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Surgery 172 (2022) 989–996

Contents lists available at ScienceDirect

Surgery

journal homepage: www.elsevier.com/locate/surg

Pediatrics

Association between COVID-19 related elective surgery cancellations and pediatric inguinal hernia complications: A nationwide multicenter cohort study

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ARTICLE INFO

Article history:
Accepted 14 May 2022
Available online 20 May 2022

ABSTRACT

Background: Optimal inguinal hernia repair timing remains controversial. It remains unclear how COVID-19 related elective surgery cancellations impacted timing of inguinal hernia repair and whether any delays led to complications. This study aims to determine whether elective surgery cancellations are safe in pediatric inguinal hernia.

Methods: This multicenter retrospective cohort study at 14 children's hospitals included patients ≤18 years who underwent inguinal hernia repair between September 13, 2019, through September 13, 2020. Patients were categorized by whether their inguinal hernia repair occurred before or after their hospital's COVID-19 elective surgery cancellation date. Incarceration and emergency department encounters were compared between pre and postcancellation.

Results: Of 1,404 patients, 604 (43.0%) underwent inguinal hernia repair during the postcancellation period, 92 (6.6%) experienced incarceration, and 213 (15.2%) had an emergency department encounter. The postcancellation period was not associated with incarceration (odds ratio 1.54; 95% confidence interval 0.88–2.71; $P = .13$) or emergency department encounters (odds ratio 1.53; 95% confidence interval 0.94–2.48; $P = .09$) despite longer median times to inguinal hernia repair (precancellation 29 days [interquartile range 13–55 days] versus postcancellation 31 days [interquartile range 14–73 days], $P =$

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https://doi.org/10.1016/j.surg.2022.05.011

.01). Infants were more likely to have the emergency department be their index presentation in the postcancellation period (odds ratio 1.69; 95% confidence interval 1.24–2.31; $P < .01$).
Conclusion: Overall, COVID-19 elective surgery cancellations do not appear to increase the likelihood of incarceration or emergency department encounters despite delays in inguinal hernia repair, suggesting that cancellations are safe in children with inguinal hernia. Assessment of elective surgery cancellation safety has important implications for health policy.

Introduction

Inguinal hernias are common, with an estimated incidence exceeding 6% in male children.[1] The primary consideration in deciding the timing of inguinal hernia repair (IHR) involves reducing the risk of incarceration. Inguinal hernia incarceration rates in children vary between 3% and 12%, with younger patients being at increased risk.[2,3] Optimal timing of IHR remains controversial among pediatric surgeons, with suggested wait times ranging from within 7 days to multiple weeks depending on the patient's adjusted gestational age.[4–6]

With the spread of the COVID-19 pandemic in the United States, the American College of Surgeons recommended on March 13, 2020 for hospitals to "minimize, postpone, or cancel electively scheduled operations."[7] This recommendation was shortly followed by states issuing mandates and guidance that caused health systems to cancel elective procedures and triage operations to better preserve resources.[8] Given the controversy surrounding the semi-elective nature of pediatric IHR, it is unclear if delays in repair occurred. Furthermore, it is uncertain if elective surgery cancellations resulted in increases in inguinal hernia incarceration given either delays in IHR or reduced access to other health care services (eg, primary care or in-person clinic visits).[9]

This study aimed to characterize the association between COVID-19 related elective surgery cancellations and delays in IHR, pediatric inguinal hernia incarceration, and related emergency department (ED) visits. With these considerations, the authors sought to determine whether elective surgery cancellations were safe in pediatric IHR and, if so, identify if there is a safe period for which repair can be delayed.

Methods

Study design

This multi-institutional retrospective cohort study was conducted at 14 US children's hospitals participating in the Pediatric Surgery Research Collaborative (www.PedSRC.org). Data were abstracted from the electronic medical record by clinicians, deidentified, and then securely transferred to the coordinating center for analysis. To ensure consistency and accuracy, a codebook with definitions and variable criteria was distributed to all participating hospitals and abstractors. The institutional review board at each participating hospital approved the study in addition to a waiver of informed consent. Data use agreements were obtained between the data coordinating center and each participating hospital (Lurie Children's IRB 2020–3940).

Study cohort

All patients ≤18 years of age undergoing a primary IHR at the 14 participating hospitals from September 13, 2019, through September 13, 2020, were considered for inclusion. We did not include patients undergoing operations that would have theoretically affected the planning of IHR timing (eg, orchiopexy for undescended testes). We excluded patients with missing outcomes data and those diagnosed with inguinal hernia as an inpatient as surgeons may have preferred to perform IHR before discharge.

