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Examining the impact of COVID-19 restrictions on the operative volumes of US general surgery residents

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ABSTRACT

Background: In March 2020, the COVID-19 virus global pandemic forced healthcare systems to institute regulations including the cancellation of elective surgical cases, which likely decreased resident operative experience. The objective of this study was to determine whether the COVID-19 pandemic affected operative experiences of US general surgery residents.

Methods: The operative experience of general surgery residents was examined nationally and locally. Aggregate Accreditation Council for Graduate Medical Education (ACGME) case logs for 2018 to 2019 (pre-COVID) and 2019 to 2020 (COVID) graduates were compared using national mean cumulative operative volume for total major and surgeon chief cases. Locally, ACGME case logs were used to analyze the operative experience among residents at a single, academic center. Average operative volumes per month per resident during peak COVID-19 quarantine months were compared with those the previous year.

Results: Compared with 2019 graduates, 2020 graduates completed 1.5% fewer total major cases (1055 ± 155 vs 1071 ± 150 , $P = .011$). This was most evident during chief year, with 8.4% fewer surgeon chief cases logged in 2020 compared with 2019 (264 ± 67 vs 289 ± 69 , $P < .001$). Institutional data revealed that during the peak of the pandemic, residents across all levels completed 42.5% fewer total major operations (12 ± 11 vs 20 ± 14 , $P < .001$). This effect was more pronounced among junior residents compared with senior and chief residents.

Conclusion: The COVID-19 pandemic was associated with decreased resident case volume. The ramifications of the COVID-19 pandemic for operative competency and autonomy should be carefully examined.

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Introduction

In early March of 2020, the World Health Organization declared the novel coronavirus disease (COVID-19) a pandemic.¹ By that time, several cases of COVID-19 had been diagnosed in the United States, and many large US cities became epicenters with a rapid increase in the volume of critically-ill patients. Major initiatives were undertaken to limit the spread of this virus within the

healthcare system. On March 13, 2020, the American College of Surgeons (ACS) recommended cancelling or rescheduling elective surgeries, while the Accreditation Council for Graduate Medical Education (ACGME) issued a statement recognizing that resident education could be negatively affected.^{2,3} Due to the pandemic and the resultant sudden, sharp decline in elective surgical cases, many surgical residencies across the country were forced to abruptly restructure surgical education.^{4,5}

Given the decrease in surgical case volume and the transition for many surgical residents away from the operating room during this time, concerns about surgical residents' operative experience and education emerged. However, the impact of reduced case volume on actual general surgery resident operative volume has not been directly studied. The aim of this study was to examine surgical

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residents' operative experiences during the COVID-19 pandemic to determine its impact on resident operative volume. We hypothesize that residents performed fewer operations in the setting of COVID-19 restrictions.

Methods

To evaluate the impact of COVID-19 quarantine policies on surgical resident operative experience on the national and local levels, 2 complementary methods were employed. Surgical residents at ACGME-accredited residencies maintain individual case logs to monitor operative experience during training. These case logs are accessible to the individual programs in real time for monitoring resident progress. Upon graduation, each resident's cumulative case log is submitted to the ACGME for program accreditation purposes. These logs are aggregated by the ACGME into publicly available annual reports containing summary statistics for each graduating class. Operations may be logged as surgeon junior, surgeon chief, or teaching assistant (TA) and the sum of these equals total major cases. Only chief residents may log cases as surgeon chief or TA such that for non-chiefs, total major cases parallels surgeon junior whereas for chiefs, surgeon chief and total major cases may differ depending on TA cases.⁶ No individual or program level data are provided within these national aggregate reports.

To study the impact on the national level, aggregate ACGME case logs were used. National mean operative volume was examined for total major and surgeon chief cases. Cumulative operative experience, which represents a graduating resident's entire clinical operative experience over their 5 or more years of training, was then compared between 2018–2019 (pre-COVID) and 2019–2020 (COVID) graduates by using total major cases. Surgeon chief cases, which can only be logged during a resident's chief year and therefore represents chief operative experience, were also examined between the same groups.

