)	1 (1-2)	1 (0-1)	<0.01*
Head and neck	2 (2-2)	1 (1-1)	1 (1-1)	<0.01*
Alimentary tract	17 (15-18)	8 (7-10)	9 (7-12)	<0.01*
Stomach	2 (1-2)	1 (1-1)	1 (1-1)	0.01*
Small intestine	2 (2-2)	1 (1-1)	1 (1-2)	0.01*
Large intestine	10 (9-11)	5 (5-6)	6 (5-8)	<0.01*
Anorectal	2 (2-3)	1 (1-1)	1 (1-1)	<0.01*
Abdomen	16 (13-21)	8 (7-15)	10 (8-16)	0.02*
Biliary	6 (5-10)	4 (3-5)	5 (4-8)	0.02*
Hernia	8 (7-9)	3 (3-4)	4 (3-6)	<0.01*
General	1 (1-2)	1 (1-2)	1 (1-2)	0.96
Operative Trauma	5 (3-5)	1 (1-2)	1 (1-1)	<0.01*
Plastics	1 (1-2)	0	0 (0-1)	0.01*

NOTE: For the operative domains of vascular, endocrine, thoracic, and pediatrics, as well as the subcategories of esophagus, liver, pancreas, and spleen, the median number of TA cases was 0 throughout Periods 1, 2, and 3 and are not listed in the table.
*p < 0.05 by Kruskal-Wallis test among the 3 groups.

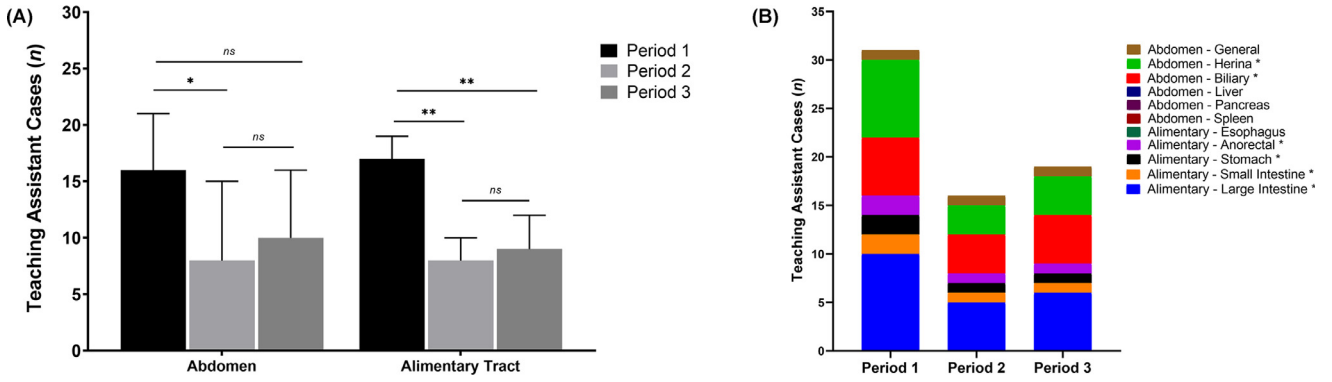

FIGURE 4. The operative experience as teaching assistant within the "core" general surgery domains has decreased markedly. (**A**) Total abdomen and alimentary tract cases as teaching assistant declined from period 1 to period 2, followed by a period of stabilization in period 3. (**B**) Within these domains, the TA composition has narrowed with decreases in 6 of 11 operative subcategories. Period 1 = 1990 to 1999, Period 2 = 2000 to 2009, and Period 3 = 2010 to 2018; *p < 0.05, **p < 0.01, ***p < 0.001, *ns* = not significant by Kruskal-Wallis test with Steel-Dwass test for multiple comparisons.

procedural skills though simulation, inherent limitations exist and OR experience involving observation, assisting, and hands-on involvement remain critical to the learning process.[6,16] In recent years, the development of the "Zwisch scale" has emerged as an effective method to advance trainees in the OR and has become widely used.[17,18] The Zwisch scale identifies levels of attending surgeon assistance and resident autonomy during an operation, with residents progressing from the stages of "show and tell" to "active help" to "passive help" to "no help." Not coincidentally, these stages parallel the ACGME's resident roles of FA, surgeon junior, surgeon chief, and TA, respectively.[19] This similarity recognizes the importance that each of these stages plays in a trainee's development to become a capable and independent surgeon.