Exposure classification and outcomes

Each participating site was contacted and asked to report when their hospital's elective surgery cancellation period started. IHRs occurring on or after the self-reported cancellation date through September 13, 2020, were considered to have occurred in the "postcancellation" period. Hernias repaired before this date were considered "precancellation." As the duration of elective surgery cancellation was not uniform among hospitals, sites were asked to report when elective surgeries resumed at their hospital. In cases where a staged resumption of elective surgeries occurred, the date at which 50% of total elective surgery capacity resumed was chosen as the date of resumption. Hospitals were divided into quartiles by their duration of elective surgery cancellation (ie, date of elective surgery cancellation through date of elective surgery resumption), which was further categorized into short (quartiles 1 and 2) and long (quartiles 3 and 4) cancellation durations.

Patient characteristics were collected including gender, race, adjusted gestational age at diagnosis, insurance status, laterality of hernia, and American Society of Anesthesiologists (ASA) Physical Status Classification. Time to inguinal hernia repair (TIHR) was defined as the date of diagnosis by the operating physician through to the date of IHR. The primary outcome of interest was any inguinal hernia incarceration, as documented by the examining surgeon. The secondary outcome was any ED encounter related to the inguinal hernia. Each outcome was treated as binary with patients with ≥1 incidence of the outcome considered to have experienced the outcome. For both outcomes, it was determined if patients experienced them at diagnosis (ie, at the index presentation) or if they occurred in the interval period (ie, after diagnosis and before repair). These were similarly treated as binary (ie, patients with ≥1 interval outcome were considered to have experienced the interval outcome). In patients who presented to the ED as their index presentation or in the interval period, the proportion of patients who underwent urgent repair, defined as within 48 hours of presentation, was examined.

Statistical analysis

Pearson's χ^2, Fishers exact, and Wilcoxon rank-sum tests were used to compare patient characteristics, TIHR, and urgent repair after ED presentation between pre and postcancellation periods. Similarly, demographics between patients with and without the outcomes of interest were compared. Multivariable logistic regression models clustered by hospital were used to estimate the association between cancellation period and (1) any incarceration (2) incarceration at diagnosis. Covariates identified from previous studies[1,3,10,11] thought to influence the rate of incarceration and significant covariates on bivariate analysis were included as covariates in the regression models. These covariates included gender,

Table I
Inguinal hernia repair patient characteristics by cancellation period at 14 US children's hospitals between September 13, 2019 and September 13, 2020

	Precancellation ($n = 800$)	Postcancellation ($n = 604$)	*P* value
	No. (%)	No. (%)	
Sex			
Male	616 (77.0%)	480 (79.5%)	.27
Female	184 (23.0%)	124 (20.5%)	
Race			
Non-Hispanic White	383 (47.8%)	319 (52.8%)	<.01
Hispanic White	79 (9.9%)	40 (6.6%)	
Black/African American	167 (20.9%)	146 (24.2%)	
Other/refused	88 (11.0%)	81 (13.4%)	
Missing	83 (10.4%)	18 (3.0%)	
Adjusted gestational age, years			
Median (IQR)	2.4 (0.2–6.1)	1.6 (0.2–5.4)	.04
Insurance			
Private	496 (62.0%)	364 (60.3%)	.37
Public	270 (33.7%)	221 (36.6%)	
Other or uninsured	14 (1.8%)	5 (0.8%)	
Missing	20 (2.5%)	14 (2.3%)	
Laterality			
Bilateral	91 (11.4%)	72 (11.9%)	.93
Left	270 (33.7%)	206 (34.1%)	
Right	439 (54.9%)	326 (54.0%)	
ASA			
ASA class 1/2	731 (91.4%)	566 (93.7%)	.10
ASA class 3/4	69 (8.6%)	38 (6.3%)	
Incarceration			
No incarceration	754 (94.2%)	558 (92.4%)	.37
Incarceration at diagnosis	26 (3.3%)	27 (4.5%)	
Interval incarceration	20 (2.5%)	19 (3.1%)	
ED encounters			
No ED encounter	696 (87.0%)	495 (82.0%)	.03
ED as index presentation	78 (9.7%)	82 (13.6%)	
Interval ED encounter	26 (3.3%)	27 (4.4%)	

Precancellation period was defined as September 13, 2019 to the date that hospitals cancelled elective surgeries, and postcancellation was defined as the date of elective surgery cancellation through September 13, 2020.
ASA, American Society of Anesthesia classification; *ED*, emergency department; *IQR*, interquartile range.

race, adjusted gestational age at diagnosis, insurance status, laterality, and ASA classification. A multivariable model including the same covariates was used to estimate association between cancellation period and (1) any ED encounter (2) ED as the index presentation. The authors hypothesized that cancellation duration may have modified the effect of cancellation period on our outcomes. Therefore, we examined the interaction between cancellation period and cancellation duration.

