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Impact of COVID-19 on common non-elective general surgery diagnoses

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Abstract

Background During the COVID-19 pandemic, public health and hospital policies were enacted to decrease virus transmission and increase hospital capacity. Our aim was to understand the association between COVID-19 positivity rates and patient presentation with EGS diagnoses during the COVID pandemic compared to historical controls.

Methods In this cohort study, we identified patients ≥ 18 years who presented to an urgent care, freestanding ED, or acute care hospital in a regional health system with selected EGS diagnoses during the pandemic (March 17, 2020 to February 17, 2021) and compared them to a pre-pandemic cohort (March 17, 2019 to February 17, 2020). Outcomes of interest were number of EGS-related visits per month, length of stay (LOS), 30-day mortality and 30-day readmission.

Results There were 7908 patients in the pre-pandemic and 6771 in the pandemic cohort. The most common diagnoses in both were diverticulitis (29.6%), small bowel obstruction (28.8%), and appendicitis (20.8%). The lowest relative volume of EGS patients was seen in the first two months of the pandemic period (29% and 40% decrease). A higher percentage of patients were managed at a freestanding ED (9.6% vs. 8.1%) and patients who were admitted were more likely to be managed at a smaller hospital during the pandemic. Rates of surgical intervention were not different. There was no difference in use of ICU, ventilator requirement, or LOS. Higher 30-day readmission and lower 30-day mortality were seen in the pandemic cohort.

Conclusions In the setting of the COVID pandemic, there was a decrease in visits with EGS diagnoses. The increase in visits managed at freestanding ED may reflect resources dedicated to supporting outpatient non-operative management and lack of bed availability during COVID surges. There was no evidence of a rebound in EGS case volume or substantial increase in severity of disease after a surge declined.

Keywords Emergency general surgery · COVID-19 · Pandemic

Non-elective general surgery, commonly referred to as emergency general surgery (EGS), has often been studied as a marker of access to healthcare [1]. Emergency general surgery diagnoses require time-sensitive management and although access to that care varies, it is generally accepted that these conditions will manifest across all types of locations and infrastructure settings.

In the setting of the SARS-CoV-2 (COVID-19) pandemic, restricting of surgical care and often redeployment of surgeons had a dramatic impact on elective surgical care, including procedures that may be time-sensitive such as cancer care [2]. Changes in recommended management of EGS diagnoses included increased emphasis on non-operative management when feasible and some initial debate regarding open versus laparoscopic approach [3, 4]. Many hospitals prepared for EGS coverage assuming that there would be a continued inflow of patients with EGS diagnoses, although many initial reports suggested a decreased volume of such patients in the early months of the pandemic [5–12].

Despite the reports of decreased EGS volume in the early months, the drivers of this observation remain unknown. Importantly, it was not clear how this common observation would manifest in the following months or during subsequent peaks. Our aim was to evaluate emergency general surgery presentation across a regional healthcare system during the timeframe of the COVID-19 pandemic compared to

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a historical cohort. We hypothesized that there would be a decreased number of patients admitted with EGS diagnoses during peak COVID periods, that there would be greater disease severity for admitted EGS patients, that our smaller hospitals would see a steeper decline in EGS presentations than urban hospitals, and that patients in lowest income categories would make up a larger percentage of EGS patients during peak COVID periods.

Methods

This observational cohort study with historical control included patients who presented with common EGS diagnoses identified a priori. Patients were identified from our administrative billing data based on principal International Classification of Disease (ICD)-10 diagnosis codes (Table 1) from March 17, 2020 to February 17, 2021 (pandemic time period) and compared to historical controls with the same diagnoses from March 17, 2019 to February 17, 2020. Patients were included if they presented for care with a primary EGS diagnosis to any ED, urgent care, or acute care hospital within the Greater Charlotte Region of our healthcare system. Patients were excluded if age < 18 years. ICD-10 EGS diagnosis codes were classified in accordance with the American Association for the Surgery of Trauma (AAST) anatomic severity scores based on first author review [13, 14]. Patient characteristics abstracted from our electronic data warehouse include age, sex, body mass index (BMI), marital status, insurance status, race, ethnicity, zip code, and comorbidities. Comorbidities were defined using Elixhauser Comorbidity Index (ECI) [15]. Patient zip code was matched with 2018 Internal Revenue Service (IRS) tax return data to determine mean household income as a potential marker of disparities [16]. Zip code level income data is commonly used as a proxy for socioeconomic status [17–19]. IRS tax return data groups adjusted gross income into 5 categories and provides information on total number of returns and total amount of income per each category. Our study combined the lowest two categories due to small volumes.