Next, to evaluate the impact of COVID-19 on a more granular level, the operative experience among residents at a single, academic tertiary care center (University of Cincinnati, Cincinnati, Ohio) was examined. ACGME operative case logs for general surgery residents from 2018 to 2020 were queried. Analysis was performed among all residents, as well as by residency level, for which residents were grouped into junior (R1–R2), senior (R3–R4), and chief (R5) cohorts. Case log data were aggregated from 31 residents in 2019 compared with 30 residents in 2020, which represented 100% of active residents for both years. Baseline demographics of these 2 groups are listed in Table 1.

In Ohio, Governor DeWine and the Ohio Department of Health declared a state of emergency on March 9, 2020, cancelled all elective procedures on March 15, and declared a stay-at-home order on March 22.^{7–9} At our center during the peak of the pandemic, residents alternated weeks on service with off-site learning to limit potential exposure and account for decreased operative volume. Based on these regulations and resultant residency structural changes, for the single-center analysis, resident average monthly operative volume was compared during the height of the COVID-19 quarantine (March, April, May) to the same time period of the previous year. To control for local confounders, we performed supplemental analyses to ensure neither seasonal nor temporal confounding in our approach. Seasonal variation was evaluated by comparing the resident operative volume in winter (December, January, February), spring (March, April, May) and summer (June, July, August) for the academic year of 2018–2019. Temporal variation was evaluated by comparing the resident operative experience in the winter of 2019 with winter 2020.

Table 1

University of Cincinnati resident demographic data during March to May of 2019 (pre-COVID) and March to May of 2020 (COVID)

	pre-COVID	COVID
All residents	31	30
Juniors	12	12
R1	6	6
R2	6	6
Seniors	13	12
R3	7	5
R4	6	7
Chief (R5)	6	6
Sex		
Female	14 (45%)	12 (40%)
Male	17 (55%)	18 (60%)

There were no statistical differences when comparing gender or number of residents per level ($P > .05$)

Statistical analyses were performed using the Student's t-test and one-way analysis of variance (ANOVA) for multiple comparisons. $P < .05$ was considered statistically significant. All statistical analyses were performed using JMP Pro Version 15.0 (SAS Institute, Cary, NC). This study was approved by the University of Cincinnati Institutional Review Board (2020-0803).

Results

National analysis

In 2019, 1,219 residents completed training at 249 US ACGME-accredited general surgery programs, and in 2020, 1,257 residents completed training at 256 programs. 2020 graduates completed 1.5% fewer total major cases throughout their residency compared with 2019 graduates (1055 ± 155 vs 1071 ± 150 , $P = .011$). Case numbers were similar between the 2 groups for all but 4 operative domains (biliary, hernia, miscellaneous endovascular, and vascular access), which were decreased for 2020 graduates (each $P < .05$). The decreased operative experience was magnified during the chief year, with 8.4% fewer total major cases as surgeon chief completed by 2020 graduates compared with 2019 graduates (264 ± 67 vs 289 ± 69 , $P < .001$) (Fig 1). Surgeon chief operative volume decreased for 15 operative domains for 2020 graduates compared with 2019

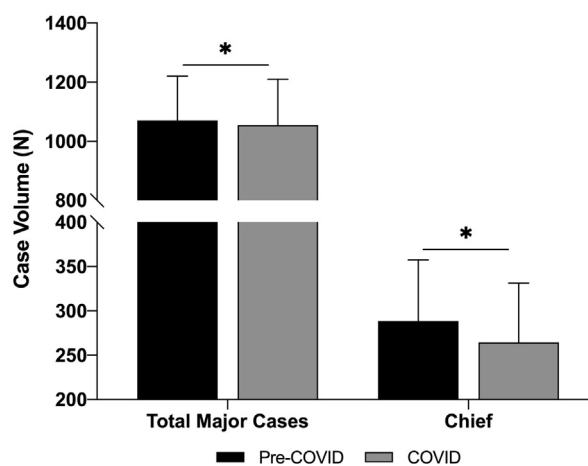


Fig 1. National surgery resident graduate operative volume decreased during the COVID pandemic.

A decrease in overall operative volume was seen (−1.47%), however a near 10% decrease was seen for the chief resident operative experience (−8.4%) ($*P < .05$).

