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Research Paper

The impact of COVID-19 on racial and ethnic disparities in presentation with perforated appendicitis in children: A retrospective cohort study

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ABSTRACT

Background: Children from racial and ethnic minority groups have higher prevalence of perforated appendicitis, and the COVID-19 pandemic worsened racial and ethnic health-related disparities. We hypothesized that the incidence of perforated appendicitis worsened for children from racial and ethnic minorities during the COVID-19 pandemic.

Methods: We performed a retrospective cohort study of the Pediatric Health Information System for children ages 2-18y undergoing appendectomy pre-pandemic (3/19/2019–3/18/2020) and intra-pandemic (3/19/2020–3/30/2021). The primary outcome was presentation with perforated appendicitis. Multivariable logistic regression with mixed effects estimated the likelihood of presentation with perforated appendicitis. Covariates included race, ethnicity, pandemic status, Child Opportunity Index, gender, insurance, age, and hospital region.

Results: Overall, 33,727 children underwent appendectomy: 16,048 (47.6 %) were Non-Hispanic White, 12,709 (37.7 %) were Hispanic, 2261 (6.7 %) were Non-Hispanic Black, 960 (2.8 %) were Asian, and 1749 (5.2 %) Other. Overall perforated appendicitis rates were unchanged during the pandemic (37.4 % intra-pandemic, 36.4 % pre-pandemic, $p = 0.06$). Hispanic children were more likely to present with perforated appendicitis intra-pandemic versus pre-pandemic (OR 1.18, 95%CI: 1.07, 1.13). Hispanic children had higher odds of perforated appendicitis versus Non-Hispanic White children pre-pandemic (OR 1.10, 95%CI: 1.00, 1.20) which increased intra-pandemic (OR 1.19, 95%CI: 1.09, 1.30). Publicly-insured children had increased odds of perforated appendicitis intra-pandemic versus pre-pandemic (OR 1.14, 95%CI: 1.03, 1.25), and had increased odds of perforated appendicitis versus privately-insured children (intra-pandemic OR 1.26, 95%CI: 1.16, 1.36; pre-pandemic OR 1.12, 95%CI: 1.04, 1.22).

Conclusions: During the COVID-19 pandemic, Hispanic and publicly-insured children were more likely to present with perforated appendicitis, suggesting that the pandemic exacerbated existing disparities in healthcare for children with appendicitis.

Key message: We found that Hispanic children and children with public insurance were more likely to present with perforated appendicitis during the COVID-19 pandemic. Public health efforts aimed at ameliorating racial and ethnic disparities created during the COVID-19 pandemic should consider increasing healthcare access for Hispanic children to address bias, racism, and systemic barriers that may prevent families from seeking care.

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Introduction

Presentation with perforated appendicitis is a marker for health disparities in children [1–6]. This delay in healthcare access leads to prolonged hospitalization, higher hospital costs [5], and increased likelihood of postoperative complications [7]. Previous studies demonstrate that children from racial and ethnic minorities [2–6], children with low socioeconomic status [1], immigrant children [4], and publicly-insured children or without insurance [2–4,6] are at higher risk of presenting with perforated appendicitis. These differences are often attributed to factors that affect access to timely care such as socioeconomic status[1] and language barriers [2,4].

A systematic review published in 2021 demonstrated that rates of perforated appendicitis in children have increased during the COVID-19 pandemic [8]. There is also evidence that health disparities have worsened during the COVID-19 pandemic; all-cause mortality in adults has increased among the uninsured, those living in poverty, those living in high exposure risk settings, and those with high occupational exposure risk [9]. Non-Hispanic Black adults demonstrate increased mortality even when adjusting for insurance status, poverty, and high exposure risk [9,10]. Hispanic and Asian adults have also had increased excess all-cause mortality when compared to White Americans [10]. City and state-wide studies assessing the impact of the COVID-19 pandemic on rates of perforated appendicitis in children are mixed [11–13]. Furthermore, there is a paucity of literature investigating the impact of the COVID-19 pandemic on presentation of perforated appendicitis in children from racial and ethnic minorities on a national scale.