Disease severity was stratified based on ICD-10 diagnosis codes (Table 1), operative vs non-operative management based on the presence of a completed surgical case in our electronic medical record, need for ICU stay, need for mechanical ventilation (based on electronic orders),

Table 1 ICD-10 diagnosis codes for inclusion

	AAST Grades based on ICD-10 Codes					
Diagnosis	**Grade 1**	**Grade 2**	**Grade 3**	**Grade 4**	**Grade 5**	**NOS**
Appendicitis	K35.80 K35.890 K35.30	K35.891 K35.31	K35.32	K35.33	K35.20 K35.21	
Cholecystitis	K81.0 K81.1 K81.2 K81.9	K82.A1	K82.A2			
Small bowel obstruction	K56.51 K56.600 K56.690	K56.52 K56.601 K56.691				K56.52 K56.609 K56.699
Diverticulitis	K57.32 K57.33		K57.20 K57.21			
Umbilical hernia with obstruction or gangrene	N/A	K42.0	K42.1			
Femoral hernia with obstruction or gangrene	N/A	K41.00 K41.01 K41.30 K41.31	K41.10 K41.11 K41.40 K41.41			
Inguinal hernia with obstruction or gangrene	N/A	K40.00 K40.01 K40.30 K40.31	K40.10 K40.11 K40.40 K40.41			
Ventral hernia with obstruction or gangrene	N/A	K43.0 K43.6	K43.1 K43.7			

AAST - American Association for the Surgery of Trauma; NOS – Not otherwise specified, N/A – not applicable

and American Society of Anesthesiologists (ASA) score for patients who underwent anesthesia. Our overall COVID timeframe was further classified into five time periods based on COVID positivity rates across our health system: 1. First peak (3/17–4/16), 2. First interval (4/17–6/16), 3. Second peak (6/17–7/16), 4. Second interval (7/17–11/16), 5. Third peak (11/17–2/17). These time periods were based on our internal rates of positive COVID tests in symptomatic patients and correlated well with public health measures put in place locally (Fig. 1). For the COVID time period COVID-19 status was classified into three groups: 1. tested COVID positive, 2. tested COVID negative, and 3. untested based on test results within our electronic medical record. Facility type (ED vs UC vs ACH), bed size for ACHs (< 200 beds, 200–500 beds, and > 500 beds), and location were included in analysis.

Our primary outcome of interest was the number of EGS patients cared for monthly during the COVID-19 pandemic timeframe compared to historical controls. Secondary outcome measures include severity of disease, length of hospital stay, utilization of intensive care unit, ventilatory requirement, in-hospital mortality and 30-day readmission rate. Severity of disease was assessed in multiple ways, including: 1. correlation of ICD-10 diagnosis codes with AAST Severity Grades (Table 1) and disease complexity [20], 2. First available vital signs and initial laboratory values (including first monitored shock index value within 2 days of admission), 3. emergency status as noted by ASA score, and 4. length of surgery (incision to wound closure). 30-day readmissions included readmission to same facility or any other facility included in our dataset.

Descriptive statistics were used to compare EGS volumes in the COVID-19 pandemic cohort compared to the historical cohort, stratified by patient characteristics, disease characteristics, and facility characteristics. Secondary outcomes were compared between the two groups using both univariate and multivariate analyses models. Normality distribution was checked for continuous outcome variables before conducting any analysis. Median and interquartile range (IQR) were reported for continuous or ordinal variables, and frequency and percentage values were reported for categorical variables. Wilcoxon two-sample test for univariate analysis and robust regression for multivariable analysis models were used for any data in which the normality assumption was not met. Pearson's chi-square or Fisher's exact test was used for categorical outcome variables. Binary logistic regression and robust regression models were conducted after adjusting for covariates whose p-values were less than 0.05 in the univariate analysis models. Variables with greater than 3% of data missing had a "missing" category created which was included in the multivariable analyses. Sensitivity analysis

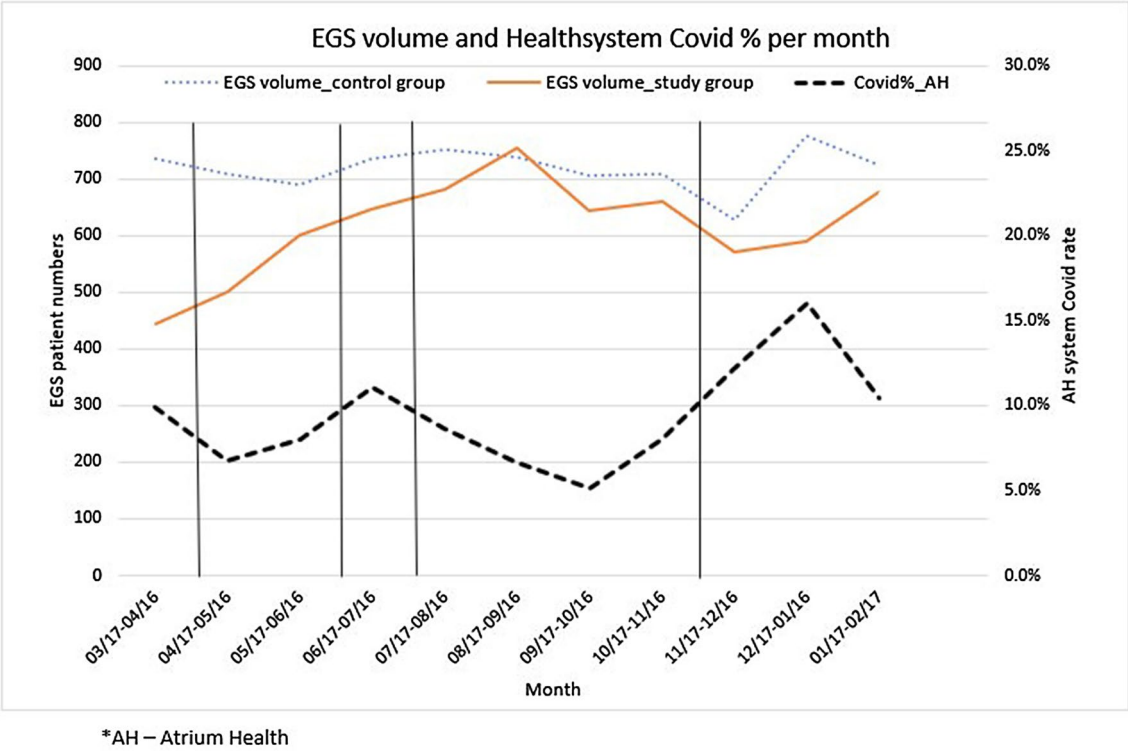

Fig. 1 EGS volume by month between historical and pandemic groups

was performed by creating models without any missing data to understand the potential impact of missing variables.