Table II

National average operative volume of graduating surgical residents in 2019–2020 (COVID year) compared with 2018–2019 (pre-COVID year)

Defined categories and operative domains	Total major cases		P value	Chief cases		P value
	pre-COVID	COVID		pre-COVID	COVID	
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
Skin and soft tissue	65.0 ± 25	64.7 ± 25	.7653	12.2 ± 8	11.5 ± 8	.0296
Head and neck	22.7 ± 13	21.8 ± 12	.0734	4.1 ± 4	3.8 ± 4	.0622
Breast	66.7 ± 28	67.0 ± 28	.7898	10.1 ± 12	9.5 ± 12	.2137
Alimentary tract						
Esophagus	14.1 ± 9	14.4 ± 9	.4071	6.8 ± 6	6.1 ± 6	.0037
Stomach	45.6 ± 27	44.2 ± 26	.1888	17.5 ± 14	15.3 ± 13	<.0001
Small intestine	10.4 ± 13	40.3 ± 13	.8483	15.8 ± 7	14.7 ± 7	.2865
Large intestine	150.3 ± 39	146.8 ± 36	.0203	48.8 ± 19	45.0 ± 18	<.0001
Anorectal	37.7 ± 16	37.8 ± 16	.8765	9.9 ± 9	8.9 ± 8	.0035
Abdomen						
General	46.7 ± 22	46.3 ± 22	.6511	15.4 ± 10	14.5 ± 9	.0186
Liver	9.9 ± 6	9.6 ± 6	.2137	4.8 ± 4	4.3 ± 4	.0019
Biliary	133.8 ± 42	130.2 ± 39	.0271	39.3 ± 17	36.1 ± 17	<.0001
Pancreas	10.0 ± 7	9.6 ± 7	.1553	6.2 ± 6	5.6 ± 6	.0129
Spleen	2.4 ± 2	2.4 ± 2	1.0000	1.1 ± 1	1.0 ± 1	.0129
Hernia	136.8 ± 36	131.8 ± 36	.0006	38.7 ± 18	34.8 ± 18	<.0001
Vascular						
Aneurysm repair	5.6 ± 6	5.5 ± 6	.6785	1.6 ± 3	1.4 ± 3	.0974
Cerebrovascular	9.5 ± 8	9.5 ± 9	1.0000	2.7 ± 4	2.5 ± 5	.2727
Peripheral obstructive	19.8 ± 15	20.1 ± 16	.6306	5.0 ± 8	4.6 ± 8	.2137
Abdominal obstructive	0.6 ± 1	0.6 ± 1	1.0000	0.2 ± 1	0.2 ± 1	1.0000
Upper extremity	2.0 ± 2	2.0 ± 2	1.0000	0.5 ± 1	0.5 ± 1	1.0000
Extra-anatomic bypass	1.6 ± 2	1.5 ± 2	.2137	0.4 ± 1	0.4 ± 1	1.0000
Thrombolysis & mech. thrombectomy	0.7 ± 1	0.8 ± 2	.1174	0.2 ± 1	0.2 ± 1	1.0000
Miscellaneous Endovascular therapy	0.2 ± 1	0.3 ± 1	.0129	0.1 ± 1	0.1 ± 0	1.0000
Trauma	2.8 ± 3	2.9 ± 3	.4071	0.7 ± 1	0.6 ± 1	.0129
Venous	7.9 ± 8	7.8 ± 8	.7559	1.0 ± 2	0.8 ± 2	.0129
Diagnostic endovascular	8.6 ± 13	8.6 ± 12	1.0000	1.5 ± 4	1.6 ± 5	.5834
Miscellaneous	7.0 ± 6	6.8 ± 6	.4071	1.4 ± 3	1.3 ± 2	.3279
Vascular access	31.9 ± 21	30 ± 18	.0156	5.4 ± 8	4.2 ± 7	<.0001
Amputations	16.3 ± 11	16.7 ± 12	.3877	2.3 ± 3	2.4 ± 4	.4827
Endocrine	33.2 ± 20	32.8 ± 20	.6189	11.2 ± 11	9.7 ± 10	.0004
Thoracic	39.1 ± 25	38.5 ± 26	.5586	7.7 ± 12	7.0 ± 13	.1643
Pediatric	25.1 ± 14	24.5 ± 13	.2690	1.8 ± 4	1.9 ± 5	.5834
Plastic	25.6 ± 21	26 ± 22	.6437	3.2 ± 5	2.9 ± 4	.0988
Organ transplant	11.3 ± 12	11.9 ± 12	.2137	1.6 ± 5	1.3 ± 4	.0988
Trauma	30.1 ± 18	30.5 ± 18	.5804	8.0 ± 8	7.9 ± 8	.7559
Endoscopy	137.5 ± 49	135.3 ± 53	.2840	24.7 ± 25	21.7 ± 24	.0023
Major operations	1070.5 ± 150	1054.8 ± 155	.0105	288.6 ± 69	264.4 ± 67	<.0001

