Trends in Routine and Complex Hepatobiliary Surgery Among General and Pediatric Surgical Residents: What is the Next Generation Learning and is it Enough?

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OBJECTIVE: Previous studies reveal a correlation between surgical volume and outcomes; thus, a similar relationship likely exists between trainee operative volume and technical competence. While routine hepatobiliary surgery is commonplace, trainee exposure to the more advanced procedures may be lacking. We hypothesize that experience in complex hepatobiliary procedures may be deficient both during general surgery residency and pediatric surgery fellowship training.

DESIGN: Case log data from the ACGME were queried for general surgery residents (2000-2017) and pediatric surgery fellows (2004-2017). Laparoscopic cholecystectomy was considered a routine hepatobiliary procedure for both specialties. For general surgery, hepatic lobectomy/segmentectomy and choledochoenteric anastomosis were considered complex and for pediatric surgery, hepatic lobectomy, biliary atresia and choledochal cyst procedures were considered complex.

SETTING: Publicly available case log data from the ACGME.

PARTICIPANTS: General surgery residents and pediatric surgery fellows at ACGME-accredited training programs.

RESULTS: The number of trainees increased over the study period for both groups. Mean case volumes for laparoscopic cholecystectomy increased by 36% in surgery graduates and by 114% in pediatric surgery graduates. In surgery, the mean volumes for choledochoenteric anastomosis procedures decreased by 53% from 3.0 to 1.4 procedures/year with increasing variability in trainee experience. Volumes for hepatic lobectomy/segmentectomy increased by 68% from 3.4 to 5.7 procedures/year with decreasing variability. In pediatric surgery, case volumes for complex procedures were low (mean <4/year), highly variable among trainees, and appear unchanged between 2004 and 2017. In every year analyzed, at least 1 pediatric surgery trainee reported doing 0 cases in one of these complex categories.

CONCLUSIONS: Case logs suggest that the volume of complex hepatobiliary surgery remains low and highly variable in both disciplines with some trainees obtaining minimal or no exposure to certain cases. The relationship between these trends and the development of competency is worthy of further study. (J Surg Ed 76:1005−1014. © 2019 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Hepatobiliary, Pediatric surgery, Training, Education, Case log, Operative experience

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

INTRODUCTION

The pediatric surgical workforce has undergone an evolution since the endorsement of specialized education in the care of neonates, infants, and children by the American Board of Surgery in the 1970s. While the population of pediatric surgeons has steadily increased since this time, the concern for the over-production of pediatric surgeons is not a novel concept. In his American Pediatric Surgical Association Presidential Address in 1976, Holder[1] warned his colleagues of the imminent danger of over-producing pediatric surgeons and aptly stated that "a significant increase in the

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number of pediatric surgeons will result in a decrease in continued experience in the care of the less common conditions which are often the ones requiring the greatest skills."

The overarching notion behind the challenges foretold by Holder is a matter of practice and expertise. Based on rigorous research and experiments, Ericsson[2] famously forged the theory that "experts are always made, not born." To acquire expertise, he makes a particular emphasis on the importance of "deliberate practice," which entails considerable, specific, and sustained efforts to do something one cannot initially do well. Gladwell[3] further distilled this concept to advise that expertise requires at least 10,000 hours of deliberate practice.

In the world of surgical expertise, or even competency, practice parallels case volume. Volume-outcome relationships in surgery have been studied extensively and evidence for the trend between better outcomes with higher case volume has been presented for essentially all specialties including hepatopancreaticobiliary (HPB), endocrine, cardiovascular, orthopedic, neurological, and oncologic surgery.[4-11]

Commonly described as the "last bastion of the true general surgeon," the field of pediatric surgery is characterized by less sub-specialization when compared to the management of adult surgical diseases. This poses further challenges to gaining surgical expertise for rare "index" cases due to the wide range of uncommon and complex congenital anomalies and childhood surgical diseases, such as those of the liver and biliary tract. In an era where up to 80% of general surgery graduates are pursuing fellowships[12-14] it is paramount that the five-year general surgery training prepares residents for subspecialty fellowships, which rely heavily on a pipeline of well-trained general surgeons. While fellowship training in disciplines that are focused to 1 or even 2 organ systems with a narrower breadth of procedures may not require previous broad-based training in their general surgery candidates, others do benefit significantly from a trainee that has been previously exposed to complex dissections and reconstructions.