In addition, we compared EGS volumes, COVID test positivity rate, intensive care unit, ventilator requirement, 30-day readmission, mortality, and length of stay (LOS) at different time points. Peaks and intervals were identified for the COVID-19 pandemic cohort—2 peaks with positivity rate > 8.0% and 3 intervals with positivity rates ≤ 8%—and outcomes were compared across these time intervals using both univariate and multivariable analyses models (controlling for covariates whose p-values were less than 0.05 in the univariate analysis models). Two-tailed p values were calculated for all tests, and $p < 0.05$ was considered statistically significant. SAS 9.4 (SAS Institute Inc., Cary, NC) was used for all data analyses. This study was reviewed and approved by the Atrium Health Institutional Review Board.

Results

We identified 14,679 patients for inclusion in this study. There was a lower volume of EGS encounters across almost all timeframes within the pandemic cohort, with the greatest percentage decrease in EGS encounters during the time periods with the highest COVID positivity rates. There was no difference in the historical cohort and the pandemic cohort in distributions of EGS diagnoses or patient sex, race, relationship status, or ECI. The pandemic cohort had a higher percentage of patients at the age extremes (75+ years and 18–44.9 years), living in highest income zip codes, and residing in a metropolitan county (Table 2). In the overall pandemic cohort, 2.5% of patients had a COVID diagnosis (12.0% mortality in this cohort of patients who had a COVID diagnosis).

Examining factors associated with disease severity, the pandemic cohort had a higher percentage of patients with a fever, with an elevated WBC, and with a lactate > 2.2 (Table 3). There was no difference in the incidence of ICU utilization between the two groups, the requirement for a ventilator, AAST Grade based on ICD Diagnosis, or AAST Complexity.

In the pandemic cohort, there was a lower percentage of patients cared for at an acute care hospital and an increased percentage of patients managed in an urgent care or a free-standing ED (Table 4). A higher percentage of patients were managed in our smallest hospitals (< 200 beds). There was no difference in rates of procedures in the operating rooms or ASA status and no difference in time to the OR, though there was a higher percentage of patients in the pandemic cohort with an "emergency" ASA status. The pandemic cohort patients were more likely to have a longer length of surgery (operative time). There was no difference in LOS, but the pandemic cohort had a lower 30-day mortality but

Table 2 Patient and disease characteristics

	Historical cohort $N = 7908$ (%)	Pandemic cohort $N = 6771$ (%)	p-value
EGS diagnosis			0.98
Appendicitis	20.8	20.9	
Cholecystitis	14.8	14.8	
Small bowel obstruction	28.7	29.1	
Diverticulitis	29.8	29.3	
Hernia w/ obstruction or gangrene	6.0	5.9	
COVID test results			N/A
Positive	N/A	2.5	
Negative	N/A	30.2	
Untested	N/A	67.4	
Age			**0.02**
18–44.9	28.1	29.2	
45–64.9	36.5	34.8	
65–74.9	18.7	17.9	
75 +	16.8	18.2	
Female sex	53.9	54.2	0.73
Race			0.82
White/Caucasian	75.3	75.6	
Black/African	22.1	22.1	
Others	2.4	2.3	
Relationship status			0.12
Married	49.9	48.3	
Divorced/legally separated	11.2	10.9	
Single/widowed	38.4	40.2	
Missing/unknown	0.4	0.5	
*Body mass index (BMI)**			**< 0.001**
≤ 18.5 kg/m^2	2.8	3.5	
18.6–24.9 kg/m^2	23.1	23.7	
25–29.9 kg/m^2	27.0	27.7	
30–39.9 kg/m^2	28.4	29.2	
≥ 40 kg/m^2	8.2	9.0	
Missing	10.6	6.9	
Elixhauser comorbidity index			0.39
0–1	40.5	41.4	
2	0.7	0.8	
≥ 3	58.8	57.8	
Average income by zip code			**0.02**
≤ $49,999	37.2	36.4	
$50,000–$74,999	39.5	38.6	
$75,000–$99,999	7.9	7.7	
≥ $100,000	15.4	17.3	
Metropolitan status by zip code			**0.01**
Metropolitan county	81.6	83.2	
Non-metropolitan county	18.4	16.7	

*If missing not included in BMI analysis, groups were not different ($p = 0.19$)

a higher 30-day readmission rate. In subgroup analysis the readmission rates were not associated with non-operative management (or operative management) and additionally do not appear to be due to premature discharge given no difference in LOS. Within the COVID-19 pandemic group, we did note an increased time to OR for patients who had COVID-19 testing (2.1 days to OR for those who tested negative, 3.4 days for those who tested positive) compared to untested patients (0.7 days, $p = 0.01$ for both).