SD, standard deviation.

graduates (Table II). Notably, this included all operative domains within the defined category abdomen.

Local analysis

During March through May of 2020, the height of COVID pandemic regulations, general surgery residents completed 42.5% fewer monthly average total major operations compared with the previous year (12 ± 11 vs 20 ± 14 , $P < .001$). By residency level, junior residents had a 50.8% decrease (6 ± 7 vs 12 ± 10 , $P = .004$) and senior residents had a 43.5% decrease (15 ± 11 vs 26 ± 16 , $P < .001$) in average total major cases per month. There was not a significant decrease in monthly total major cases for chief residents (16 ± 11 vs 21 ± 13 , $P = .177$) (Fig 2). However, there was a notable decrease in logged surgeon chief cases among chief residents in 2020 compared with 2019 (12 ± 7 vs 19 ± 11 , $P = .041$). For the entire 2020 cohort, decreased operative volume was observed in 8 operative domains, including skin and soft tissue, stomach, hernia, biliary, endocrine, plastic and both basic and complex laparoscopy. Junior residents completed fewer cases in 5 operative domains (hernia, biliary, trauma, endoscopy, basic laparoscopy), while senior residents completed fewer cases in 8 operative domains (skin and soft tissue, stomach, large intestine, hernia, endocrine,

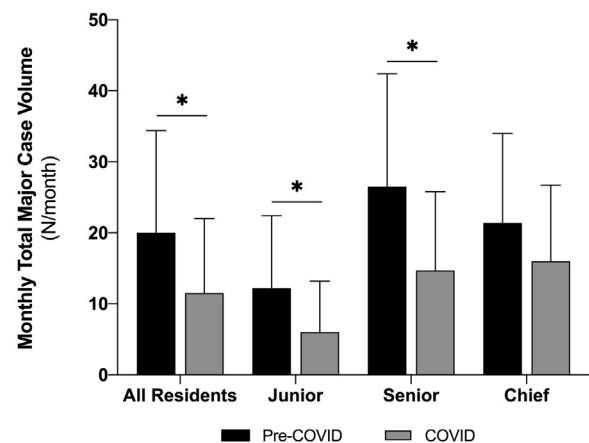


Fig 2. Monthly average operative volume during March to May 2020 (COVID) compared with 2019 (pre-COVID) at the University of Cincinnati. Overall, residents saw a 42.5% decrease in operative volume. While junior residents had a 50.8% decrease, and senior residents had a 43.5% decrease, no decrease was observed among chief residents ($*P < .05$).

plastic, colonoscopy, complex laparoscopy). Case volume was similar across all operative domains for chief residents (Tables III, IV). Of note, case volumes were similar in our analysis

Table III
Monthly average operative volume for all residents during peak COVID quarantine (March–May 2020) compared with the previous year (pre-COVID, March–May 2019) at a single academic surgical residency program