Next, we estimated the association between cancellation period and interval outcomes (ie, those occurring after the index presentation). Patients who, at their index presentation, were either incarcerated or had undergone an urgent repair after an ED encounter were excluded. This model adjusted for TIHR treated as a categorical variable (<2 weeks, >2 weeks and ≤4 weeks, >1 month and ≤3 months, ≥4 months) in addition to patient characteristics. In this same cohort, we developed Kaplan-Meier survival curves where an elective repair was considered a censoring event, while interval incarceration or an interval ED encounter was considered an event outcome. Event-free survival for patients undergoing IHR in both pre and postcancellation periods was compared using the log-rank test.

As age is a risk factor for incarceration, with infants (<1 year of age) being at greatest reported risk,[12] we performed a sensitivity analysis to determine consistency of our findings in this age group. We recognized that examining patients 6 months after the enactment of cancellations likely included patients not affected by cancellations. We intentionally did this to ensure capture of patients who had significantly delayed IHRs. To minimize the effects of resumption of usual clinical practice, and to capture the more acute postcancellation setting, we examined differences in incarceration and ED encounters 3 months pre and postcancellation. Given the more limited sample size, we chose not to examine interaction terms in either of these analyses.

The reported incidence of inguinal hernia incarceration varies significantly in the literature. After agreement by the study team and review of the literature, it was determined that an increase from a baseline 5% incarceration rate to 10% would be clinically significant.[3] The necessary overall sample size for such a study would be 868 patients. The α value was set at .05, and all statistical tests were 2-tailed. Statistical analyses were performed using Stata, version 17.0 (StataCorp LLC).

Results

Study cohort

In total, 1,564 patients were identified to have undergone a primary IHR at the 14 participating US children's hospitals during the study period. Of these, 136 were excluded for being diagnosed as an inpatient, and 24 were excluded for missing outcomes data. Of the 1,404 patients included in our final analyses, 1,096 (78.1%) were male, 702 (50.0%) were non-Hispanic White, and 860 (61.3%) were privately insured. The median adjusted gestational age was 1.8 years (interquartile range [IQR], 0.2–5.8 years). The average number of patients per hospital was 100 (standard deviation [SD], 62 patients).

Table II
Patient characteristics in patients with inguinal hernia incarceration and emergency department encounters at 14 US children's hospitals between September 13, 2019 and September 13, 2020

	No incarceration (n = 1,312)	Any incarceration (n = 92)	P *value*	No emergency department (n = 1,191)	Any emergency department (n = 213)	*P* value
	No. (%)	No. (%)		No. (%)	*i*	
Sex						
Male	1011 (77.1%)	85 (92.4%)	<.01	909 (76.3%)	187 (87.8%)	<.01
Female	301 (22.9%)	7 (7.6%)		282 (23.7%)	26 (12.2%)	
Race						
Non-Hispanic White	671 (51.1%)	31 (33.7%)	.01	620 (52.1%)	82 (38.5%)	<.01
Hispanic White	108 (8.2%)	11 (12.0%)		96 (8.1%)	23 (10.8%)	
Black/African American	285 (21.7%)	28 (30.4%)		243 (20.4%)	70 (32.9%)	
Other/refused	152 (11.6%)	17 (18.5%)		143 (12.0%)	26 (12.2%)	
Missing	96 (7.4%)	5 (5.4%)		89 (7.5%)	12 (5.6%)	
Adjusted gestational age, years						
Median (IQR)	2.19 (0.23–5.89)	0.33 (0.11–1.82)	<.01	2.50 (0.25–6.12)	0.38 (0.12–2.23)	<.01
Insurance						
Private	822 (62.7%)	38 (41.3%)	<.01	757 (63.6%)	103 (48.4%)	<.01
Public	447 (34.1%)	44 (47.8%)		394 (33.1%)	97 (45.5%)	
Other or Uninsured	15 (1.1%)	4 (4.4%)		14 (1.2%)	5 (2.4%)	
Missing	28 (2.1%)	6 (6.5%)		26 (2.2%)	8 (3.8%)	
Laterality						
Bilateral	147 (11.2%)	16 (17.4%)	.13	131 (11.0%)	32 (15.0%)	.03
Left	451 (34.4%)	25 (27.2%)		419 (35.2%)	57 (26.8%)	
Right	714 (54.4%)	51 (55.4%)		641 (53.8%)	124 (58.2%)	
ASA						
ASA class 1/2	1217 (92.8%)	80 (87.0%)	.04	1,107 (93.0%)	190 (89.2%)	.06
ASA class 3/4	95 (7.2%)	12 (13.0%)		84 (7.1%)	23 (10.8%)	
Cancellation period						
Precancellation	754 (57.5%)	46 (50.0%)	.16	696 (58.4%)	104 (48.8%)	.01
Postcancellation	558 (42.5%)	46 (50.0%)		495 (41.6%)	109 (51.2%)	