In this study, we aim to assess the trends in routine and complex hepatobiliary training experiences during general surgery residency and pediatric surgery fellowship. In particular, we hypothesize that experience in complex hepatobiliary index procedures is lacking both in the preparation of the general surgery resident and during the subsequent pediatric surgery fellowship.

METHODS

Data Acquisition

Publicly available case log data from the Accreditation Council for Graduate Medical Education (ACGME) were queried.[15] Data were available from academic year (AY) 1999-2000 to AY 2016-2017 for general surgery case logs and from AY 2003-2004 to AY 2016-2017 for pediatric surgery case logs. Laparoscopic cholecystectomy was considered a routine hepatobiliary procedure for both specialties. For general surgery case logs, hepatic lobectomy/segmentectomy (any indication) and choledochoenteric anastomosis were considered complex and for pediatric surgery, hepatic lobectomy (for tumor), biliary atresia, and choledochal cyst procedures were considered complex. For general surgery case logs, the total number of cases performed as operating surgeon (both as Surgeon Chief and Surgeon Junior) was chosen. For pediatric surgery case logs, only cases performed as the primary operation were chosen. Assistant cases were excluded and were unusual.

To assess whether the rise in specialty training in HPB surgery may be temporally associated with trends in case volumes, the number of HPB fellowships was ascertained. A publicly available Directory of Fellowships was queried from The Fellowship Council.[16]

Statistical Analysis

Mean, standard deviation, median, mode, maximum, and minimum case numbers were identified when available. Data were summarized into graphs using GraphPad Prism version 7.0a for MAC OS X (Graphpad Software, La Jolla, CA). The change in the number of trainees was analyzed using Poisson regression for count data, with linear and polynomial effects for time. The coefficient of variation (CV) was calculated as a ratio of the standard deviation to the mean and expressed as a percentage. CV is a simple measure of relative variation and is particularly useful when comparing dispersion of data points when the means are drastically different, as in our study. Significance was assumed when $p < 0.05$.

RESULTS

Statistical reports from the Accreditation Council for Graduate Medical Education general surgery and pediatric surgery case logs are summarized in Tables 1 and 2. The number of general surgery trainees significantly increased over the years, with a faster upward trend starting in 2010 ($p = 0.002$). The number of pediatric surgical trainees exhibited a significant linear increase over time ($p = 0.0001$). In particular, there was a 22% increase (989-1211) in general surgery trainees from 2000 to 2017 (Fig. 1A) and 88% increase (24-45) in pediatric surgery trainees from 2004 to 2017 (Fig. 1B).

The mean number of laparoscopic cholecystectomy cases performed per resident increased over the study period for both groups with a 36% increase (84-114.1) in

TABLE 1. Summary of General Surgery Routine and Complex Hepatobiliary ACGME Case Logs

	Laparoscopic Cholecystectomy				Choledochoenteric Anastomosis				Liver Lobectomy/Segmentectomy			
	Mean	Max	SD	CV	Mean	Max	SD	CV	Mean	Max	SD	CV
2000	84	254	36	42.9	3	26	3	100	3.4	35	4	117.6
2001	86.4	263	37	42.8	3	18	2	66.7	3.5	28	4	114.3
2002	90.2	298	39	43.2	2.9	19	3	103.4	3.6	34	4	111.1
2003	91	288	40	44	2.7	17	2	74.1	3.7	30	4	108.1
2004	90.5	312	37	40.9	2.6	19	2	76.9	4.1	27	4	97.6
2005	100.6	397	40.5	40.3	2.6	25	2.6	100	3.9	38	4	102.6
2006	101.5	278	37.1	36.6	2.4	12	2.3	95.8	4.2	34	4.3	102.4
2007	103.1	312	38	36.9	2.3	16	2	87	4.5	30	4	88.9
2008	103.9	254	37	35.6	2.2	17	2	90.9	4.7	26	4	85.1
2009	106.7	242	37	34.7	2.2	27	2	90.9	5.2	35	5	96.2
2010	101.1	281	38	37.6	2	11	2	100	5.1	26	5	98
2011	105.7	278	40	37.8	2	22	2	100	5.1	108	5	98
2012	108.8	291	41	37.7	1.8	12	2	111.1	5.1	36	4	78.4
2013	110.3	309	42	38.1	1.8	14	2	111.1	5.2	28	4	76.9
2014	112	282	41	36.6	1.6	14	2	125	5.3	27	4	75.5
2015	109	340	40	36.7	1.6	22	2	125	5.5	39	5	90.9
2016	109.4	314	40	36.6	1.5	14	2	133.3	5.6	32	5	89.3
2017	114.1	312	42	36.8	1.4	11	2	142.9	5.7	42	5	87.7