Defined categories and operative domains	All residents		
	pre-COVID	COVID	P value
	Mean ± SD	Mean ± SD	
Skin and soft tissue	1.5 ± 2.0	0.7 ± 1.3	.0012
Head and neck	1.1 ± 2.3	0.7 ± 1.3	.1378
Breast	1.2 ± 3.7	1.1 ± 2.7	.7556
Alimentary tract	5.9 ± 7.1	4.2 ± 5.8	.0745
Esophagus	0.3 ± 1.1	0.2 ± 0.7	.4592
Stomach	1.4 ± 2.7	0.7 ± 1.3	.0138
Small intestine	0.7 ± 1.1	0.7 ± 1.1	.7367
Large intestine	1.9 ± 3.8	1.1 ± 1.9	.0783
Appendix	0.9 ± 1.4	0.9 ± 2.3	.9890
Anorectal	0.7 ± 1.4	0.7 ± 2.5	1.0000
Abdomen	6.6 ± 6.7	3.3 ± 4.7	.0002
Biliary	1.9 ± 3.2	1.1 ± 2.1	.0300
Hernia	2.4 ± 3.1	1.1 ± 2.1	.0008
Liver	0.3 ± 1.2	0.2 ± 0.7	.4308
Pancreas	0.3 ± 1.2	0.1 ± 0.7	.1957
Vascular	1.0 ± 2.8	0.5 ± 1.3	.0888
Vascular access	0.3 ± 0.9	0.2 ± 0.6	.1993
Anastomosis, repair, exposure, or endarterectomy	0.3 ± 1.6	0.1 ± 0.7	.2236
Endocrine	0.6 ± 1.6	0.2 ± 0.6	.0178
Trauma	0.8 ± 1.9	0.7 ± 1.5	.4643
Thoracic	0.5 ± 1.3	0.3 ± 0.8	.0783
Pediatric	0.9 ± 3.7	0.6 ± 2.8	.5468
Plastic	0.8 ± 2.6	0.1 ± 0.4	.0182
Endoscopy	1.7 ± 3.9	1.2 ± 2.3	.2695
Upper endoscopy	0.7 ± 1.8	0.8 ± 1.6	.8236
Colonoscopy	1.0 ± 3.0	0.3 ± 1.1	.0527
Laparoscopic - basic	2.8 ± 4.1	1.7 ± 3.0	.0343
Laparoscopic - complex	3.0 ± 4.8	1.3 ± 2.3	.0028
Total major cases	20.0 ± 14.4	11.5 ± 10.5	<.0001
Surgeon, junior	15.4 ± 15.4	8.0 ± 9.6	.0001
Surgeon, chief	3.7 ± 8.9	2.5 ± 5.6	.2588
Teaching asst.	0.7 ± 2.8	1.0 ± 2.8	.4913

SD, standard deviation.

by season in 2018–2019, as well as by year, when comparing winter of 2020 with 2019 (data not shown, all $P > .05$).

Discussion

The impact of COVID-19 on surgical residents' technical training and operative experience is yet unknown. In this study, we found notable decreases in general surgery resident operative volume in 2020 compared with 2019. Nationally, surgeon chief volume was significantly lower among 2020 graduates, indicating a greater impact during the graduates' chief year. This was most apparent in the domains of stomach, large intestine, biliary and hernia. To further examine the specific effect of COVID-19 quarantine restrictions on resident experience, a local analysis was performed. This showed that residents of all levels experienced reduced surgical volume, with the greatest impact on junior residents' monthly case logs. Local analysis mirrored the national trends, identifying a significant decline in surgeon chief cases among its 2020 graduates. To our knowledge, this is the first study to demonstrate a direct relationship between COVID-19 and diminished operative volume for general surgery trainees on both the national and local levels.

At the beginning of the COVID-19 pandemic in early March 2020, several changes to the structure of general surgery residencies were implemented to promote patient and resident safety. These changes included the use of virtual lectures, the reassignment of general surgery residents to non-traditional rotations, and the cancellation of elective cases.^{4,5,10,11} Ultimately, these changes meant surgical residents spent less time in the operating room.

Recognizing the possibility that these changes could limit in-person operative experiences, several surgical societies issued statements acknowledging the likely decrease in case volume for 2020 general surgery graduates.^{3,12,13} General surgery residents and faculty also recognized the possible effects of COVID-19 regulations. Surveys of general surgery residents and educators conducted after the initial wave of the pandemic found a significant decrease in self-reported operative cases with associated concerns regarding the negative impact on operative experience and expected progression to operative autonomy.^{11,14,15} The results of our study validate the apprehensions of many US general surgery residents and educators regarding operative experiences during the COVID-19 pandemic.