Precancellation period was defined as September 13, 2019 to the date that hospitals cancelled elective surgeries, and postcancellation was defined as the date of elective surgery cancellation through September 13, 2020.
ASA, American Society of Anesthesiologist classification; *IQR*, interquartile range.

Cancellation period and duration

All participating hospitals reported that they had halted elective surgeries by March 23, 2020 and resumed elective surgeries by June 1, 2020. The median duration of elective surgery cancellation was 43 days (IQR 34.8–50.8 days). Eight hospitals had short cancellation durations with a median duration of 35.5 days (IQR 34.0–39.0 days), while 6 had long cancellation durations with a median duration of 52 days (IQR 48.3–54.3 days). Of the study cohort, 604 (43.0%) patients underwent IHR during the postcancellation period. In bivariate analyses, younger and non-Hispanic White patients were more common in the postcancellation period. There was no other significant difference in patient demographics between pre and postcancellation periods (Table I).

Incarceration and emergency department encounters

Inguinal hernia incarceration occurred in 92 (6.6%) patients, of which 53 (3.8%) occurred at diagnosis and 39 (2.8%) in the interval period. In bivariate analysis, patients who experienced incarceration were more commonly male, younger, non-White, publicly insured, and ASA class 3/4 patients when compared with patients who did not experience incarceration. Incarceration was not observed more frequently in the postcancellation period. There were 213 (15.2%) patients who had ED encounters, of which 160 (11.4%) occurred at the index presentation and 53 (3.8%) occurred in the interval period. Patients who had an ED encounter were more commonly male, non-White, younger, publicly insured, and had bilateral hernias compared to those without an ED encounter. ED encounters were more common in the postcancellation period (Table II). Compared to precancellation rates, both rates of ED as the index presentation and interval ED encounters increased, while no significant difference was noted in incarceration at either diagnosis or in the interval period (Table I).

Cancellation period and incarceration or emergency department encounters

Compared to the precancellation period, the postcancellation period was not associated with an increased likelihood of incarceration (odds ratio [OR] 1.36; 95% confidence interval [CI] 0.85–2.18; P = .19) in unadjusted analysis or after adjusting for patient characteristics (adjusted odds ratio [aOR] 1.54; 95% CI 0.88–2.71; P = .13). Incarceration was associated with male gender, younger age, Hispanic-White and other races, and unknown or uninsured patients (Table III). The postcancellation period was not associated with incarceration in either short (aOR 1.54; 95% CI 0.87–2.43; P = .13) or long elective surgery cancellation durations (aOR 1.21; 95% CI 0.64–2.32; P = .54). The likelihood of incarceration attributed to the postcancellation period was not significantly different between cancellation durations (P = .58).

In unadjusted analyses, the postcancellation period was associated with an increased likelihood of the patient having an ED encounter (OR, 1.47; 95% CI 1.04–2.07; P = .03) but not after adjusting for patient characteristics (aOR, 1.53; 95% CI 0.94–2.48; P = .09). Patients of male gender, younger age, Black or "other" race, and with public or unknown/uninsured insurance status were more likely to have ED encounters (Table III). The postcancellation period was not associated with an increased likelihood of ED encounters in patients treated at hospitals with either short (aOR 1.52; 95% CI 0.94–2.47; P = .09) or long cancellation durations (aOR

Table III
Association of elective surgery cancellation with inguinal hernia incarceration and emergency department encounters at 14 US children's hospitals between September 13, 2019 and September 13, 2020

