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ORIGINAL PAPER

Characterizing the volume of surgery and post-operative complications during the COVID-19 pandemic

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Abstract

Purpose The COVID-19 pandemic led to unprecedented changes in volume and quality of surgery. Utilizing the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database, the current study assesses the impact of COVID-19 on surgical volume during each quarter of 2020 in comparison to 2019. Quality of surgical care during 2020 was also investigated by assessing postoperative complications, readmissions, and reoperations during 2020 in comparison to the previous 5 years.

Materials and methods The NSQIP database was queried from 2015 to 2020. Descriptive statistics and a chi-squared test were utilized to compare demographic variables. A seasonal autoregressive integrated moving average time-series model was fit to assess the trend and seasonality of complications from 2015 to 2019 and was used to forecast the proportion of complications in the year 2020 and compared the forecast with the actual proportions graphically.

Results There were fewer patients operated on in 2020 compared to 2019, with the most dramatic drop in Q2 with a nearly 27% decrease. Patients with ASA class 3 or greater were operated on at a greater proportion in every quarter of 2020. Q2 of 2020 represented the highest proportion of any operative complications since 2015 at ~13%. Q4 of 2020 demonstrated a return to 2020 Q1 complication proportions.

Conclusion Surgical volume was heavily affected in 2020, particularly in Q2. Patients during Q2 of 2020 were generally of a higher ASA class and had increased operative complications. Operative volume and overall surgical complication rate normalized over the next two quarters.

Keywords Surgery · Quality · Volume · COVID-19 · 2020 · Complications

Introduction

The declaration of coronavirus disease 2019 (COVID-19) as a global pandemic in March 2020 ushered in a new era of challenges for hospital systems around the world. With surging COVID-19 cases, hospitals were forced to shift their focus and resources to the prevention and treatment of COVID-19 and its associated sequelae [1]. This led to several changes within healthcare, including cancellation of most outpatient clinics, an increasing trend toward telehealth visits, as well as limitations to visitation in healthcare settings [2–4]. In line with this paradigm, several healthcare systems announced suspension of non-urgent elective surgeries. The reasons for cancellation of "non-essential" procedures were numerous, including lack of hospital staff and resources, risk reduction to prevent nosocomial COVID-19 spread, and potential repurposing of surgical theatres to negative-pressure rooms to handle COVID caseloads [4, 5].

In the USA, the American College of Surgeons (ACS) called for suspension of elective surgical procedures in mid-March [6]. After 35 days, new guidelines were issued by the ACS and other surgical societies on how to resume elective surgeries [7]. The impact of this unprecedented contraction in surgical volume is still being investigated. A study analyzing surgical caseloads in Veterans Affairs hospitals

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revealed surgical procedures rebounded between May and June of 2020; however, surgical volume did not return to pre-pandemic levels during the same period in 2019 [8]. Another study utilizing nationwide claims data reported a decrease in overall surgical procedures by 48% during the initial COVID-19 shutdown compared to 2019 [9].

The current study utilizes the ACS National Surgical Quality Improvement Program (NSQIP) database to assess the impact of COVID-19 on volume of surgical practice through the quarters of 2020 in comparison to 2019. In addition to quantitative assessment, a secondary aim is to investigate the quality of surgical care during 2020 by assessing postoperative complications, readmissions, and reoperations during this time in comparison to the previous 5 years.

Material and methods

Data

The American College of Surgeons NSQIP database was utilized for analysis which currently gathers data from over 700 hospitals [10]. The number of hospitals included in the database varies by year: 2020 — 706 hospitals; 2019 — 719 hospitals; 2018 — 722 hospitals; 2017 — 708 hospitals; 2016 — 680 hospitals; and 2015 — 603 hospitals [11]. Data from 2015 to 2020 was included, and detailed information regarding NSQIP data collection methods, data monitoring, and data validation has been previously described [12]. Complications were defined by ventilation >48 h (FAILWEAN), superficial incisional surgical site infection (SSI) (SUPINFEC), deep incisional SSI (WNDINFD), organ space SSI (ORGSPCSSI), wound disruption (DEHIS), unplanned intubation (REINTUB), pneumonia (OUPNEUMO), acute renal failure (OPRENAFL), urinary tract infection (URNINFEC), cardiac arrest (CDARREST), bleed requiring transfusion (OTHBLEED), sepsis (OTHSYSEP), and septic shock (OTHSESHOCK). Data was broken down by quarters of the year with Q1 representing January–March, Q2 representing April–June, Q3 representing July–September, and Q4 representing October–December. Our institutional review board has given this study exempt status (IRB00068446).