Although there was a global decrease in operative volume among general surgery residents, we noted that operative experience varied by resident PGY level. Locally, junior and senior residents, but not chief residents, experienced a significant decrease in overall monthly operative volume. This trend was slightly more pronounced for junior residents. This may have been due to a more significant restructuring of junior residents' roles.¹⁵ Furthermore, the operative domains most affected at the local level—hernia, biliary, and basic laparoscopy—comprise some of the core operations for junior residents. The loss of this core operative experience is concerning for a resultant lack of progression toward operative competence and autonomy, identifying junior residents as a group requiring targeted skills remediation after the pandemic.^{11,15} However, given the overall length of general surgery training and the increasing vaccination and public health efforts to halt the

Table IV

Monthly average operative volume for residents by level during peak COVID quarantine (March–May 2020) compared with the previous year (pre-COVID, March–May 2019) at a single academic surgical residency program.

Defined categories and operative domains	Junior (R1-R2)			Senior (R3-R4)			Chief (R5)		
	pre-COVID	COVID	P value	pre-COVID	COVID	P value	pre-COVID	COVID	P value
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
Skin and soft tissue	1.4 ± 2.2	0.7 ± 1.2	.1113	1.8 ± 2.0	0.6 ± 1.6	.0046	0.8 ± 1.2	0.6 ± 0.9	.5260
Head and neck	0.2 ± 0.4	0.3 ± 0.4	.4277	2.2 ± 3.0	1.2 ± 1.7	.0760	0.7 ± 1.4	0.7 ± 1.5	1.0000
Breast	2.2 ± 5.5	1.9 ± 3.9	.7497	0.8 ± 1.5	0.5 ± 1.5	.4904	0.2 ± 0.4	0.6 ± 1.1	.1878
Alimentary tract	2.1 ± 3.4	1.2 ± 2.2	.2043	6.8 ± 6.5	4.8 ± 6.1	.1821	11.7 ± 9.4	8.9 ± 6.5	.3096
Esophagus	0.0 ± 0.0	0.1 ± 0.5	.2104	0.4 ± 1.6	0.1 ± 0.4	.2557	0.7 ± 1.0	0.6 ± 1.1	.7559
Stomach	0.5 ± 1.3	0.2 ± 0.6	.2672	1.9 ± 3.1	0.8 ± 1.2	.0359	2.3 ± 3.3	1.3 ± 2.1	.3117
Small intestine	0.3 ± 0.5	0.2 ± 0.4	.6049	1.0 ± 1.1	0.7 ± 1.1	.3072	1.2 ± 1.5	1.6 ± 1.5	.4374
Large intestine	0.2 ± 0.4	0.2 ± 0.4	.7823	1.7 ± 2.6	0.8 ± 1.0	.0490	5.8 ± 6.3	3.7 ± 2.7	.2132
Appendix	0.4 ± 0.8	0.1 ± 0.3	.0757	1.3 ± 1.8	1.6 ± 3.3	.5724	1.1 ± 1.2	0.9 ± 1.7	.7312