	Any incarceration		Incarceration at diagnosis		Any ED encounter		ED as index presentation	
	aOR (95% CI)	*P* value	aOR (95% CI)	*P* value	aOR (95% CI)	*P* value	aOR (95% CI)	*P* value
Cancellation period								
Precancellation	Ref		Ref		Ref		Ref	
Postcancellation	1.54 (0.88–2.71)	.13	1.57 (0.68–3.65)	0.29	1.53 (0.94–2.48)	0.09	1.34 (0.94–1.89)	.10
Cancellation duration								
Short cancellation	Ref		Ref		Ref		Ref	
Long cancellation	1.36 (0.76–2.43)	.30	1.38 (0.55–3.51)	0.49	1.00 (0.61–1.62)	0.98	0.73 (0.36–1.50)	.39
Period ## Duration*	0.79 (0.34–1.82)	.58	0.81 (0.28–2.36)	0.69	0.89 (0.40–1.99)	0.78	1.18 (0.53–2.62)	.68
Sex								
Female	Ref		Ref		Ref		Ref	
Male	3.39 (1.44–7.96)	.01	4.44 (1.20–16.46)	0.03	1.93 (1.04–3.58)	0.04	1.86 (1.04–3.32)	.04
Adjusted gestational age, years	0.89 (0.81–0.97)	.01	0.88 (0.79–0.99)	0.04	0.90 (0.86–0.95)	<0.001	0.91 (0.85–0.97)	<.01
Race								
Non-Hispanic White	Ref		Ref		Ref		Ref	
Hispanic White	1.97 (1.19–3.27)	.01	1.38 (0.77–2.48)	0.29	1.60 (0.95–2.71)	0.08	1.42 (0.89–2.26)	.14
Black/African American	1.62 (0.94–2.81)	.08	1.30 (0.74–2.29)	0.36	1.77 (1.14–2.74)	0.01	1.55 (1.01–2.37)	.04
Other	2.53 (1.52–4.22)	<.01	2.26 (1.09–4.66)	0.03	1.42 (1.03–1.96)	0.03	1.44 (0.86–2.41)	.16
Unknown/refused	2.20 (0.98–4.90)	.06	2.83 (1.41–5.69)	<0.01	1.32 (0.78–2.23)	0.30	1.57 (0.89–2.79)	.12
Insurance								
Private	Ref		Ref		Ref		Ref	
Public	1.63 (0.93–2.88)	.09	1.67 (0.83–3.36)	0.15	1.35 (1.06–1.74)	0.02	1.45 (1.13–1.86)	<.01
Unknown/uninsured	5.26 (2.80–9.89)	<.01	3.09 (1.28–7.47)	0.01	2.21 (1.64–2.99)	<.001	1.84 (1.40–2.41)	<.01
Laterality								
Bilateral	Ref		Ref		Ref		Ref	
Left	0.76 (0.44–1.31)	.32	0.55 (0.27–1.11)	.09	0.76 (0.45–1.27)	.29	0.78 (0.47–1.27)	.32
Right	0.99 (0.54–1.81)	.98	0.91 (0.53–1.57)	0.74	1.11 (0.73–1.70)	0.62	1.07 (0.70–1.65)	.75
ASA class								
ASA class 1/2	Ref		Ref		Ref		Ref	
ASA class 3/4	1.61 (0.91–2.84)	.10	1.56 (0.93–2.61)	0.09	1.33 (0.52–3.38)	0.55	1.43 (0.57–3.56)	.45

Precancellation period was defined as September 13, 2019, to the date that hospitals cancelled elective surgeries, and postcancellation was defined as the date of elective surgery cancellation through September 13, 2020.
aOR, adjusted odds ratio; *ASA*, American Society of Anesthesiologist classification; *CI*, confidence interval; *ED*, emergency department.
* This represents the interaction term between cancellation period and cancellation duration.

1.36; 95% CI 0.71–2.60; $P = .35$). There was no significant difference in likelihood between cancellation durations ($P = .78$).

The postcancellation period was not associated with an increased likelihood of incarcerated inguinal hernia at diagnosis (aOR 1.57; 95% CI 0.68–3.65; $P = .29$) or having an ED encounter as their index presentation (aOR 1.34; 95% CI 0.94–1.89; $P = .10$). Of the 160 patients presenting to the ED as their index presentation, 72 (45.0%) underwent an urgent repair, which was similar between cancellation periods (precancellation, $n = 35/78$ [44.9%] vs postcancellation, $n = 37/82$ [45.1%]; $P = .97$).

Cancellation and time to inguinal hernia repair

We excluded patients presenting with an incarcerated inguinal hernia at diagnosis and those presenting to the ED as their index presentation who underwent an urgent operation. In total, 1,321 patients were included in our analysis examining cancellation period and TIHR. The median TIHR was 29 days (IQR 14–63 days). There was a statistically significant difference in median TIHR between cancellation periods (precancellation median TIHR 29 days [13–55 days] vs postcancellation median TIHR 31 days [14–73 days], $P = .01$). The mean TIHR was 47.8 days (SD 92.2 days) in the precancellation period and 63.6 days (SD 119.7 days) in the postcancellation period.