the general surgery group and 114% increase (11.8-25.3) in the pediatric surgery group (Figs. 2A and 3A). The trends for complex hepatobiliary cases were variable in the general surgery group; the mean volumes for choledochoenteric anastomosis procedures decreased by 53% from 3.0 to 1.4 procedures per year between 2000 and 2017 while volumes for hepatic lobectomy/segmentectomy increased by 68% from 3.4 to 5.7 procedures per year (Fig. 2B and C). In pediatric surgery, mean case volumes for complex hepatobiliary procedures were low, highly variable among trainees and overall appear unchanged between 2004 and 2017 (Fig. 3B-D). In every year examined, at least 1 trainee reported doing 0 cases in one of these complex categories during the entire 2-year pediatric surgery training program (Table 2).

CV was calculated to compare the relative variation of caseloads across different operations (Fig. 4). Laparoscopic cholecystectomy had the lowest CV for both groups and variation remained steady over the study period. In general surgery, there was an uptrend in the CV for choledochoenteric anastomosis and a downtrend in the CV for liver lobectomy/segmentectomy. In pediatric surgery, the CV for biliary atresia, choledochal cyst excision, and liver lobectomy were higher than that of laparoscopic cholecystectomy and varied from year to year without an apparent trend.

The number of accredited HPB fellowship programs in the U.S. and Canada remained low and with little change from 1985 to 2004 (increased from 2-4 programs over a 20-year period) then increased to 17 programs in the subsequent 8 years (Fig. 5). There are currently 17 HPB fellowship programs in North America.

DISCUSSION

In this study, we tested the hypothesis that training in complex hepatobiliary operations may be lacking both during general surgery residency and subsequent pediatric surgery fellowship. We demonstrate that while the number of pediatric surgery trainees continues to rise, the number of complex hepatobiliary cases remains unchanged with generally low numbers and high variability among trainees. Most concerningly, in every complex category, the minimum number of cases reported was 0. A concurrent assessment of the experience of general surgery trainees, some of whom would eventually enter a pediatric surgical residency, also revealed low volumes of complex hepatobiliary operations performed during general surgery residency. Mean volume of choledochoenteric anastomosis, a complex biliary reconstruction operation, decreased by half from an already low number, with a corresponding uptrend in the CV indicating that the variation between trainees is increasing. In an attempt to explain this, we identified an increase in the number of HPB fellowship programs over the study period, which may account, at least in part, for the diminishing number of complex hepatobiliary cases experienced by general surgery trainees.

TABLE 2. Summary of Pediatric Surgery Routine and Complex Hepatobiliary ACGME Case Logs