In addition, the American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

Statistical analysis

We provide descriptive statistics in the form of mean (SD), median (IQR), and range for continuous variables and counts (%) for categorical variables. An ANOVA test was used to compare average age and a chi-squared test was used to compare other demographic categorical variables from 2019 to 2020. A seasonal autoregressive integrated moving average (SARIMA) time-series model was fit to assess the trend and seasonality of complications from 2015 to 2019 at the quarterly level. We used the model fit to forecast the proportion (with 80% and 95% prediction interval) of complications in the year 2020 and compared the forecast with the actual proportions graphically. We performed all analyses using R version 3.6.1 and used the auto.arima function to choose the best fitting SARIMA model [13–15].

Results

Overall, there were less patients operated on in every quarter of 2020 in comparison to 2019 with the most dramatic drop in Q2 with nearly 74,000 fewer surgical patients (~27% decrease). Though the number of hospitals included in NSQIP varies from year to year, the average number of operative cases per hospital is similar (Table 1). The age, gender, and race of patients were generally comparable between all quarters of 2019 and 2020. Comorbidities were slightly different, with those of an ASA class of 3 or greater being operated on at a greater proportion in every quarter of 2020. Operatively, in Q2 of 2020, there were fewer elective cases and more emergent cases by ~7%, with similar operative proportions for each surgical specialty (Supplemental Table 1). Elective cases in Q3 and Q4 of 2020 surpassed the proportion of elective cases in the same quarters of 2019. In Q2 of 2020, outpatient case counts also decreased, though less dramatically, and then recovered by Q3.

Thirty-day complication proportions from every quarter since 2015 are represented in Fig. 1. In general, the proportion of complications had decreased and then plateaued until Q2 of 2020, which represented the highest proportion of any operative complications since 2015 at ~13%. Utilizing a SARIMA time-series model, predicted rates of patients having at least one 30-day postoperative complication can be speculated based on the previous 5 years of complication data. Using this model in Fig. 1, Q2 of 2020 was greater than the upper bound of the 95% prediction interval for that timeframe. Q3 remained above the 80% prediction, while Q4 dropped within the expected prediction interval. Q4 demonstrated a return to 2020 Q1 complication proportions which coincides to previous, pre-pandemic years.

In Fig. 2, 30-day readmissions had been steadily decreasing until Q2 of 2020 where it reached ~5.5% and then quickly normalized by 2020 Q3 and Q4 (~4.5%). Though operative rates were lower than previous quarters, Fig. 2 also demonstrates that proportions of 30-day reoperations increased in Q2 of 2020 to ~3%, but again normalized by