Multivariable analysis on secondary outcomes

Variables that were statistically significant in our univariate analysis and thus were included in the multivariable regression are age, BMI, income, metropolitan status, facility type, hospital size, emergency status by ASA score, temperature, WBC, and lactate (for both binary logistic regression and robust regression models). Cases without WBC or lactate were labeled as "clinically not obtained." ASA statuses without the "emergency" designation were identified as "non-emergency." Missing value categories were created for temperature, BMI, and metropolitan status. All outcomes continued to demonstrate significant differences between the pandemic group and historical group (Table 5). Compared to patients from the historical group, pandemic patients had lower odds of requiring ICU or ventilation and of 30-day mortality. There remained increased odds of 30-day readmission and a shorter LOS. A sensitivity analysis was performed by completing the multivariable analysis without the missing values and there was minimal impact on the odds ratios and all p values remained statistically significant.

Peak and interval analysis

Comparisons were made between Peaks 1 and 2 and Peak 3 based on initial review of outcomes. While Peak 3 had the highest rate of COVID positive patients, it had a lower percentage of patients with ICU utilization, ventilator use, surgical intervention and 30-day mortality (Table 6). There was no difference in LOS or distribution of EGS diagnoses between the early and late peaks (Table 6).

Discussion

Our study demonstrated that the volume of EGS cases during the COVID pandemic timeframe was decreased compared to a historical group, and that there did not appear to be an overall increase in disease severity across several measures nor a rebound effect in the timeframes after the COVID peaks. However, there did appear to be increased use of the ICU and ventilator and increased mortality in the first two COVID peaks compared to the third peak.

Table 3 Disease severity

	Historical cohort $N = 7908$ (%)	Pandemic cohort $N = 6771$ (%)	p-value
Temperature			**0.002**
< 96.8	0.4	0.2	
96.8–100.3	96.1	94.0	
> 100.3	2.7	3.6	
WBC			**0.04**
Not obtained	3.1	3.1	
< 3.6	1.3	1.9	
3.6–10.4	41.4	39.9	
> 10.4	54.1	55.2	
SBP			0.57
< 90	1.2	14	
90–130	48.5	47.7	
> 130	50.3	50.9	
HR			0.14
< 60	4.2	3.7	
60–99.9	69.9	69.3	
100–140	25.1	26.0	
> 140	0.8	1.0	
Lactate			**< 0.01**
Not obtained	62.1	43.6	
≤ 2.2	32.4	47.6	
> 2.2	5.6	8.8	
Monitored shock index			0.26
Not available	76.5	75.2	
Low (< 0.5)	3.7	4.2	
Normal (0.5–0.8)	13.3	13.5	
Elevated (0.8–1.0)	3.9	4.3	
Critically high (> 1.0)	2.7	2.8	
Intensive care unit	5.9	5.8	0.84
Ventilator requirement	2.0	2.1	0.59
*AAST grade based on ICD diagnosis**			0.93
Grade 1	69.3	69.3	
Grade 2	8.1	8.4	
Grade 3	9.3	8.9	
Grade 4	2.1	2.1	
Grade 5	0.5	0.6	
Unable to assign	10.6	10.6	
AAST complexity (based on Scott)			0.63
Low	83.3	83.6	
High	16.7	16.4	

WBC white blood cell, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *HR* heart rate, *AAST* American Association for the Surgery of Trauma

*If ICD Diagnosis code spanned multiple Grades, patients were assigned to lowest possible grade

While multiple prior studies have similarly demonstrated a decrease in EGS volumes during COVID peaks, many

Table 4 Management and outcomes

	Historical cohort $N = 7908$ (%)	Pandemic cohort $N = 6771$ (%)	*p*-value
Encounter status			0.34
Outpatient	43.4	44.6	
Observation	13.6	13.0	
Inpatient admission	43.4	44.6	
Facility type			**< 0.001**
Urgent care	0.3	0.5	
Freestanding ED	8.1	9.6	
Acute care hospital	91.6	89.9	
Acute care hospital size			**0.01**
< 200 beds	36.3	38.2	
200–500 beds	46	45.7	
> 500 beds	17.7	16.1	
Surgical management, %	40.8	41.2	0.63
ASA status			0.13
I	11.2	11.4	
II	46.0	42.7	
III	32.4	34.9	
IV–V	10.5	11.0	
Emergency status (by ASA score), %	34.4	37.1	**0.04**
Days to OR, median (IQR)	0 (0–1)	0 (0–1)	0.06
Number of surgical procedures			0.07
1	95.4	95.4	
2	3.6	3.1	
≥ 3	0.9	1.6	
Length of surgery			**< 0.001**
< 1 h	21.2	13.6	
1–3 h	67.1	74.2	
> 3 h	11.7	12.1	
Length of stay, median days (IQR)	2 (0.4)	1 (0.4)	0.33
30-day mortality	8.7	6.8	**< 0.001**
30-day readmission	33.9	36.2	**0.003**

ASA American Society of Anesthesiologists

Table 5 Multivariable analysis

Pandemic group vs. historical cohort			
	OR	95% CI	*p*-value
Mortality	0.7	(0.6, 0.8)	< 0.01
ICU utilization	0.7	(0.6, 0.8)	< 0.01
Ventilator use	0.7	(0.5, 0.9)	< 0.01
30-day readmission	1.2	(1.1, 1.3)	< 0.01
	Coefficient	95% CI	*p*-value
LOS	− 0.3	− 0.4, − 0.2	< 0.01