	Laparoscopic Cholecystectomy					Biliary Atresia					Choledochal Cyst					Liver Lobectomy				
	Mean	Med	Range	SD	CV	Mean	Med	Range	SD	CV	Mean	Med	Range	SD	CV	Mean	Med	Range	SD	CV
2004	11.8	-	26 max	6	50.8	3.7	-	9 max	3	81.1	2.6	-	11 max	3	115.4	2.6	-	10 max	3	115.4
2005	12.1	-	31 max	7	57.9	2.9	-	7 max	2	69	2.5	-	6 max	1	40	2.5	-	6 max	2	80
2006	14.9	-	39 max	8	53.7	3.4	-	8 max	2	58.8	2.7	-	8 max	2	74.1	3.5	-	10 max	3	85.7
2007	15.6	-	35 max	8	51.3	4	-	9 max	3	75	2.4	-	8 max	2	83.3	2.8	-	12 max	3	107.1
2008	15.5	16	3-29	7	45.2	3.7	4	0-9	2	54.1	2.5	2	0-7	2	80	2.8	2	0-9	2	71.4
2009	18.8	19	4-43	9	47.9	3.7	3	0-10	3	81.1	3	3	0-9	2	66.7	3.3	2	0-12	3	90.9
2010	22.3	21	6-54	11	49.3	2.4	2	0-8	2	83.3	2.7	2	0-9	2	74.1	3.5	3	0-12	3	85.7
2011	20.6	20	5-45	9	43.7	3.2	3	0-10	3	93.8	2.9	2	0-9	2	69	3.4	2	0-14	3	88.2
2012	23.5	21	4-51	12	51.1	3.8	4	0-8	3	78.9	2.6	3	0-6	2	76.9	3.3	3	0-17	3	90.9
2013	23.2	20	8-48	11	47.4	3.3	3	0-13	3	90.9	2.7	2	0-7	2	74.1	2.9	2	0-12	3	103.4
2014	26.5	23	9-59	12	45.3	3.3	3	0-10	3	90.9	2.4	2	0-7	2	83.3	3.1	2	0-17	3	96.8
2015	23.7	23	9-61	11	46.4	3.8	4	0-12	3	78.9	2.8	3	0-9	2	71.4	3.3	3	0-13	3	90.9
2016	27.7	25	6-61	14	50.5	3.6	3	0-11	2	55.6	2.5	2	0-7	2	80	3.4	3	0-12	3	88.2
2017	25.3	27	5-54	11	43.5	3.4	3	0-10	3	88.2	2.8	2	0-8	2	71.4	3.1	2	0-17	4	129

In contrast, we observed increasing trends for the volume of laparoscopic cholecystectomy, a routine hepatobiliary case, performed in both groups over time. The reason for this is multifactorial and in part likely due to the increasing incidence of gallbladder disease in the pediatric population associated with the rise in pediatric and adolescent obesity,[17] advancement and increased use of diagnostic imaging[18] and evolving indications for the operation, such as for biliary dyskinesia.[19] Mean numbers of hepatic lobectomy/segmentectomy cases, a complex hepatobiliary operation, performed by general surgery residents also exhibited an uptrend over time, possibly attributed to the broadened indications for liver resection for metastatic disease.[20,21]

The field of pediatric surgery may be changing due to the disproportionately increasing number of trained pediatric surgeons compared to the pediatric population, leading to the dilution of complex caseloads performed per surgeon.[22,23] It has been 40 years since Dr. Holder's presidential address and his words are still echoed in the pediatric surgical literature today. A recent study analyzing the supply and demand of pediatric surgeons projected that by the year 2030, there would be a 21% to 45% increase in the number of pediatric surgeons, based on the range of historical highs and lows of entry into pediatric surgery fellowships, compared to only a 9% increase in the pediatric population.[24]

The growing disparity between supply and demand poses challenges for both gaining competency and maintaining proficiency in complex cases. In a study of the operative trends of pediatric surgery trainees, Fingeret et al.[25] reported a 42% increase in the number of trainees from 2003 to 2010. While overall case volume remained unchanged, they found an increasing positive skew of the mean case volumes over time suggesting increasing variability in trainees' experience. In addition, for many of the "select important pediatric cases," the mode was significantly less than the mean volume and reached 0 for nearly half, consistent with our findings for complex hepatobiliary cases in the pediatric surgery cohort. Gow et al.[26] performed a similar study examining pediatric surgery caseloads for general surgery residents over a 22-year period. They found a steady drop in the case volume over the study period with a persistent rightward skew of case distributions, indicating that most residents performed fewer cases than the mean, while a relatively small group of residents performed a very large number of cases.

The variability seen in operative experience may represent some degree of regionalization that already exists, a strategy advocated by some as a means to improve outcomes in uncommon and complex cases.[27,28] The idea of regionalization was first catalyzed by a landmark paper published in 1979 by Luft et al.[29] Here the authors