Table 1 Patient demographics by quarter of 2019 and 2020

	Q1 of 2019: *N* =270,425	Q1 of 2020: *N* =258,367	*P*-value	Q2 of 2019: *N* = 269,707	Q2 of 2020: *N* = 195,792	*P*-value
Average number of surgical cases per hospital	376.1	365.9		375.1	277.3	
Mean age (SD)	40.8 (17.2)	41.0 (17.2)	<0.001	40.9 (17.1)	40.4 (17.6)	<0.001
Sex						
Female	154,181 (57%)	147,577 (57.1%)	0.09	157,267 (58.3%)	110,987 (56.7%)	<0.001
Male	116,227 (43%)	110,760 (42.9%)		112,405 (41.7%)	84,780 (43.3%)	
Non-binary	17 (0%)	30 (0%)		35 (0%)	25 (0%)	
Race						
American Indian or Alaska Native	1355 (0.5%)	1375 (0.5%)	<0.001	1325 (0.5%)	1116 (0.6%)	<0.001
Asian	8080 (3%)	8807 (3.4%)		8815 (3.3%)	7494 (3.8%)	
Black or African American	25,741 (9.5%)	25,007 (9.7%)		25,822 (9.6%)	19,407 (9.9%)	
Native Hawaiian or other Pacific Islander	960 (0.4%)	916 (0.4%)		836 (0.3%)	761 (0.4%)	
Unknown/other	53,874 (19.9%)	55,792 (21.6%)		53,626 (19.9%)	43,929 (22.4%)	
White	180,415 (66.7%)	166,470 (64.4%)		179,283 (66.5%)	123,085 (62.9%)	
BMI > 30	118,501 (44.9%)	111,353 (44.2%)	<0.001	119,136 (45.1%)	79,939 (42.6%)	<0.001
ASAclass ≥ 3	125,145 (46.3%)	122,635 (47.5%)	<0.001	125,711 (46.6%)	97,954 (50%)	<0.001
History of diabetes	40,228 (14.9%)	39,238 (15.2%)	0.002	41,157 (15.3%)	30,110 (15.4%)	0.27
History of congestive heart failure	2295 (0.8%)	2349 (0.9%)	0.018	2131 (0.8%)	2074 (1.1%)	<0.001
Hypertension requiring medication	116,194 (43%)	110,725 (42.9%)	0.41	117,857 (43.7%)	82,369 (42.1%)	<0.001
History of smoking	42,459 (15.7%)	38,827 (15%)	<0.001	41,591 (15.4%)	30,742 (15.7%)	0.009
History of chronic obstructive pulmonary disease	10,992 (4.1%)	10,123 (3.9%)	0.006	10,886 (4%)	7649 (3.9%)	0.026
	Q3 of 2019: *N* = 275,342	Q3 of 2020: *N* = 239,720	*P*-value	Q4 of 2019: *N* = 260,967	Q4 of 2020: *N* = 209,089	*P*-value
Average number of surgical cases per hospital	383.0	339.5		363.0	296.2	
Meanage (SD)	41.0 (17.3)	40.7 (17.3)	<0.001	40.7 (16.9)	40.4 (17.1)	<0.001
Sex						
Female	160,421 (58.3%)	138,934 (58%)	0.010	149,936 (57.5%)	120,591 (57.7%)	0.30
Male	114,888 (41.7%)	100,740 (42%)		110,997 (42.5%)	88,473 (42.3%)	
Non-binary	33 (0%)	46 (0%)		34 (0%)	25 (0%)	
Race						
American Indian or Alaska Native	1358 (0.5%)	1199 (0.5%)	<0.001	1358 (0.5%)	1303 (0.6%)	<0.001
Asian	9266 (3.4%)	9002 (3.8%)		8822 (3.4%)	8040 (3.8%)	
Black or African American	26,506 (9.6%)	24,502 (10.2%)		24,585 (9.4%)	21,669 (10.4%)	
Native Hawaiian or other Pacific Islander	893 (0.3%)	778 (0.3%)		847 (0.3%)	598 (0.3%)	
Unknown/other	55,818 (20.3%)	52,452 (21.9%)		54,584 (20.9%)	45,401 (21.7%)	
White	181,501 (65.9%)	151,787 (63.3%)		170,771 (65.4%)	132,078 (63.2%)	
BMI > 30	119,461 (44.5%)	103,643 (44.6%)	0.34	114,216 (44.8%)	90,754 (44.6%)	0.28

Table 1 (continued)

	Q1 of 2019: *N* =270,425	Q1 of 2020: *N* =258,367	*P*-value	Q2 of 2019: *N* = 269,707	Q2 of 2020: *N* = 195,792	*P*-value
ASA class ≥ 3	129,762 (47.1%)	115,829 (48.3%)	<0.001	121,752 (46.7%)	98,688 (47.2%)	<0.001
History of diabetes	42,260 (15.3%)	36,611 (15.3%)	0.45	39,633 (15.2%)	31,390 (15%)	0.10
History of congestive heart failure	2388 (0.9%)	2121 (0.9%)	0.50	2237 (0.9%)	1875 (0.9%)	0.15
Hypertension requiring medication	119,944 (43.6%)	102,803 (42.9%)	<0.001	112,525 (43.1%)	88,358 (42.3%)	<0.001
History of smoking	42,715 (15.5%)	35,782 (14.9%)	<0.001	41,591 (15.4%)	30,742 (15.7%)	0.009
History of chronic obstructive pulmonary disease	11,247 (4.1%)	9018 (3.8%)	<0.001	10,886 (4%)	7649 (3.9%)	0.026