*Controlling for age, BMI, income, metropolitan status, facility type, hospital size, emergency status by ASA score, lactate, temperature, WBC with historical cohort as reference group

Table 6 Comparisons between Peak 1 and 2 vs. Peak 3

	Peak 1 and Peak 2 patients $N = 1092$ (%)	Peak 3 patients $N = 1837$ (%)	*p*-value
EGS diagnoses			0.23
Appendicitis	21.1	19.4	
Cholecystitis	14.9	14.2	
Small bowel obstruction	28.5	30.7	
Diverticulitis	29.4	29.8	
Hernia w/ obstruction or gangrene	6.0	5.8	
COVID Positivity	1.7	3.9	< 0.01
Intensive Care Unit utilization	7.3	4.2	< 0.01
Ventilator requirement	2.8	1.5	0.02
Surgical management	45.0	39.1	< 0.01
LOS, median days	1 (0,4)	1 (0,4)	0.29
30-day readmission	35.7	37.7	0.02
Mortality	8.0	5.8	0.02
Multivariable regression Peak 1 and 2 compared to Peak 3	OR	95% CI	*p*-value
ICU	1.7	(1.3–2.4)	< 0.01
Ventilator	1.7	(1.0–2.9)	0.04
Mortality	1.5	(1.1–2.0)	0.01

*Controlling for surgical management and ASA Score

Table 7 Literature summary

Author/year	Country/setting	Time frame	Comparison	Volume	Outcomes
Aviran 2020 [6] 2	Israel Single hospital	March 15–April 14, 2020	March 15–April 14, 2019	25% fewer admissions	Longer time interval prior to admission, worse clinical condition, more urgent surgery
Callan 2020 [7] 3	United Kingdom Single hospital	March 23–April 5, 2020	March 25–April 7, 2019	50% fewer admissions	Lower admission rate, similar intervention rate
D'Urbano 2020 [8] 4	Italy Single hospital	March 9–April 9, 2020	March 9–April 9, 2019	41% reduction in the number of patients who underwent emergency surgery	Higher complication rate
Tarim 2020 [9] 5	Turkey	March 15–May 15, 2020	March 15–May 15, 2019	32% reduction in surgical patients	Higher proportion of patients who had surgery, higher morbidity
McGuinness 2020 [10] 6	New Zealand Single hospital	March 26–April 27, 2020	February 22–March 25, 2020	26% decrease in admissions 43% reduction in operations performed	Shorter LOS No difference in mortality
Dick 2020 [11] 1	Scotland Single hospital	March 23–July 5, 2020	March 23–July 5, 2019	58% reduction in admissions	Increased proportion of patients having surgery and increased operative time
Paul 2020 [12] 7	USA New Jersey Healthsystem	January–April 2020	January–April 2019	Decrease in ED visits and admissions	Not reported

have been in single institutions or focused only on care provided during an admission to an acute care hospital [6–11], (Table 7). In a report of ED visits and inpatient admissions across a large academic New Jersey Healthcare system over a 4 month period, there were similar findings of a decrease in both ED visits and hospital admissions [21]. Within our healthcare system, many resources were redirected to focus on how to safely provide outpatient care or care within our smaller acute care hospitals whenever feasible in order to reserve our inpatient beds and highest acuity hospitals for the anticipated surge of COVID patients. These activities included increased threshold to admit patients who may be able to be managed as an outpatient, transfer of patients from high acuity hospitals to lower acuity hospitals when safe [22], and support of outpatient transition clinics that could provide "intermediate" care such as advanced imaging, intravenous fluids, and intravenous antibiotics.

The common theme throughout all publications is a decreased volume of emergency general surgery patients during the COVID-19 pandemic timeframes, and the reasons for this remain unclear. There were many concerns that patients who needed care were avoiding hospitals due to a fear of being infected with SARS-CoV-2 [6–8, 21]. One study also hypothesized that a general lack of accessibility to healthcare in the community—or dependence on telephone or video-based communication—during the COVID-19 pandemic may have led to delayed or missed diagnoses [6]. Previous publications examining EGS volumes during the COVID-19 timeframe were limited to 1–4 month periods [6–11, 21]. Our study is unique in that it examines presentation over a longer time period, and we did not identify a notable increase in EGS diagnoses in the post-peak time periods. It remains possible that patients delayed seeking care to such an extreme that they either died at home or died so shortly after arrival that they were unable to be diagnosed with an EGS etiology, and these remain difficult to assess. What is notable is that the decrease in EGS presentations during our third peak—almost a year after the pandemic initially occurred—was both still present, yet less pronounced than in the first two peaks. This was similarly seen in an examination of overall non-COVID-19 admissions to the emergency department in Italy [23]. The authors hypothesized that this could be due to decreased fear of the SARS-CoV-2 or increased healthcare preparedness.

An alternative explanation is that there was a shift in surgical management during this time, such as an increased willingness to treating patients in the community and an increased threshold for patient admission [7, 10, 24]. This is certainly an intriguing potential lesson learned from the COVID-19 pandemic. It has become evident from the recent boom in publications examining the EGS population that the majority of patients admitted with an EGS diagnosis do not undergo a surgical procedure [25]. Our study attempted to understand a portion of the outpatient management by including patients who were seen at an urgent care or ED but did not require observation stay or inpatient admission. Surprisingly, there was not a significant increase in the proportion of patients being managed as an outpatient after initial presentation. This suggests that any increase in outpatient management may have been driven by structures outside of urgent care and emergency departments, such as a primary care physicians or gastroenterology colleagues. Across both time periods, upwards of 40% of patients were managed as an outpatient and this again raises an interesting question about future structures of EGS care. Although the rate of readmissions was higher in the pandemic cohort, that was not associated with rates of non-operative management or LOS. Readmissions may provide useful insights into future opportunities to improve care, but we do not believe this should discourage the work that has been done to support appropriate outpatient management. Much of the work as we move out of the pandemic will focus on better understanding ways in which we can safely manage an increased proportion of EGS patients as an outpatient with the appropriate support structures in place.