The primary objective of this study was to compare the likelihood of perforated appendicitis before and during the COVID-19 pandemic as a marker of health equity and access for children in the United States (U.S.). We hypothesized that perforated appendicitis in children increased during the COVID-19 pandemic, particularly among children from racial and ethnic minority groups. We also hypothesized that other metrics of healthcare access such as insurance and neighborhood resources (Child Opportunity Index) contributed to racial and ethnic disparities for perforated appendicitis in children. The findings in this study could help pediatric healthcare providers and policy makers direct resources to children whose access to surgical care was disproportionately affected by the COVID-19 pandemic and to guide future pandemic planning.

Methods

Study design and data collection

We performed a retrospective cohort study of 43 children's hospitals across 25 US states using the Pediatric Health Information System (PHIS), an administrative and billing database maintained by Children's Hospital Association (Lenesa, Kansas and Washington, D.C). The PHIS database contains de-identified clinical and resource utilization data for inpatient and outpatient encounters at children's hospitals throughout the U.S. Data quality is monitored by the PHIS data quality program with issuance of quarterly data quality reports, chart audits, and feedback to participating hospitals. Institutional review board approval was obtained.

All children ages 2–18 years with a diagnosis of appendicitis and who underwent appendectomy between 3/19/2019 and 3/30/2021 during an inpatient or observation admission were identified. Diagnosis of appendicitis was identified using International Classification of Diseases 10th Revision (ICD-10) codes K35, K35.3, K35.30, K35.31, K35.8, K35.80, K35.89, K35.890, K35.891, K36, K37. Perforated appendicitis was identified by ICD-10 codes K35.2, K35.20, K35.21, K35.32, K35.33 [14]. Appendectomy was identified using ICD-10 procedure codes 0DTJ0ZZ, 0DTJ4ZZ, 0DTJ7ZZ, 0DTJ8ZZ. Current Procedural Terminology (CPT) codes 44870, 44950, 44960, 44970, were also used to identify appendectomy. The pre-pandemic period was defined as 3/19/2019–3/18–2020, and the intra-pandemic period was defined as 3/19/2020–3/30/2021. The pandemic start date was selected based on the date that the first state issued an official stay-at-home order.

Four hospitals that did not have complete data during our defined study period were excluded from analysis ($N = 2152$). Children with complex chronic conditions as classified by the ICD-10 [15] ($N = 2033$), unknown race or ethnicity ($N = 2351$), unknown sex ($N = 1$), or unavailable Child Opportunity Index (COI) ($N = 58$) information were also excluded from analysis (Fig. 1). Those with missing covariates and outcomes of interest were excluded as we could not assess if this data was missing at random, as only data missing at random would be appropriate to retain for multiple imputation. We excluded patients with complex chronic conditions to increase the homogeneity of the baseline health of our cohort.

Observed characteristics between participants with complete and incomplete data (missing race, sex, and COI) were compared using bivariate analysis. Observations from the four excluded hospitals that did not contribute data during the defined pandemic period and remaining hospitals with complete data were also compared using bivariate analysis. Sociodemographic data included age, sex, race and ethnicity, insurance status, and COI. Hospital demographic data included region (Midwest, Northeast, South, West).

Outcome measures

Our primary outcome was diagnosis of perforated appendicitis during hospitalization for appendectomy. Our secondary outcome was hospital length-of-stay.

Covariates

Demographics

Demographics included age, sex, race and ethnicity, insurance type, and hospital region. Race and ethnicity were combined and categorized based on previous studies using PHIS [16,17]: Asian, Hispanic, non-Hispanic Black, non-Hispanic White, and Other (defined as Native Hawaiian/Pacific Islander, American Indian, and Alaska Native). PHIS does not have a category for mixed race or mixed ethnicity. Insurance type was categorized as private (commercial plans, TRICARE, military insurance), public (Medicare, Medicaid, Children's Health Insurance Program) and other (any other government insurance, self-pay, charity care, any insurance not previously mentioned). Private insurance was chosen as the reference category as previous literature demonstrates that children with public insurance or without insurance are more likely to present with perforated appendicitis [2–4,6].