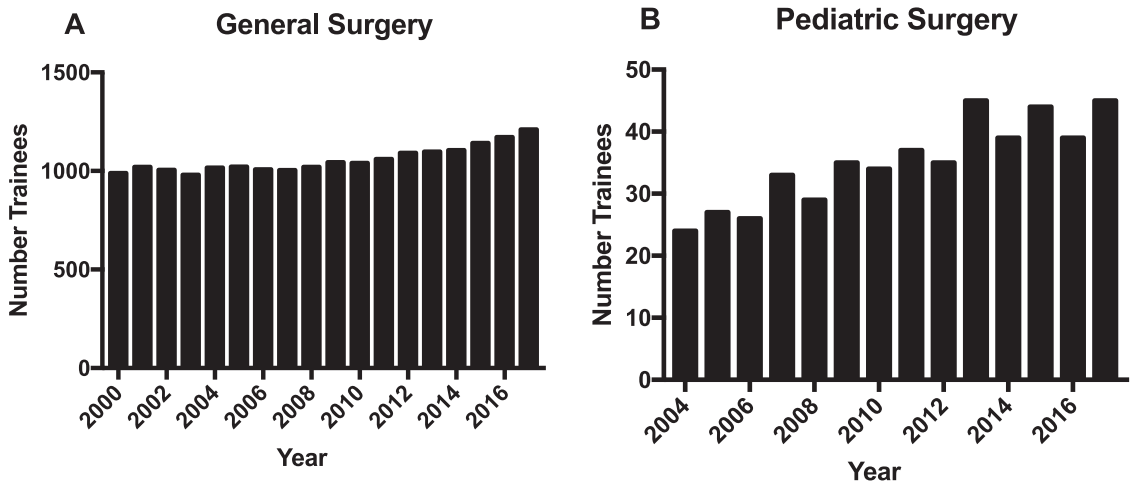

FIGURE 1. Number of (A) general surgery and (B) pediatric surgery trainees over time.