Our data did not support our hypothesis that patients in the lowest income categories would make up a larger percentage of EGS patients during the highest peak period. We had hypothesized that patients in higher income quartiles would have more resources available to be able to manage diagnoses in an outpatient setting and avoid hospitalization. On the contrary, we found that a higher percentage of patients were in the highest income categories in the COVID timeframe. Our health system has a strong infrastructure of primary care and specialty care services targeted at the underserved population as part of our mission, which may have had an impact on this finding. Many other factors may have influenced differential utilization of care, such as decreased availability of EMS services or other forms of transportation, access to childcare, or level of understanding of safety of interacting with the healthcare system during the COVID-19 pandemic. Understanding the impact of disparities in access to care during times of limited hospital resources will inform future care paradigms.

In line with the concerns about patients not seeking appropriate care, there have also been fears that secondary to patients delaying care they may present with more severe disease processes, which would be predicted to result in worse outcomes. In Israel, patients in the COVID-19 timeframe were identified as having worse clinical condition based on an increased heart rate, increased leukocyte count, higher creatinine and CRP levels in the setting of increased days between onset of symptoms and presentation to the ED [6]. Notably, while all the clinical and laboratory values were statistically significant in that study, it's unclear if they were clinically different. In a study in Turkey, authors

found a higher rate of abscess and delayed abdominal emergency diseases, but no difference in time from beginning of complaints to presentation to the ED [9]. There remains no objective standardized method to measure severity of disease across a large cohort of patients, therefore, we attempted to examine severity of disease from multiple angles. In our study, evaluation of hemodynamics and laboratory values on admission revealed an increased percentage of patients with elevated temperatures and a decreased percentage of patients with a normal WBC, though these differences are small and of unclear clinical significance. There was notably a substantial increase in patients with an elevated lactate, which alternatively may represent advanced severity of disease. Concurrently there was a decrease in patients with no lactate value obtained, suggesting that there was either a concern for increased severity of disease or a change in clinical practice. However, there was no significant difference in presenting vital signs (systolic blood pressure, heart rate, or monitored shock index).

The American Association for the Surgery of Trauma has created severity scores across multiple EGS diagnoses and these have performed well as predictors of outcome [26–29]. While many authors have attempted to pair ICD-9 and ICD-10 diagnoses with AAST severity scores, this mapping remains imperfect. There was no difference in distribution of EGS diagnoses across our time periods, similar to other studies [9]. We similarly attempted to examine severity based on ICD-diagnosis codes mapped to AAST severity grades and to AAST Complexity levels as described in a previous publication [20]. There was no difference in distribution of severity grade or complexity in the historical versus pandemic time periods. Furthermore, there was no difference in the percentage of patents who required an ICU stay or required mechanical ventilation, further supporting the concept that there was no substantial increase in patient severity during the pandemic timeframe.

There has been conflicting data about rates of operative management and outcomes of EGS patients during the COVID timeframe. In Israel there was an increased proportion of patients who underwent surgical management while there was no difference in another a study from the United Kingdom [6, 7]. In our population there was no difference in the percent of patients who underwent surgical management and no difference in distribution of ASA physical status classification, although notably there was an increase in patients designated as "emergency" based on ASA scores. It's unclear if this reflects a true surgical emergency or is a reflection of a desire to document the need to do this case in the setting of a pandemic in which non-essential surgeries were delayed. However, the higher percentage of cases lasting over an hour and over 3 hours would suggest that there may have been some increased technical intraoperative challenges. Similar to Tarim, et al., we did not identify a difference in overall LOS [9]. Our COVID-19 pandemic population had lower 30-day mortality but higher 30-day readmission rates. Though statistically significant, it may be that the 3.3% higher readmission rate is not clinically significant.

Our study is the first to our knowledge to look at the distribution of EGS care across hospital settings within a healthcare system or region. There has been an ongoing discussion of the potential value of regionalization of EGS care as a method to improve outcomes [30]. Prior to COVID-19 our healthcare system had begun a process to "right-size" EGS care in which in addition to the historical practice of transferring critically ill patients to a "higher level of care" we had begun to transfer low-risk EGS patients to a nearby hospital [22]. In concordance with our on-the-ground experience, our data demonstrated an increased proportion of patients being managed at our smallest regional hospitals, which we believe was an intentional attempt to offload our highest volume tertiary care facilities. This required frequent communication and collaboration between our surgeons across multiple facilities to identify creative solutions and provide support for management in local settings. While these types of collaborations had been historically supported though our interfacility transfer process and the Atrium Health National Surgical Quality Improvement Program (NSQIP) Collaborative, they were further supported by a recently created Acute Care Surgery Network structure.