In a FA case, a resident assists another surgeon who is responsible for the operation.[19] While the opportunity to operate early in the course of one's training is rewarding, serving as the assistant should not be thought of as a lesser experience but rather as a vital exercise for anyone learning a new procedure. Despite today's drive for hospitals to maximize patient throughput, gaining operative experience as a FA remains at least as great a priority for surgical residents as providing nonoperative patient care. In fact, the new training requirement of 250 cases

by the PGY3 year is consistent with this notion as minor and FA cases count toward this requirement, and this minimum encourages residents to be in the OR in any capacity.[20] Surgical educators and senior residents can facilitate increased observational operative experiences by encouraging junior residents to come to the OR whenever able, even if only for a portion of the case. In addition, inclusion of simulation-based techniques, such as deliberate practice, mental imagery, and training to automaticity serve as adjuncts to maximize learning in the OR.[6,21] While it is incumbent upon program directors and surgical educators to understand these trends, trainees are also responsible for their operative experience. Our opinion is that in the modern era of surgical training there appears to be a decreased desire among residents to participate in cases in a purely observational or assistant capacity. There is little doubt that residents face pressure to efficiently complete numerous patient care tasks, many of which can be offloaded to physician extenders to enhance resident education,[22,23] but the pendulum seems to have swung too far such that in today's training environment residents have less tenacity to get to the OR.

Despite one's preferred learning style, ideal learning incorporates both active and passive modalities.[24,25] A reflection of both active and passive learning, observational experiences in surgical training are effective for a number of reasons. First, residents face a steep learning curve, with most interns entering training after having completed very few basic procedures as a medical student, let alone a robust OR experience.[26,27] Observing, assisting, and participating in the nonoperative aspects of an operation (e.g. patient positioning and prep, room setup, interpersonal communication with OR team, etc.) are critical to becoming an independent surgeon. Second, an understanding of how an operation should progress requires repeated exposure, allowing learners to observe cues from master surgeons. Third, developing the skill set of a quality assistant is imperative for all surgeons because assisting requires a trainee to understand the steps of an operation, maneuvers to improve exposure, and techniques to aid the surgeon in operating.[28]

Prior analyses of residents' observational/assisting experiences in the OR are limited. Kairys et al. noted similar decrements in the FA experience over a shorter timeframe.[29] Additionally, an analysis of the FA experience relative to the 2011 duty hour restriction (i.e. the 16-hour intern work limit) concluded that these diminishing experiences were likely a result of work hour limitations.[30] Duty hour restrictions may limit the cases residents choose to participate in, as well as influence their decision or ability to participate in cases "after hours." However, our data clearly demonstrate that these trends began well before duty hour restrictions came into effect in 2004.[31] When, exactly, the experience in FA cases began is not clear. The number *appears* to have already been in steep decline when ACGME began collecting case log data in 1989 to 1990. Nevertheless, our regression model analysis demonstrated that, beginning in 1989 to 1990, FA cases decreased at a decreasing rate over time and appeared to have reached a "floor" around 2010. Our time-period analysis demonstrates that the largest decrements were seen for the domains of large intestine, breast, hernia, biliary, trauma, and thoracic, whereas the other domains experienced smaller declines (as a result of residents in the early era having less operative volume in the areas to begin with). This suggests that while there were global decreases in all domains, loss of select cases largely contributed to the FA decline. While reassuring that the overall decrease appears to have halted, the absolute decrease from years past remains problematic.

As surgical residents progress through residency and spend countless hours honing their skills in the OR, the TA experience serves as the pinnacle of training. TA experiences allow a trainee to draw upon years of stored procedural memories, and the resulting recall of lessons learned facilitates the transition of knowledge from short-term, working memory to long-term, procedural memory.[32] As with FA cases, we cannot discern from available data when the decline in TA cases actually began. That number *appears* to have been in decline when case log data collection began in 1989 to 1990. However, the declining TA volume of 38 cases between period 1 and period 2 is deeply concerning. In response to this, and to highlight the importance of TA cases, the ABS enacted several changes. In 2008, residents were allowed to count up to 50 TA cases toward their total number of cases and in 2013, it was announced that the minimum number of TA cases would be set at 25 beginning with graduates of 2018. the minimum number of TA cases would be 25.[20] These efforts appear to have halted the steep decline in the TA experience given that period 3 saw a small, though not statistically significant, increase in TA cases, and our regression model identified 2008 as a "breakpoint" in which the trend in TA cases reversed. The domains responsible for this shift appear to be core general surgery areas of large intestine, biliary, and hernia. Nonetheless, with a median of 29 TA cases for today's residents, there remains concern as to whether all residents can meet this minimum requirement and efforts to continue to encourage educators to maximize TA opportunities are needed. Unfortunately, our analysis cannot address on a granular level why this TA deficiency occurred, but we propose 3 potential explanations. First, while TA cases count toward the 850 total major case requirement, they do not count toward the 250 surgeon chief case requirement.[20] Therefore, chief residents may not be performing TA cases (or are instead logging them as surgeon chief) in order to meet this requirement.