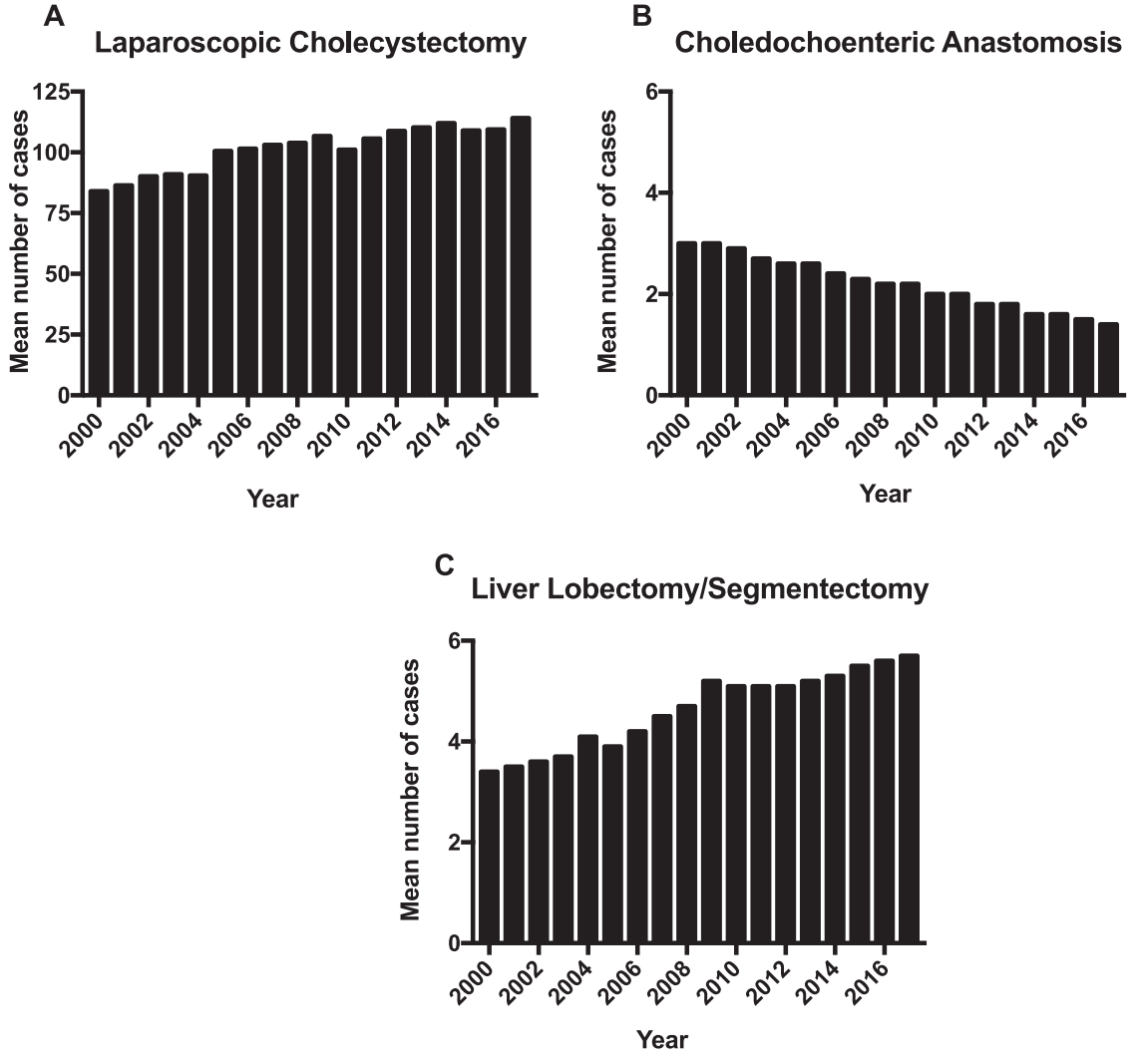

FIGURE 2. Mean number of routine (A, laparoscopic cholecystectomy) and complex (B, choledochoenteric anastomosis and C, liver lobectomy/segmentectomy) hepatobiliary cases performed by general surgery trainees over time.