Interval incarceration and emergency department encounters

The postcancellation period was not associated with an increased likelihood of interval incarceration (OR 1.21; 95% CI 0.68–2.13; $P = .50$) in unadjusted analysis or after adjusting for TIHR and patient demographics (aOR 1.15; 95% CI 0.64–2.05; $P = .65$). No time period of TIHR was associated with incarceration. Non-White races and unknown/uninsured patients were more likely to experience interval incarceration (Table IV).

Similarly, the postcancellation period was not associated with an increased likelihood of interval ED presentations (OR 1.48; 95% CI 0.71–3.09; $P = .29$) in unadjusted analysis or after adjusting for demographics and TIHR (aOR 1.27; 95% CI 0.62–2.59; $P = .52$). However, patients were more likely to present to the ED in the 2-week and ≥4-month period after diagnosis. Hispanic White, Black, and unknown/uninsured patients were more likely to have an interval ED encounter (Table IV). Of the 50 patients who had an interval ED encounter, 24 (48.0%) were incarcerated, while 31 (62.0%) underwent an urgent repair. There was no difference in the proportion of patients undergoing urgent repair between cancellation periods (precancellation, $n = 16/24$ [66.7%] vs postcancellation, $n = 15/26$ [57.7%]; $P = .57$).

Event-free survival time is demonstrated in Figure 1. Log-rank test of equality demonstrated no difference in event-free survival between pre and postcancellation periods ($P = .96$).

Sensitivity analyses

Of the 1,404 patients in the analysis cohort, 679 (48.4%) had their IHR within 3 months of their hospital's elective surgery cancellation date. In this cohort, TIHR in the postcancellation period was significantly longer than the precancellation period (postcancellation median TIHR 38 days [14–91 days] versus precancellation median TIHR 29.5 days [15–56 days], $P = .02$). The average TIHR in this cohort was 68.5 days (SD 120.3 days) in the

Table IV
Association of elective surgery cancellation and time to inguinal hernia repair with interval incarceration and emergency department encounters at 14 US children's hospitals between September 13, 2019 and September 13, 2020

	Interval incarceration		Interval ED encounter	
	aOR (95% CI)	*P* value	aOR (95% CI)	*P* value
Cancellation period				
Precancellation	Ref		Ref	
Postcancellation	1.15 (0.64–2.05)	.65	1.27 (0.62–2.59)	.52
Time to inguinal hernia repair				
<2 weeks	2.80 (0.82–9.54)	.10	6.78 (1.65–27.95)	.01
>2 weeks & ≤4 weeks	Ref		Ref	
>1 month & ≤3 months	1.52 (0.33–7.06)	.59	1.72 (0.62–4.82)	.30
≥4 months	2.61 (0.65–10.53)	.18	5.18 (1.61–16.70)	.01
Sex				
Female	Ref		Ref	
Male	2.28 (0.90–5.79)	.08	1.70 (0.63–4.63)	.30
Adjusted gestational age, years	0.91 (0.80–1.04)	.18	0.92 (0.82–1.03)	.14
Race				
Non-Hispanic White	Ref		Ref	
Hispanic White	3.24 (1.36–7.69)	.01	2.06 (1.05–4.03)	.04
Black/African American	2.54 (1.09–5.91)	.03	2.33 (1.32–4.13)	<.01
Other	2.73 (1.06–7.05)	.04	1.43 (0.74–2.75)	.29
Unknown/refused	1.47 (0.40–5.33)	.56	0.40 (0.08–2.08)	.28
Insurance				
Private	Ref		Ref	
Public	1.43 (0.73–2.78)	.30	1.09 (0.55–2.19)	.80
Unknown/uninsured	7.61 (3.80–15.21)	<.01	2.65 (1.17–6.01)	.02
Laterality				
Bilateral	Ref		Ref	
Left	1.45 (0.70–2.99)	.32	0.86 (0.46–1.60)	.63
Right	1.30 (0.56–3.05)	.54	1.30 (0.61–2.76)	.49
ASA class				
ASA class 1/2	Ref		Ref	
ASA class 3/4	1.85 (0.65–5.25)	.25	1.17 (0.40–3.44)	.77

Precancellation period was defined as September 13, 2019, to the date that hospitals cancelled elective surgeries, and postcancellation was defined as the date of elective surgery cancellation through September 13, 2020. Cohort excluded those presenting with incarceration or undergoing an urgent operation at diagnosis.
aOR, adjusted odds ratio; *ASA*, American Society of Anesthesiologist classification; *CI*, confidence interval; *ED*, emergency department.