Second, there may not be enough residents to teach because junior residents are pulled elsewhere to cover cases or perform nonoperative patient care activities, leaving chiefs without someone to take through the case. Third, and most concerningly, chief residents may simply not be receiving opportunities from faculty to teach coresidents.

Our compositional analysis identified select domains that have been most impacted by the decreasing TA experience. For the majority of operative domains, general surgery residents have, in large part, never had a robust teaching experience. Because general surgery residents have the largest exposure to the core domains of abdomen and alimentary tract, it is not surprising that these serve as the most frequent stage for TA cases. However, the majority of subcategories within these domains were associated with decreased experiences, with today's residents primarily functioning as TA for large intestine and biliary cases. It is important to note that laparoscopic appendectomy and cholecystectomy fall within these subcategories, respectively, and are likely the predominant cases residents are offered to TA. This should be viewed positively since these are common operations performed by general surgeons; however, it raises the question of whether senior residents have opportunities to take less experienced residents through more complex or open operations.

There are many benefits to a senior resident performing TA cases. As TA, residents serve as the lead surgeon and have the opportunity to develop effective communication skills with their trainee surgeon, as well as members of the nursing and anesthesia teams, which is paramount to ensuring quality outcomes in high-acuity medical situations.[33] Moreover, "to teach is to learn twice"—there is a depth of learning that occurs during a near-peer teaching experience. An important learning experience occurs when a resident has the opportunity to discover what he or she doesn't know about an operation while serving as a TA in a protected environment. Finally, the TA role is arguably the opportune time and place for attending surgeons to provide residents meaningful intraoperative assessments. Evaluation of a resident who is teaching a peer is more informative and holistic than simply receiving feedback from a scrubbed attending during variable portions of an operation. This more closely approaches the ideals of surgical coaching, which have a positive impact on surgical trainees.[34] Obvious benefits notwithstanding, there are no policies in place to protect the experience of residents operating autonomously. Initiatives such as improving faculty development to achieve better assessment of resident skills, educating hospital administrators and the public on graduated responsibility, and revising program policies are important to training tomorrow's surgeons and preserving the profession of surgery.[4]

There are several limitations to our study. First, it is retrospective and relies on self-reported data logged by residents. Second, analysis of case logs is subject to heterogeneity resulting from systems-based changes in the case log system, including the transition to online reporting, permitting 2 residents to log different portions of the same operation, and changes to procedure codes tracked by the ACGME. Third, some have raised concern that case logs may not reflect the actual surgical resident operative experience.[35] Recent work, however, suggests that case log variation likely does not result from case logging behavior alone, but in fact reflects true interresident variability.[36] There may also be inaccuracies or inconsistencies among residents regarding their perceptions of their surgeon role. Data as to whether residents accurately describe their role in the OR is conflicting. It has been shown that residents and faculty disagree on the resident role, with residents often thinking they performed more of the case.[37] Conversely, another study suggested that residents actually underestimate their contribution to operations.[38] Finally, the ACGME case logs represent aggregate national data and do not contain resident or program-level information. Consequently, we cannot account for individual and institutional factors that may impact operative experience. The aggregate graduate data also does not provide operative volume segregated by PGY year, and therefore, we are unable to identify when during the 5 clinical years of training the FA shifts occurred. As for TA cases, these can only be counted on chief rotations (which occur during one's PGY-4 or PGY-5 year), so the drop in these numbers represent a narrower time frame.

CONCLUSION

General surgery residents in today's training environment have a much weaker operative experience as nonprimary surgeon than ever before. Our analysis provides concrete evidence for the anecdotal phenomenon that residents today double scrub less often, resulting in fewer FA and TA cases compared to graduates of years past. More concerningly, these diminishing experiences are most notable within the core general surgery domains of abdomen and alimentary tract. Although simulation-based learning has emerged in the modern era, these techniques serve to improve the efficiency and efficacy of procedural learning, not replace it, and are predicated on the concept that being in the OR is vital, whether as a primary or nonprimary surgeon. Consequently, we advocate that programs examine this trend internally for monitoring of trainee progress and increasing operative experiences as

nonprimary surgeon. Future work is needed to determine the association between diminishing FA and TA experiences and a graduate's ability to function as a capable and independent surgeon.