Putting together the myriad of data available regarding EGS volume, management and outcomes during the COVID-19 pandemic, several have concluded that the COVID-19 pandemic may have shed light on overuse of EDs by low complexity cases that could be managed as outpatients and highlights the opportunity for ongoing work to realize the benefits of a reduction in the number of hospital admissions for patients with nonurgent conditions [7, 9, 21, 24].

One interesting finding was the difference between Peak 1 and 2 patients in early 2020 and the Peak 3 patients in 2021. Although there was a higher percentage of EGS admissions who tested positive for COVID-19 in Peak 3, this cohort had a lower rate of ICU utilization, ventilator requirement and surgical management than in Peak 1. These findings suggest that although there was no difference in the overall comparison of pandemic vs. historical cohorts, there likely was some increased severity of disease in the earliest phases of the COVID-19 pandemic. Notably, Peak 3 did have some overlap with the first availability of COVID vaccines as the first COVID vaccination in North Carolina was given on December 14th, 2020 [31]. However, as of early February 2021, only 6.75% of the Mecklenburg County population had received a single dose of the vaccine and only 1.8% were fully vaccinated, suggesting that the vaccine likely had minimal impact on Peak 3 [32].

Despite the benefits of our study being across a healthcare region, including ED, urgent care, and hospital visits, and examining the impact of the COVID-19 pandemic on EGS diagnoses across a longer timeframe, our study does have limitations. Due to the high volume of patients in each cohort, it was not feasible to obtain information on the time interval from onset of symptoms to presentation for evaluation. Additionally, it is possible that patients sought care at a facility outside of our system during the COVID-19 pandemic and thus would not be available within our dataset. Finally, there is no way to determine if patients died due to delay in seeking care and thus would not have been able to be included in our dataset.

Conclusions

Our study demonstrated that there was a decreased volume of patients with EGS diagnoses who received care at an urgent care, freestanding ED, or hospital facility during the peaks of the COVID-19 pandemic in our healthcare system. There was a decrease in patients evaluated at an acute care hospital and an increase in patients managed at our smaller hospitals, potentially reflecting efforts on both the part of the healthcare system and patients to offload our highest acuity facilities during the time of a healthcare crisis. We agree with other authors that this offers the opportunity to examine lessons learned during the COVID-19 pandemic and thoughtfully consider how they can be applied to future management of EGS patients to reduce healthcare utilization while maintaining patient outcomes.

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Declarations

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References

1. Khubchandani JA, Shen C, Ayturk D, Kiefe CI, Santry HP (2018) Disparities in access to emergency general surgery care in the United States. Surgery 163:243–250
2. COVIDSurg Collaborative (2021) Effect of COVID-19 pandemic lockdowns on planned cancer surgery for 15 tumour types in 61 countries: an international, prospective, cohort study. Lancet Oncol 22:1507–1517
3. (2020) COVID 19: Elective Case Triage Guidelines for Surgical Care - Emergency General Surgery. American College of Surgeons. https://www.facs.org/covid-19/clinical-guidance/elective-case
4. Di Saverio S, Khan M, Pata F, Ietto G, De Simone B, Carceno G (2020) Laparoscopy at all costs? Not now during COVID-19 outbreak and not for acute care surgery and emergency colorectal surgery: a practical algorithm from a hub tertiary teaching hospital in Northern Lombardy, Italy. J Trauma Acute Care Surg 88:715–718
5. Ross SW, Lauer CW, Miles WS, Green J, Christmas AB, May AK, Matthews BD (2020) Maximizing the calm before the storm: tiered surgical response plan for novel coronavirus (COVID-19). J Am Coll Surg 230:1080
6. Aviran E, Laks S, Benvenisti H, Khalilieh S, Assaf D, Aviran N, Hazzan D, Klein Y, Cohen A, Gutman M, Nissan A, Segev L (2020) The impact of the COVID-19 pandemic on general surgery acute admissions and urgent operations: a comparative prospective study. Isr Med Assoc J 11:673–679
7. Callan R, Assaf N, Bevan K (2020) Impact of the COVID-19 pandemic on acute general surgical admissions in a district general hospital in the United Kingdom: a retrospective cohort study. Surg Res Pract 2020:2975089
8. D'Urbano F, Fabbri N, Koleva Radica M, Rossin E, Carcoforo P (2020) Emergency surgery in COVID-19 outbreak: has anything changed? Single center experience. World J Clin Cases 8:3691–3696
9. Tarim IA, Derebey M, Ozbalci GS, Ozsay O, Yuksek MA, Buyukakincak S, Bircan R, Gungor BB, Basoglu M (2021) The impact of the COVID-19 pandemic on emergency general surgery: a retrospective study. Sao Paulo Med J 139:53–57
10. McGuinness MJ, Hsee L (2020) Impact of the COVID-19 national lockdown on emergency general surgery: Auckland City Hospital's experience. ANZ J Surg 90:2254–2258
11. Dick L, Green J, Brown J, Kennedy E, Cassidy R, Othman S, Berlansky M (2020) Changes in emergency general surgery during Covid-19 in Scotland: a prospective cohort study. World J Surg 44:3590–3594
12. Paul S, Sesti J, Hilden P, Turner A, Pencak D, Anderson A, Bonamo J, Salemi A (2020) Decrease in hospital admissions for acute surgical conditions during the COVID-19 pandemic. Ann Surg Open 1:e020
13. Data Dictionaries for AAST Grading System for EGS Conditions. https://www.aast.org/resources-detail/egs
14. Tominaga GT, Staudenmayer KL, Shafi S, Schuster KM, Savage SA, Ross S, Muskat P, Mowery NT, Miller P, Inaba K, Cohen MJ, Ciesla D, Brown CV, Agarwal S, Aboutanos MB, Utter GH, Crandall M, Association A, for the Surgery of Trauma Committee on Patient A, (2016) The American Association for the Surgery of Trauma grading scale for 16 emergency general surgery conditions: disease-specific criteria characterizing anatomic severity grading. J Trauma Acute Care Surg 81:593–602
15. Quan H, Sundararajan V, Halfon P, Fong A, Burnand B, Luthi JC, Saunders LD, Beck CA, Feasby TE, Ghali WA (2005) Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. Med Care 43:1130–1139
16. SOI Tax Stats—Individual Income Tax Statistics—2018 ZIP Code Data. Internal Revenue Service. https://www.irs.gov/statistics/soi-tax-stats-individual-income-tax-statistics-2018-zip-code-data-soi
17. ZIPINC_QRTL—Median Household income for patient's ZIP Code. Agency for Healthcare Research and Quality. https://www.hcup-us.ahrq.gov/db/vars/zipinc_qrtl/nisnote.jsp
18. Montgomery E, Pernik M, Johnson Z (2021) Perioperative factors associated with chronic opioid use after spine surgery. Global Spine J Published online August 20, 2021. https://doi.org/10.1177/21925682211035723