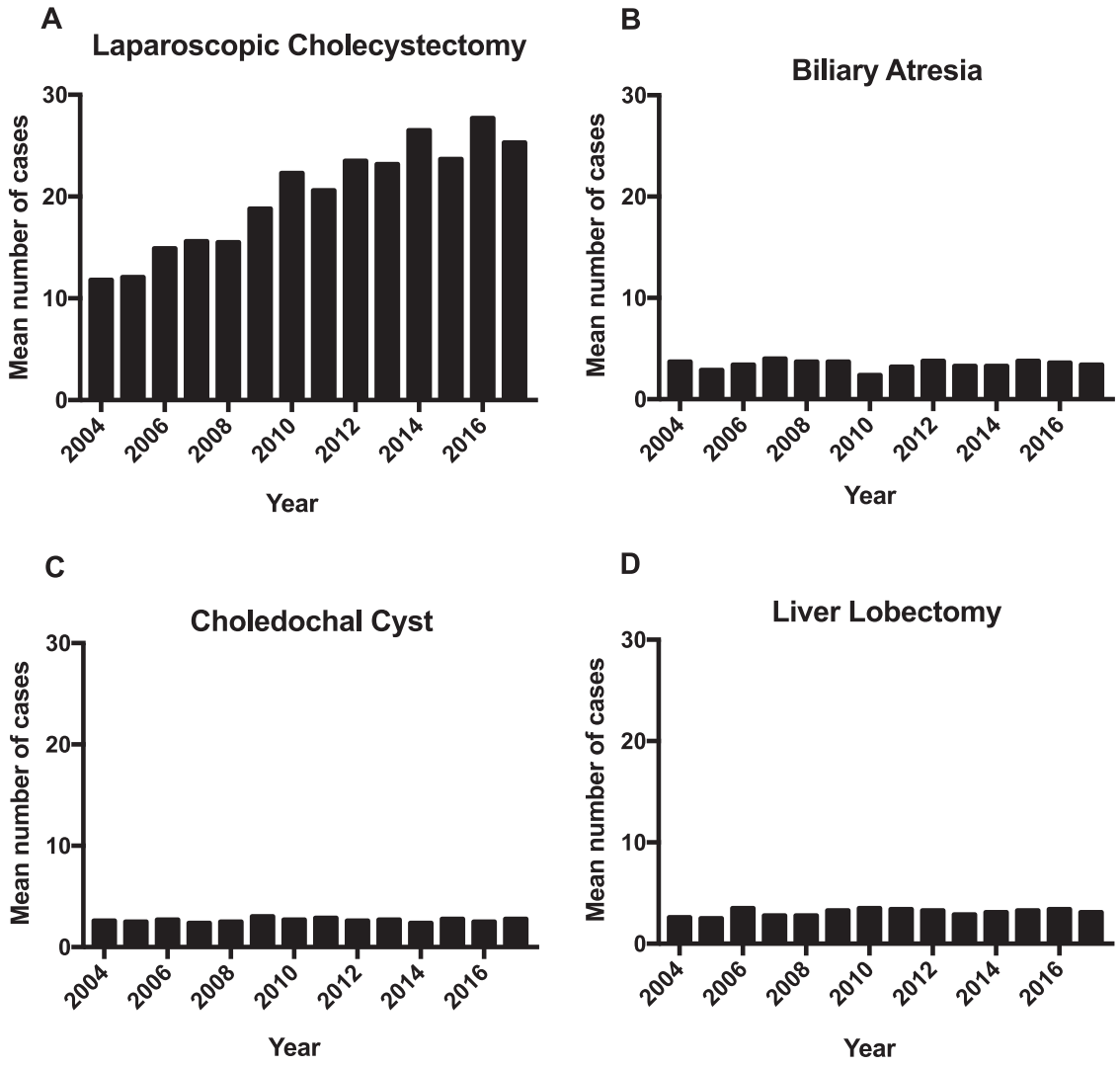

FIGURE 3. Mean number of routine (A, laparoscopic cholecystectomy) and complex (B, biliary atresia; C, choledochal cyst; D, liver lobectomy/segmentectomy) hepatobiliary cases performed by pediatric surgery trainees over time.

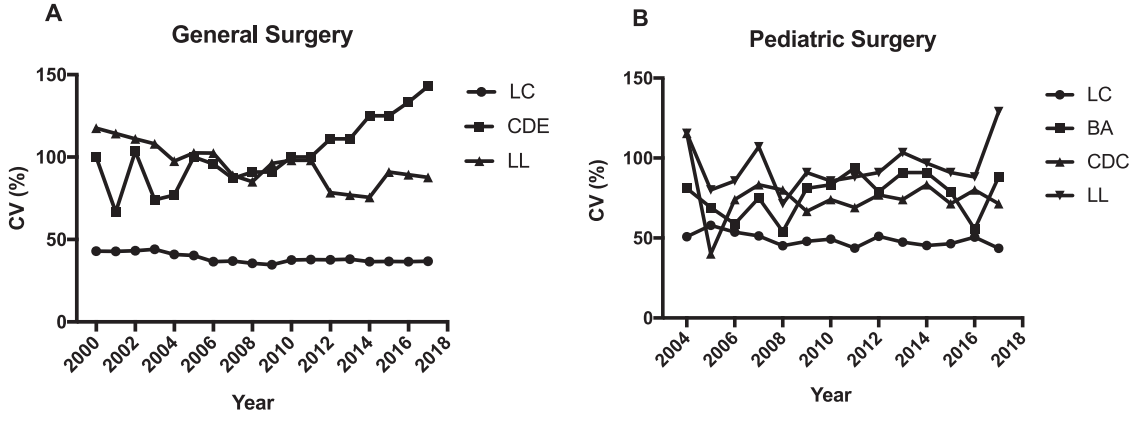

FIGURE 4. Plotted coefficient of variation of routine and complex hepatobiliary cases performed by (A) general surgery and (B) pediatric surgery trainees over time (LC, laparoscopic cholecystectomy; CDE, choledochoenteric anastomosis; LL, liver lobectomy; BA, biliary atresia; CDC, choledochal cyst).

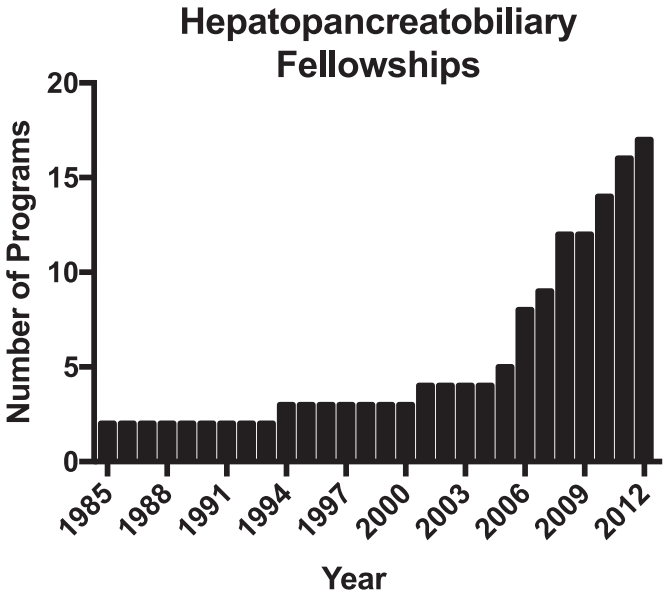

FIGURE 5. Number of accredited (U.S. and Canada) HPB fellowship programs over time.

provided novel evidence of an inverse relationship between volume and surgical mortality for several procedures, which would become the impetus for ensuing surgical research in volume-outcomes relationships. While it is important to acknowledge that a variety of factors including operating teams, hospital resources, staffing, and patient selection may confound the relationship between volume and outcome, undeniably, operative skill sets require practice to gain and to maintain proficiency.