REFERENCES

1. 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. https://doi.org/10.1056/NEJMp1315408.
2. Bell RH. Jr., Banker MB, Rhodes RS, Biester TW, Lewis FR. Graduate medical education in surgery in the United States. *Surg Clin North Am*. 2007;87:811–823. https://doi.org/10.1016/j.suc.2007.06.005. v-vi.
3. Potts JR. 3rd. Shifting sands of surgical education. *J Am Coll Surg*. 2018;227:151–162. https://doi.org/10.1016/j.jamcollsurg.2018.02.012.
4. Potts JR. 3rd. You can't blame the wreck on the train. *Am J Surg*. 2017;214:974–978. https://doi.org/10.1016/j.amjsurg.2016.11.046.
5. McKenna DT, Mattar SG. What is wrong with the training of general surgery? *Adv Surg*. 2014;48:201–210. https://doi.org/10.1016/j.yasu.2014.05.010.
6. Stefanidis D, Sevdalis N, Paige J, et al. Simulation in surgery: what's needed next? *Ann Surg*. 2015;261:846–853. https://doi.org/10.1097/SLA.0000000000000826.
7. Hanks JB. Simulation in surgical education: influences of and opportunities for the southern surgical association. *J Am Coll Surg*. 2019;228:317–328. https://doi.org/10.1016/j.jamcollsurg.2018.12.029.
8. Dutta S, Gaba D, Krummel TM. To simulate or not to simulate: what is the question? *Ann Surg*. 2006;243:301–303. https://doi.org/10.1097/01.sla.0000200853.69108.6d.
9. Bell RH. Jr. Why Johnny cannot operate. *Surgery*. 2009;146:533–542. https://doi.org/10.1016/j.surg.2009.06.044.
10. Eberlein TJ. A new paradigm in surgical training. *J Am Coll Surg*. 2014;218:511–518. https://doi.org/10.1016/j.jamcollsurg.2013.12.045.
11. Drake FT, Aarabi S, Garland BT, et al. Accreditation council for graduate medical education (ACGME) surgery resident operative logs: the last quarter century. *Ann Surg*. 2017;265:923–929. https://doi.org/10.1097/SLA.0000000000001738.
12. Drake FT, Horvath KD, Goldin AB, Gow KW. The general surgery chief resident operative experience: 23 years of national ACGME case logs. *JAMA Surg*. 2013;148:841–847. https://doi.org/10.1001/jamasurg.2013.2919.
13. Cortez AR, Katsaros GD, Dhar VK, et al. Narrowing of the surgical resident operative experience: a 27-year analysis of national ACGME case logs. *Surgery*. 2018;164:577–582. https://doi.org/10.1016/j.surg.2018.04.037.
14. Kieu V, Stroud L, Huang P, et al. The operating theatre as classroom: a qualitative study of learning and teaching surgical competencies. *Educ Health (Abingdon)*. 2015;28:22–28. https://doi.org/10.4103/1357-6283.161845.
15. Ziv A, Wolpe PR, Small SD, Glick S. Simulation-based medical education: an ethical imperative. *Acad Med*. 2003;78:783–788.
16. Zevin B, Aggarwal R, Grantcharov TP. Surgical simulation in 2013: why is it still not the standard in surgical training? *J Am Coll Surg*. 2014;218:294–301. https://doi.org/10.1016/j.jamcollsurg.2013.09.016.
17. DaRosa DA, Zwischenberger JB, Meyerson SL, et al. A theory-based model for teaching and assessing residents in the operating room. *J Surg Educ*. 2013;70:24–30. https://doi.org/10.1016/j.jsurg.2012.07.007.
18. Bohnen JD, George BC, Williams RG, et al. The feasibility of real-time intraoperative performance assessment with SIMPL (system for improving and measuring procedural learning): early experience from a multi-institutional trial. *J Surg Educ*. 2016;73:e118–e130. https://doi.org/10.1016/j.jsurg.2016.08.010.
19. Accreditation Council for Graduate Medical Education. Graduate Case Log Requirements. 2018. https://www.acgme.org/Portals/0/DefinedCategoryMinimumNumbersforGeneralSurgeryResidentsandCreditRole.pdf. Accessed 6 February 2019.
20. American Board of Surgery. Booklet of Information - Surgery. 2018. http://www.absurgery.org/xfer/BookletofInfo-Surgery.pdf. Accessed 6 February 2019.
21. de Montbrun SL, Macrae H. Simulation in surgical education. *Clin Colon Rectal Surg*. 2012;25:156–165. https://doi.org/10.1055/s-0032-1322553.
22. Johal J, Dodd A. Physician extenders on surgical services: a systematic review. *Can J Surg*. 2017;60:172–178.