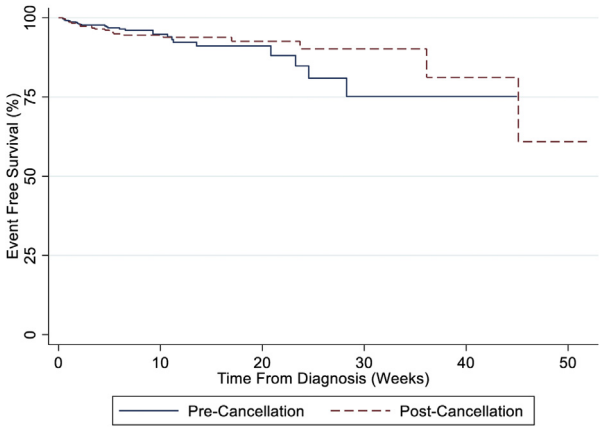

Figure 1. Precancellation period was defined as September 13, 2019 to the date that hospitals canceled elective surgeries, and postcancellation was defined as the date of elective surgery cancellation to September 13, 2020.

postcancellation period (compared to 63.6 days in the overall cohort). Our results remained consistent with no association between cancellation period and incarceration or ED encounters (Table V).

Similarly, of the 1,404 patients included in the sensitivity analysis cohort, 571 (42.7%) were infants at diagnosis. Of these, 59 (10.3%) experienced incarceration, and 127 (22.2%) experienced an ED encounter related to their inguinal hernia. In this population, the postcancellation period was not associated with incarceration. However, infants were more likely to experience an ED encounter and have an ED encounter be their index presentation during the postcancellation period. There was no increase in the likelihood of interval ED encounters in this population (Table V).

Table V
Association of elective surgery cancellation and inguinal hernia incarceration or emergency department in either infants or within 3 months of cancellation

	Within 3 months of cancellation		Infants	
	aOR (95% CI)	*P* value	aOR (95% CI)	*P* value
Any incarceration	1.56 (0.65–3.73)	.32	1.56 (1.00–2.43)	.05
Incarceration at diagnosis	1.23 (0.52–2.88)	.63	1.29 (0.69–2.41)	.42
Interval incarceration	1.21 (0.32–4.47)	.77	1.67 (0.58–4.77)	.34
Any ED encounter	1.51 (0.95–2.37)	.07	1.85 (1.24–2.76)	<.01
ED as index presentation	1.41 (0.90–2.19)	.13	1.69 (1.24–2.31)	<.01
Interval ED encounter	2.02 (0.78–5.23)	.14	2.27 (0.85–6.07)	.10

aOR, adjusted odds ratio; *CI*, confidence interval; *ED*, emergency department.

Discussion

This multicenter, retrospective study found that there were short delays in IHR associated with COVID-19 related elective

surgery deferment or cancellations. Cancellations did not increase the likelihood for incarceration, but they did increase the risk of infants having their inguinal hernia diagnosed in the ED. While incarceration was not associated with a specific time interval after diagnosis, ED encounters were found to be significantly more likely in the first 2 weeks after diagnosis.

This is the first study to examine the association between COVID-19 related elective surgery cancellations and inguinal hernia complications in children. Pediatric and adult gastrointestinal surgical case volumes decreased significantly during the early phases of COVID-19.[13–15] In adults, pauses in elective hernia repair were not associated with short-term adverse outcomes.[14,16] This study demonstrates similar findings in the pediatric population. These findings may suggest that elective surgery cancellations appear to be safe for children awaiting inguinal hernia repair. It is notable that although the difference in TIHR between pre and postcancellation groups was statistically significant, the clinical significance of this difference may be minimal. Despite elective surgery cancellations of at least 4 weeks, IHRs were delayed an average of only 15 days compared to before COVID-19. This may reflect the study's design, which included cases after COVID-19 cancellations were in place and then were subsequently lifted. TIHR may have been shortened as surgeons sought to clear backlogged cases. However, the sensitivity analyses in this study that focused on the peak COVID-19 cancellation period found that, despite increased delays for IHR, there was no significant increase in the likelihood of incarceration.