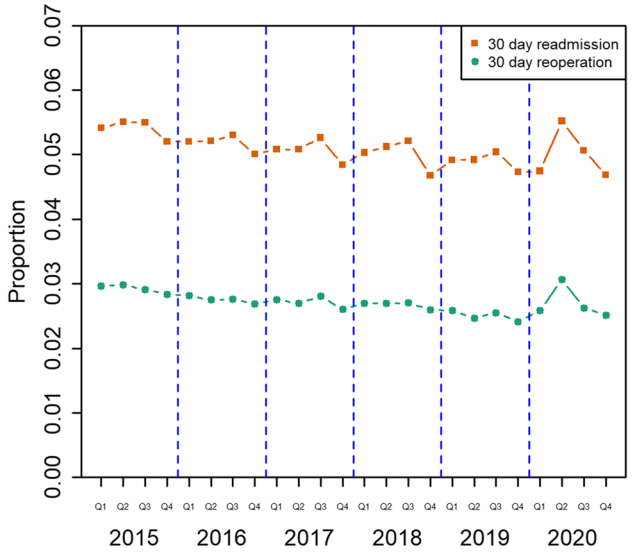

Fig. 1 The proportion of 30-day readmissions and reoperations measured across time

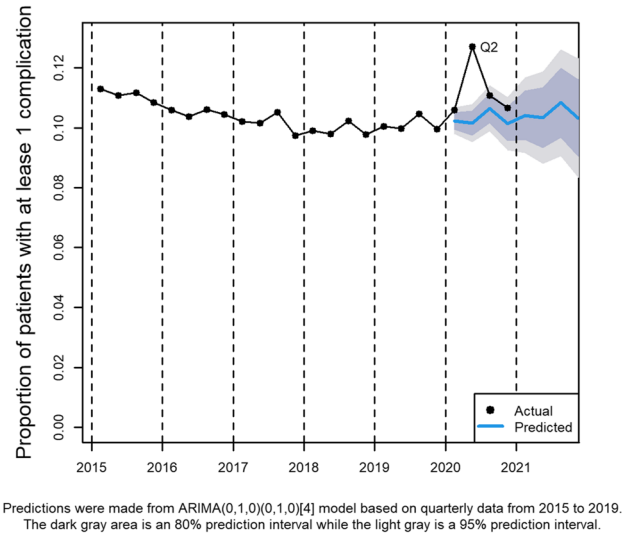

Fig. 2 A seasonal autoregressive integrated moving average (SARIMA) time-series model showcasing projected 30-day complication rates across time

2020 Q3 and Q4. When assessing specific 30-day complications, all increased in proportion in Q2 of 2020 to varying degrees. Bleeds requiring transfusion and sepsis had some of the most dramatic increases during Q2 of 2020, while pneumonia and prolonged ventilation (>48 h) were only mildly increased (Fig. 3). Rates of pneumonia continue to be elevated in comparison to pre-pandemic levels even in 2020 Q3 and Q4; however, prolonged ventilation normalized in Q3. Infections, which included superficial incisional, deep incisional, and organ space infections, have been increasing over the past two years, and Q2 of 2020 resulted in the highest proportion of infections in the past 6 years. Infections continued to be elevated in comparison to 2015–2018 even through 2020 Q3 and Q4. Rates of unplanned intubation and cardiac arrest within 30 days postoperative have been relatively stable the past 6 years and appeared to only slightly increase during Q2 of 2020 (Supplemental Fig. 1). A graphic summary of specific complication proportions between the quarters of 2019 and 2020 is provided by Supplemental Fig. 2.

Figure 4 demonstrates that over the past 6 years, the proportion of patients with higher ASA class has been positively correlated with the proportions of complications. However, the proportion of patients with an ASA class of 3 or greater undergoing surgery during Q2 of 2020 was greater than 3 SD (>95% significance) above the average proportion of patients with ASA class of 3 or greater during other quarters during the study period. We also observed that the proportion of patients with at least one 30-day postoperative complication increased during Q2 of 2020 by more than 3 SD (>95% significance) compared to the other quarters during the same time period. Similar analysis including sex, age, race, history of diabetes, and BMI >30 did not yield such results.