Anorectal	0.8 ± 1.9	0.4 ± 0.9	.3025	0.5 ± 0.9	0.8 ± 3.7	.6436	0.8 ± 1.3	0.9 ± 1.6	.8163
Abdomen	3.4 ± 1.2	1.2 ± 1.7	.0039	9.3 ± 8.2	4.7 ± 6.0	.0065	7.2 ± 5.6	4.8 ± 4.2	.1661
Biliary	1.1 ± 0.3	0.3 ± 0.7	.0308	2.6 ± 3.9	1.5 ± 2.5	.1458	2.1 ± 2.8	1.9 ± 2.3	.7974
Hernia	1.3 ± 0.4	0.4 ± 0.8	.0108	3.3 ± 3.9	1.6 ± 2.7	.0349	2.8 ± 2.6	1.4 ± 1.9	.0793
Liver	0.2 ± 0.1	0.1 ± 2.0	.2174	0.6 ± 1.6	0.4 ± 1.0	.5154	0.1 ± 0.2	0.2 ± 0.7	.3686
Pancreas	0.0 ± 0.0	0.0 ± 0.0	.3242	0.3 ± 0.6	0.1 ± 0.4	.3474	1.1 ± 2.5	0.4 ± 1.4	.3300
Vascular	0.8 ± 1.2	0.4 ± 0.8	.1068	1.6 ± 4.0	0.8 ± 1.9	.2184	0.2 ± 0.4	0.1 ± 0.5	.7006
Vascular access	0.3 ± 0.8	0.3 ± 0.7	.7573	0.5 ± 1.1	0.2 ± 0.6	.1643	0.0 ± 0.0	0.0 ± 0.0	1.0000
Anastomosis, repair, exposure, or endarterectomy	0.1 ± 0.5	0.0 ± 0.2	.2023	0.6 ± 2.4	0.3 ± 1.1	.4302	0.2 ± 0.4	0.0 ± 0.0	.0827
Endocrine	0.0 ± 0.0	0.1 ± 0.2	.1602	1.2 ± 2.3	0.3 ± 0.8	.0195	0.4 ± 1.0	0.2 ± 0.5	.2982
Trauma	0.4 ± 0.9	0.1 ± 0.2	.0382	1.6 ± 2.6	1.5 ± 2.0	.8649	0.2 ± 0.5	0.2 ± 0.5	.7558
Thoracic	0.4 ± 1.3	0.2 ± 0.5	.3451	0.8 ± 1.4	0.4 ± 0.8	.1562	0.2 ± 0.5	0.2 ± 0.4	.7271
Pediatric	0.0 ± 0.2	0.0 ± 0.2	1.0000	2.0 ± 5.6	1.4 ± 4.3	.5964	0.1 ± 0.2	0.0 ± 0.0	.3313
Plastic	1.5 ± 4.0	0.1 ± 0.5	.0537	0.4 ± 0.8	0.1 ± 0.3	.0496	0.2 ± 0.7	0.1 ± 0.2	.5340
Endoscopy	0.4 ± 1.0	1.2 ± 1.8	.0298	2.8 ± 4.5	1.2 ± 2.8	.0660	1.8 ± 5.3	1.1 ± 2.2	.5722
Upper endoscopy	0.3 ± 0.8	0.8 ± 1.5	.1174	1.1 ± 2.1	0.7 ± 1.6	.4176	0.7 ± 2.3	0.9 ± 2.1	.8231
Colonoscopy	0.1 ± 0.4	0.3 ± 0.9	.3986	1.7 ± 3.3	0.5 ± 1.5	.0369	1.1 ± 4.7	0.2 ± 0.5	.4096
Laparoscopic - basic	1.8 ± 2.9	0.6 ± 1.1	.0292	3.7 ± 5.2	2.4 ± 3.8	.2293	3.0 ± 3.0	2.3 ± 3.5	.5430
Laparoscopic - complex	1.0 ± 2.3	0.6 ± 1.5	.3151	3.2 ± 4.8	0.9 ± 1.5	.0073	6.4 ± 6.3	3.6 ± 3.2	.1011
Total major cases	12.2 ± 10.2	6.0 ± 7.2	.0042	26.0 ± 15.5	14.7 ± 11.1	.0004	21.4 ± 12.6	16.0 ± 10.7	.1767
Surgeon junior	12.2 ± 10.2	6.0 ± 7.2	.0042	25.5 ± 15.9	14.0 ± 10.5	.0004	0.0 ± 0.0	0.0 ± 0.0	-
Surgeon chief	0.0 ± 0.0	0.0 ± 0.0	-	0.2 ± 1.3	0.1 ± 0.7	.6884	18.7 ± 11.3	12.1 ± 6.5	.0407
Teaching asst.	0.0 ± 0.0	0.0 ± 0.0	-	0.4 ± 1.0	0.6 ± 2.8	.6943	2.7 ± 5.3	3.9 ± 7.0	.5583

impact of the virus on health care capacity, there should hopefully be adequate time and opportunity to help junior residents overcome the educational obstacles posed by the pandemic.