The Education and Training Committee for the International Hepato-Pancreato-Biliary Association[30] requires that each fellow participate in the critical portions of a minimum of 100 major hepatopancreatobiliary operations including 25 hepatic operations and 20 complex biliary operations. If pediatric surgeons are to be the specialists for congenital and childhood hepatobiliary surgical disease, similar standards could be expected; however, pediatric surgery trainees' experiences appear to fall short even when their experience as general surgery residents and pediatric surgery fellows are combined. Moreover, an examination of the general surgery resident experience revealed low and further diminishing volumes of complex biliary reconstructions, indicating that a trainee entering a fellowship in pediatric surgery may be ill-prepared for complex hepatobiliary operations and potentially without sufficient exposure to make up for the volume during fellowship training.

Several changes in practice at the level of the trainee and training institution may mitigate the negative impact of the imbalanced supply and demand for pediatric surgeons. General surgery residents entering subspecialties often seek out relevant cases during their senior years at the individual level; therefore, those planning a career in pediatric surgery would be prudent to seek out more experience in advanced hepatobiliary cases during their general surgery training period if possible. Such efforts may be further supported by the training institution as resources permit.

Since 2011, the American Board of Surgery has had a policy in place to allow greater flexibility in a general surgery resident's last 36 months of training, allowing up to 12 months to be customized by the program director. This allows for earlier specialty training and early findings reported by the 9 participating programs of the Flexibility in Surgical Training Research Consortium are positive.[31] These practices may be limited in smaller programs due to logistics in service coverage and lack of affiliation with tertiary centers, and should not be mandated but rather individualized to each aspiring pediatric surgeon. Adjunctively, simulation-based training has been shown to be an effective learning method. A systematic review examining 34 studies, including 27 randomized control trials encompassing a wide range of procedures, provided strong evidence that subjects who participated and reached proficiency in simulation-based training performed better in patient-based settings than their counterparts.[32]

In contrast to adult studies, data advocating for centralization of the surgical care of children is lacking. A systematic review by McAteer et al.,[33] while highlighting some studies that demonstrated positive associations between volume and outcome, reported that lack of robust data and variability in methodology precluded the authors from drawing any final conclusions. However, improved mortality rates at low-volume centers

after implementing a partnership model with high-volume centers have been reported in adult HPB literature,[34] and may be modified and applied to practicing pediatric surgeons in the form of a partnership with adult HPB surgeons for appropriate cases. Such system is implemented at our institution for pediatric thyroid operations.

This study has several important limitations. As a descriptive study based on public domain self-reported case logs, the accuracy of the results is limited by the reporting individuals. This limitation may be minimized in the current study by aggregating all results and analyzing overall trends rather than individual case logs; however, despite utilizing all available data from the online-based reporting system, the small sample size remains a limitation and warrants future studies with longer duration. Additionally, since the launch of the current online-based reporting system in 2001 there have been minor changes to case definitions and categories for roles played in the operation, which may result in inconsistency in reporting over time. It should also be mentioned that general surgery case logs encompass experience of all general surgery trainees. Therefore, findings extrapolated from these data do not specifically represent the experiences of trainees subsequently entering pediatric surgery fellowships and should be interpreted with caution.

CONCLUSIONS

The number of complex hepatobiliary procedures encountered by pediatric surgical trainees alone is likely insufficient to result in competency. While some exposure to complex hepatobiliary procedures exists during general surgery residency, trends shown in this study suggest this may be diminishing, specifically for biliary reconstruction. The combination of decreasing experience in complex hepatobiliary surgery during general surgery residency with the already low baseline numbers seen during pediatric surgical fellowship suggests that the overall experience of trainees finishing pediatric surgical training may be deficient. Therefore, changes in practice such as the recommendation for HPB electives for future pediatric surgery trainees and standardized curricula for simulation training must be considered.

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SUPPLEMENTARY INFORMATION

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jsurg.2019.02.007.