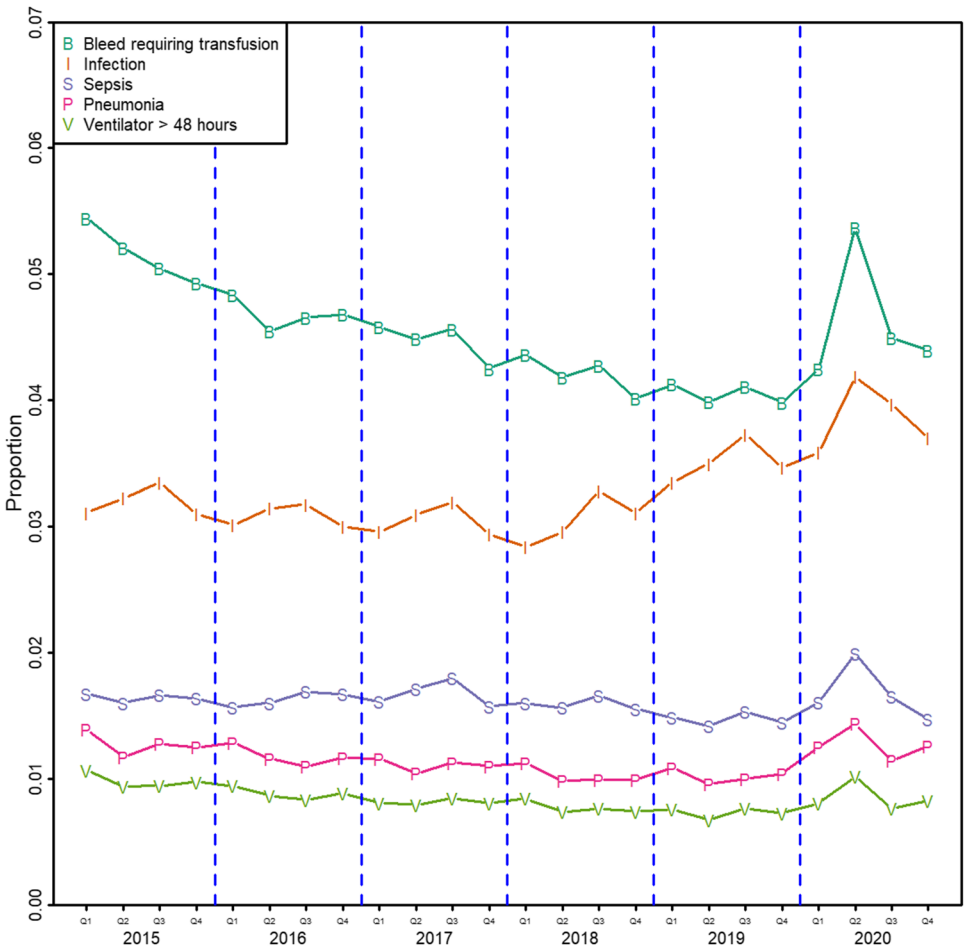

Fig. 3 The proportion of 30-day specific complications by quarter including bleed requiring transfusion, infection, sepsis, pneumonia, and prolonged ventilation

Discussion

While anecdotal evidence regarding the negative impact of COVID-19 on surgery in the USA is widespread, objective data to quantify the extent to which surgical practice was affected by the pandemic is still being determined. An article published in JAMA by Mattingly et al. used administrative claims from *Change Healthcare* to report that overall surgical cases in 2020 decreased by 48.0%, which is more drastic than what we determined from the NSQIP data [9]. They report that of major surgical procedures, cataract surgery, and joint arthroplasty decreased the most at 89.5% and 82.1%, respectively, while organ transplant and caesarean section volumes were not changed statistically from the 2019 baseline. Their claims data show surgical volumes rebounded to pre-pandemic levels after the initial shutdown period of March-April 2020, which is concordant with the presented NSQIP data. Surgical volumes remained largely unchanged in subsequent COVID-19 surges both within their reporting and our reporting, suggesting adaptation of healthcare operative systems to function at pre-pandemic capacity despite higher levels of COVID-19 cases and hospitalizations [9].

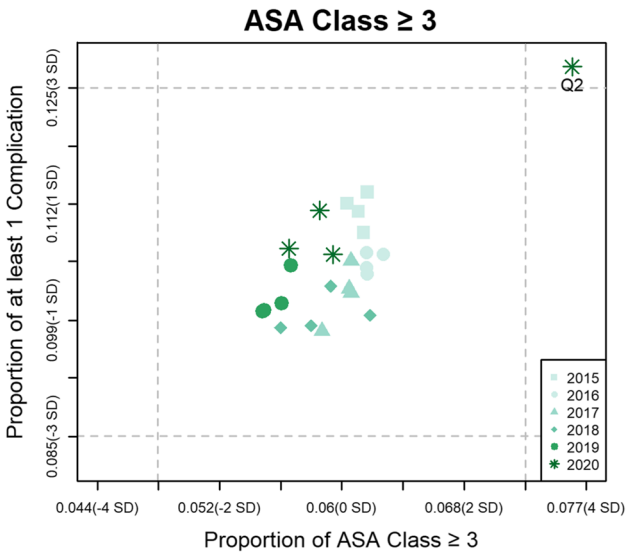

Fig. 4 The proportion of patients ASA class greater than or equal to 3 and their proportion of experiencing at least 1 complication