The short delays observed may reflect hesitancy on the part of pediatric surgeons to significantly delay IHR in children. Literature on the optimal timing between diagnosis and repair vary in their findings, ranging from increased incarceration rates within 2 weeks of diagnosis to other studies suggesting no association between wait times and complications.[1,3,17–20] It is therefore no surprise that opinions on optimal timing for repair are incongruent among surgeons.[6] This study corroborates the notion that, regardless of age group, wait times are not associated with incarceration. However, the same does not appear true for ED encounters. One potential explanation is that parental concern for incarceration may cause presentation to the ED. Regardless of whether a hernia is truly incarcerated when examined by a surgeon, an ED presentation may prompt clinicians to perform an IHR. This explanation is substantiated by this study's results demonstrating that a significant proportion of patients who had interval ED encounters went on to have a repair within 48 hours despite not being incarcerated. It is likely that parental anxiety is greatest in the initial period after diagnosis,[21,22] which could explain why interval ED encounters were more likely in the first 2 weeks. Increased likelihood of ED encounters in the $\geq$4-month period may represent patients re-engaging with the health system as it is unlikely that elective repairs are purposefully delayed this long without reason.

One notable consequence of elective surgery cancellations was the increased risk of infants having their inguinal hernia diagnosed in the ED. This finding likely reflects the changes in health-seeking behavior and health care access restrictions brought on by the worsening of the COVID-19 pandemic.[23] Inguinal hernias that would have been diagnosed, before COVID-19, in primary care offices may have instead presented to the ED given its availability for urgent care throughout the pandemic. Further examination of trends in the utilization of the ED for elective surgical evaluation may provide a more holistic approach when considering the implications of elective surgery cancellations. In infants, the increased likelihood of any incarceration was just insignificant. Future studies, more suitably powered to study this population, may help discern the true influence of elective surgery cancellations in this population.

Incarceration rates vary from 8.2% to 30% in infants, whereas a study in children up to 15 years of age reported an incarceration rate of 4.2%.[1,5,24] Younger age appears to be the most prominent factor associated with incarceration, with conflicting reports on laterality, prematurity, and patient gender.[1,10] The findings of this study are similar, with an incarceration rate of 6.5% overall and 10.3% in infants, and confirm that younger age is a significant predictor of incarceration.

The findings of this study must be carefully considered in the context of its limitations. First, data were collected retrospectively, and errors in medical record documentation and data abstraction are possible. We attempted to reduce errors and variation through the development and distribution of a variable dictionary. Second, this study focused on patients identified via repair of their inguinal hernia and potentially missed children diagnosed with an inguinal hernia who did not receive an operation. However, this scenario is not the standard of care for pediatric inguinal hernia, and any such cases would be considered an exception. Third, this study included only 14 children's hospitals and did not include patients from epicenters of the pandemic during this time (eg, New York). This does limit the generalizability of our findings; however, this study still represents a diverse national sample of hospitals from multiple geographic regions (eg, California, Illinois, Maryland, Texas). Fourth, this study was powered to detect a 100% increase in incarceration rate, thereby not being able to detect smaller but significant increases in incarceration. However, the authors would argue elective surgery cancellations are a matter of last resort in calamitous situations and that smaller increases in incarceration rates may be relatively acceptable. Larger sample sizes are necessary to fully study the impact of elective surgical cancellations on pediatric inguinal hernias. Finally, this study excluded patients diagnosed as inpatients, which may have disproportionately affected the neonatal population. The safety of elective surgery cancellation in neonates deserves further research.

Despite these limitations, this study suggests that elective surgery cancellations were safe in pediatric patients with inguinal hernia. Although it appears that inguinal hernia repairs can be delayed without significant increases in hernia incarceration, ED utilization may increase in infants and is more likely in the first 2 weeks after diagnosis. Understanding the impact of elective surgery cancellations and wait times for an operation has important implications as health systems seek to prepare for COVID-19 variants, future pandemics, and other stressors (eg, staff shortages). The experience of such widespread elective surgery cancellations represents a learning opportunity to granularly study the safety of these cancellations in different procedures. By refining triage strategies and tailoring practices to specific patient populations, local and federal policy makers can aim to minimize the ramifications of surgery cancellation and better ensure the safety of all patients.

In conclusion, COVID-19 related elective surgery cancellations do not appear to increase the likelihood of inguinal hernia incarceration, and repair can be safely delayed. ED encounters are most likely in the first 2 weeks after diagnosis. These findings may have important implications for future health policy, and the safety of elective surgery cancellation in other procedures should be examined.

Funding/Support

The authors did not receive any direct or indirect financial support by extramural sources for this study.

Conflict of interest/Disclosure

The authors have no related conflicts of interest to declare.

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