23. Kang R, Columbo JA, Kunkel ST, et al. Residents' impressions of the impact of advanced practice providers on surgical training. *J Am Coll Surg*. 2018;226:1036–1043. https://doi.org/10.1016/j.jamcollsurg.2017.11.019.

24. Kolb DA. Experiential Learning: Experience as the Source of Learning and Development. Englewood Cliffs, NJ: Prentice Hall; 1984.

25. Kolb DA, Boyatzis RE, Mainemelis C. Experiential learning theory: previous research and new directions. In: Sternberg RJ, Zhang LF, eds. Perspectives on Cognitive, Learning, and Thinking Styles, NJ: Lawrence Erlabaum; 2000.

26. Nakayama DK, Steiber A. Surgery interns' experience with surgical procedures as medical students. *Am J Surg*. 1990;159:341–343. discussion 4.

27. Lazaro EJ, Rush BF. Jr., Blackwood JM, Swaminathan AP. Assessment of student experiences in technical procedures in surgical clerkship. *Can J Surg*. 1978;21:540–541.

28. Chiu A, Bowne WB, Sookraj KA, Zenilman ME, Fingerhut A, Ferzli GS. The role of the assistant in laparoscopic surgery: important considerations for the apprentice-in-training. *Surg Innov*. 2008;15:229–236. https://doi.org/10.1177/1553350608323061.

29. Kairys JC, McGuire K, Crawford AG, Yeo CJ. Cumulative operative experience is decreasing during general surgery residency: a worrisome trend for surgical trainees? *J Am Coll Surg*. 2008;206:804–811. https://doi.org/10.1016/j.jamcollsurg.2007.12.055. discussion 11-3.

30. Schwartz SI, Galante J, Kaji A, et al. Effect of the 16-hour work limit on general surgery intern operative case volume: a multi-institutional study. *JAMA Ssurgery*. 2013;148:829–833. https://doi.org/10.1001/jamasurg.2013.2677.

31. Accreditation Council for Graduate Medical Education. Common Program Requirements (Residency). 2004. https://www.acgme.org/Portals/0/PFAssets/ProgramRequirements/CPRResidency2019-TCC.pdf. Accessed 25 February 2019.

32. Kavic MS. Teaching and learning of surgery. *JSLS*. 2012;16:341–344. https://doi.org/10.4293/108680812X13427982376103.

33. Sundar E, Sundar S, Pawlowski J, Blum R, Feinstein D, Pratt S. Crew resource management and team training. *Anesthesiol Clin*. 2007;25:283–300. https://doi.org/10.1016/j.anclin.2007.03.011.

34. Min H, Morales DR, Orgill D, Smink DS, Yule S. Systematic review of coaching to enhance surgeons' operative performance. *Surgery*. 2015;158:1168–1191. https://doi.org/10.1016/j.surg.2015.03.007.

35. Naik ND, Abbott EF, Aho JM, et al. The ACGME case log system may not accurately represent operative experience among general surgery interns. *J Surg Educ*. 2017. https://doi.org/10.1016/j.jsurg.2017.09.032.

36. Cairo SB, Craig W, Gutheil C, et al. Quantitative analysis of surgical residency reform: using case-logs to evaluate resident experience. *J Surg Educ*. 2019;76:25–35. https://doi.org/10.1016/j.jsurg.2018.05.013.

37. Perone JA, Fankhauser GT, Adhikari D, et al. Who did the case? Perceptions on resident operative participation. *Am J Surg*. 2017;213:821–826. https://doi.org/10.1016/j.amjsurg.2016.11.002.

38. Morgan R, Kauffman DF, Doherty G, Sachs T. Resident and attending perceptions of resident involvement: an analysis of ACGME reporting guidelines. *J Surg Educ*. 2017;74:415–422. https://doi.org/10.1016/j.jsurg.2016.10.012.