Similarly, chief residents at both the local and national level experienced a decrease in surgeon chief cases. While these graduating residents logged cases above the ACGME-defined minima during their residency, they may have lost important chief-level operative experience during the COVID-19 pandemic. These experiences are important because they help establish operative autonomy and develop intraoperative decision-making, which is immensely valuable for near-graduating residents approaching fellowship or independent practice. Locally, although the number of monthly surgeon chief cases decreased, total major cases did not decline as a result of a slight increase in TA cases. This suggests that to optimize their more limited opportunities during COVID-19, residents more frequently double-scrubbed with faculty, allowing chiefs to lead junior residents through cases. Ultimately, our local data demonstrate that all residents were impacted on some level. However, the effects by level will be important to consider in progression through general surgery residency, with junior residents requiring more attention to technical skills and chief residents requiring experiences focusing on operative autonomy.

Although there is controversy regarding the correlation between ACGME case logs and operative competency or technical proficiency, the global reduction in operative experience during COVID-19 is concerning as studies have shown an association between higher operative volume and improved outcomes, which has been used as a surrogate for competence.^{16–20} In examining how to remedy the volume deficit observed in this study, it is evident that

surgical education across the US will need to adapt and modernize to continue high-quality education of residents. Video-based education (VBE), which has been previously shown to be an effective technique for operating room preparation, could provide an easily accessible and cost-effective resource for residents to supplement their operative education.^{21,22} Surgical simulators, cadaver labs, and skills labs are additional useful adjuncts that could be provided by individual residency programs to focus on certain technical operative skills on a resident level basis. Furthermore, local hospitals and different surgical residencies within a region could collaborate to identify critical deficiencies in potential operative experiences and work together to ensure equitable exposure for those trainees in need. Undoubtedly, these platforms are not a substitute for actual operative experience. In certain cases, remediation or delaying progression of residents most affected by the pandemic may need to be considered. Based on the results of this study and previous surveys, surgery educators and residencies will likely need to consider assessing residents' skills on a case-by-case basis with the knowledge that some may require more intensive training or even remediation to achieve level-appropriate competency.²³

Moving forward, an examination of operative volume in the year after removal of COVID-19 regulations could give insight into a possible "catch up" period as many cases cancelled during the pandemic could be performed during this time. This suggests that, although case volumes did decrease during the pandemic, there may be an opportunity to make up the deficit and meet ACGME case log minima. However, as previously described, completion of a general surgery residency and ACGME case log minima do not necessarily correlate with operative competency, technical

proficiency, or readiness for fellowship training.^{16,24} Furthermore, recent studies have suggested that operative proficiency in the current training paradigm is achieved in the years directly after residency, which includes fellowship training or a transition to practice environment.^{24,25} These facts are comforting as the overall small amount of operative volume lost during the COVID-19 pandemic will likely not affect global operative proficiency if trainees work diligently to make up the lost experience.

There are several limitations to this study. Case logs are self-reported, and therefore, analysis is subject to inconsistencies and inaccuracies of the logging process. Furthermore, these are aggregate national data, and we are unable to make conclusions about individual programs, individual trainees, or complexity of cases performed as it relates to overall volume. We cannot evaluate how a resident's interest in a specific field or a given program's strength in various surgical subspecialties influences the local variability of operative composition. The data sets differ in that the national data represent graduating residents and examines the aggregate cumulative performance of surgical residency training, while the local data represent case logs of all active residents on a monthly basis. This difference in data presentation likely accounts for the more dramatic decrease seen on the local level during the months most significantly impacted by COVID-19 regulations. Finally, this study was unable to examine the variation in the decrease in case volume across individual programs during the months affected by COVID-19 as only a single center was examined in this study. This means that magnitudes of decrease related to COVID-19 experienced by individual residents in individual programs could not be assessed and will likely differ based on individual center's baseline volumes.

In conclusion, the COVID-19 pandemic was associated with decreased operative experience for general surgery residents. This has impacted surgical residents' operative volume at all levels of residency with unknown future consequences regarding operative competency and autonomy. General surgery residents and educators will need to be mindful of these findings during the remaining training of those affected by this diminished operative experience. Techniques to address this loss of operative experience include VBE, surgical simulation, and skills labs, as well as careful, individual evaluation by surgical residency programs to ensure operative competency before graduation.

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