19. Kadar RB, Amici DR, Hesse K, Bonder A, Ries M (2019) Impact of telemonitoring of critically Ill emergency department patients awaiting ICU transfer. Crit Care Med 47:1201–1207
20. Scott JW, Staudenmayer K, Sangji N, Fan Z, Hemmila M, Utter G (2021) Evaluating the association between American Association for the Surgery of Trauma emergency general surgery anatomic severity grades and clinical outcomes using national claims data. J Trauma Acute Care Surg 90:296–304
21. Paul S, Sesti J, Hilden P, Turner A, Pencak D, Anderson A, Bonamo J, Salemi A (2020) Decrease in hospital admissions for acute surgical conditions during the COVID-19 pandemic. Ann Surg Open 1:e020
22. Baimas-George M, Schiffern L, Yang H, Paton L, Barbat S, Matthews B, Reinke CE (2021) Emergency general surgery transfer to lower acuity facility: the role of right-sizing care in EGS regionalization. J Trauma Acute Care Surg 92:38
23. Mantica G, Riccardi N, Terrone C, Gratarola A (2021) Non-COVID-19 admissions to the emergency department during the pandemic second wave in Italy: what is changed from the first wave? Am J Emerg Med 45:625–626
24. Patriti A, Eugeni E, Guerra F (2020) What happened to surgical emergencies in the era of COVID-19 outbreak? Considerations of surgeons working in an Italian COVID-19 red zone. Updates Surg 72:309–310
25. Gale SC, Shafi S, Dombrovskiy VY, Arumugam D, Crystal JS (2014) The public health burden of emergency general surgery in the United States: a 10-year analysis of the Nationwide Inpatient Sample–2001 to 2010. J Trauma Acute Care Surg 77:202–208
26. Hernandez M, Murphy B, Aho JM, Haddad NN, Saleem H, Zeb M, Morris DS, Jenkins DH, Zielinski M (2018) Validation of the AAST EGS acute cholecystitis grade and comparison with the Tokyo guidelines. Surgery 163:739–746
27. Hernandez MC, Aho JM, Habermann EB, Choudhry AJ, Morris DS, Zielinski MD (2017) Increased anatomic severity predicts outcomes: validation of the American Association for the Surgery of Trauma's Emergency General Surgery score in appendicitis. J Trauma Acute Care Surg 82:73–79
28. Hernandez MC, Birindelli A, Bruce JL, Buitendag JJP, Kong VY, Beuran M, Aho JM, Negoi I, Clarke DL, Di Saverio S, Zielinski MD (2018) Application of the AAST EGS grade for adhesive small bowel obstruction to a multi-national patient population. World J Surg 42:3581–3588
29. Shafi S, Priest EL, Crandall ML, Klekar CS, Nazim A, Aboutanos M, Agarwal S, Bhattacharya B, Byrge N, Dhillon TS, Eboli DJ, Fielder D, Guillamondegui O, Gunter O, Inaba K, Mowery NT, Nirula R, Ross SE, Savage SA, Schuster KM, Schmoker RK, Siboni S, Siparsky N, Trust MD, Utter GH, Whelan J, Feliciano DV, Rozycki G, American Association for the Surgery of Trauma Patient Assessment C (2016) Multicenter validation of American Association for the Surgery of Trauma grading system for acute colonic diverticulitis and its use for emergency general surgery quality improvement program. J Trauma Acute Care Surg 80:405–410
30. Santry H, Kao LS, Shafi S, Lottenberg L, Crandall M (2019) Pro-con debate on regionalization of emergency general surgery: controversy or common sense? Trauma Surg Acute Care Open 4:e000319
31. First person in NC receives COVID-19 Vaccine: "I couldn't be more excited" WBTV. 14 December 2020. https://www.wbtv.com/2020/12/14/first-person-nc-receives-covid-vaccine-i-couldnt-be-more-excited/
32. Mecklenburg County, NC COVID-19 Vaccine Tracker. https://data.democratandchronicle.com/covid-19-vaccine-tracker/north-carolina/mecklenburg-county/37119/

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