Like the USA, most of the world incorporated changes to surgical care secondary to COVID-19. Many countries noted a delay in presentation for urgent and emergent surgical problems during the initial shutdown period which, though not yet published, likely negatively impacted surgical outcomes. In Spain, a 58.9% decrease in acute care

surgery was identified with a statistically significant delay in presentation to emergency department (44.6 vs. 71.0 h) [16]. In Italy, increased admissions were seen due to abdominal emergencies that were inappropriately attempted to be managed at home [17]. McLean et al. also reported patients in the post shutdown period to be older with worse clinical presentations, require longer hospital stays, and have increased complication rates, which are thought to be due to delays in presentation [18]. Cancer treatment was also affected. In China, Liang et al. noted that cancer patients had a higher risk of adverse events relating to COVID-19 following chemotherapy or surgery and recommended delaying cancer treatment in high transmission areas [19]. In the UK, only 26% of melanoma patients underwent the guideline recommended sentinel lymph node biopsies during the lockdown phase [20]. Our data also demonstrates an increase of operative complications through the COVID-19 pandemic, likely due to a generally sicker operative patient population as demonstrated by the higher proportion of patients of ASA class 3 or greater, in addition to presumed staffing shortages and the fact that only emergent cases were permitted for a time. The surgical complication rate increase could at least in part be due to the proportion of elective cases decreasing and only emergent cases proceeding which carry inherently more risk.

COVID-19 is not the first infectious phenomena to bring about changes in the field of surgery. In 2003, an outbreak of severe acute respiratory syndrome-related coronavirus (SARS-CoV) resulted in an epidemic involving 29 countries. Adaptive infection control measures were established to prevent intrahospital transmission, such as cancelling elective surgeries, altering surgical procedures to minimize aerosolizing viral particles, and modifying operating room logistics and protocols [21]. The practices developed during the SARS-CoV outbreak later helped to formulate a similar response to the Middle East respiratory syndrome in 2012, the West African Ebola epidemic in 2014, and arguably the initial response to COVID-19 in 2020.

As the world continues to adapt to COVID-19, the field of surgery continues to gain valuable information on responding to future pandemics. For example, telemedicine, virtual surgical education, and even virtual away rotations for medical students pursuing surgery have become essential to the American healthcare system [22–28]. Additionally, it has been reported that elective surgical cases use small amounts of hospital resources, which may assist in guiding future resource utilization conversations in times of unprecedented increases in patient hospitalizations [29]. Another important takeaway from the current study is that because the rate of surgical complications increased during a portion of 2020, perhaps future pandemic responses should allocate additional resources to surgical sites, including adequate staffing, to anticipate the needs of a sicker population of operative patients. Importantly, the overall trajectory of surgical complications, readmissions, and reoperations since 2015 continues to plateau or decrease, confirming the overall safety of current surgical practices within the USA.

Utilizing the American College of Surgery NSQIP database is not without limitations. Importantly, post-operative outcomes are only tracked for 30-day following a surgical procedure. In addition, the dataset does not provide information regarding the severity of patient comorbidities, indications for surgery, or specific outcomes related to a given procedure. Lastly, the NSQIP database is dependent on CPT/ICD coding, which were not originally developed for research purposes and may be influenced by reimbursement strategies or coded by non-medical team members [30].

Conclusion

Overall surgical volume was heavily affected in 2020, particularly in Q2 when the COVID-19 pandemic struck the USA. Patients during Q2 of 2020 were generally of a higher ASA class and had an increase in operative complications, as cases were only being done on an emergent basis at that time. Operative volume and overall surgical complication rate normalized over the next two quarters.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00423-022-02605-6.

Authors' contributions All authors above appropriately contributed to the development of this manuscript. The conceptualization of the goals/aims of the article was driven by Alvin Kwok, Jay Agarwal, Giovanna Pires, and Whitney Moss. The formal acquisition and analysis of the data was carried out by Devin Eddington and Benjamin Brintz. Giovanna Pires, Whitney Moss, Erika Samlowski, Justin Webb, Jay Agarwal, and Alvin Kwok were involved in drafting and revising the final version for submission.

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Declarations

Conflict of interest The authors declare no competing interests.

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