Of note, the authors of this study are aware that using non-Hispanic White children as a reference category could be viewed as problematic by reinforcing the idea that White equals “normal” [18]. Great care was taken in the consideration of our reference category for race and ethnicity. Non-Hispanic White children were chosen because of the abundance of previous literature that shows that racial and ethnic minority children more frequently present with perforated appendicitis [2–6].

Child Opportunity Index

The Child Opportunity Index (COI) 2.0 is a composite index of neighborhood resources that contribute to healthy childhood development that can be measured by zip code or census tract. COI in this study was measured by zip code. The index is a composite of 29 different indicators divided across three domains education, health and environment, and social and economic domains. Metrics include but are not limited to early childhood education enrollment, third grade reading and math proficiency, high school graduation rates, access to healthy food and green spaces, exposure to industrial pollutants, employment rate, poverty rate, and home ownership. Based on these metrics, each zip code is assigned a neighborhood opportunity score from 1(lowest) to

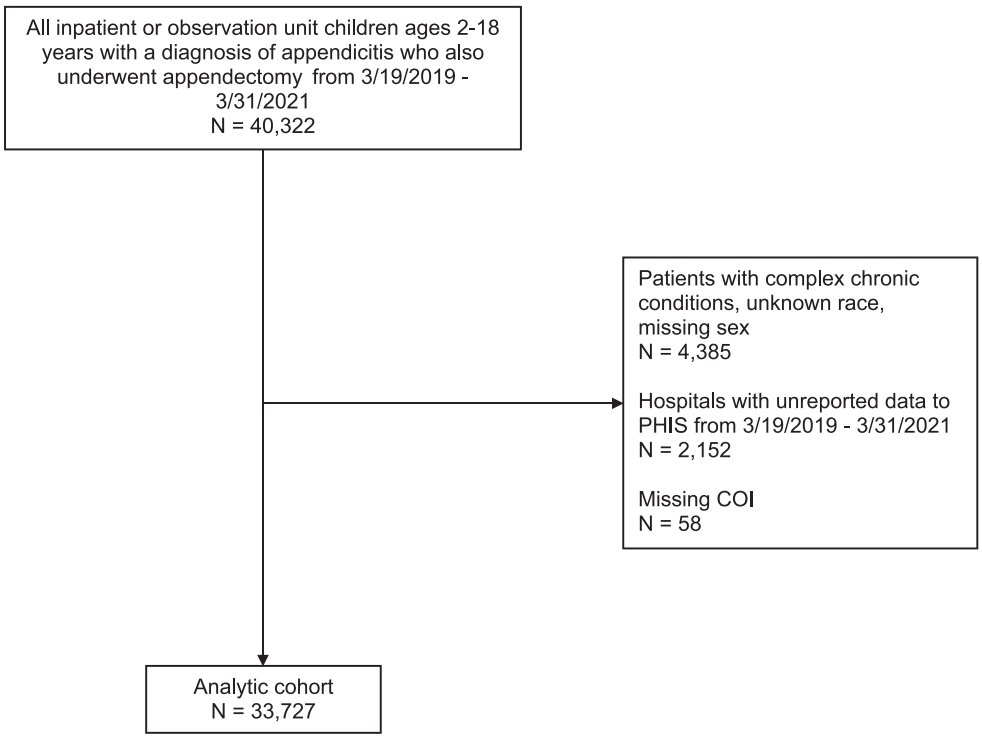

Fig. 1. Cohort selection flowchart.

100 (highest) and is also ranked based on opportunity. The ranking levels from lowest to highest are very low, low, moderate, high, and very high opportunity. The COI is administered by diveresitydatakids.org at the Institute for Child, Youth and Family Policy at the Heller School for Social Policy and Management at Brandeis University (Waltham, MA) [19].

Statistical analysis

Categorical variables were described using frequencies and percentages, bivariate comparisons were conducted using Chi-square tests. Continuous variables were described either using mean and standard deviation or median and interquartile range, and comparisons were done Student's *t*-test or Wilcoxon Mann-Whitney test. A generalized linear mixed model with a binary family specification and random intercept for hospitals was used to identify patient-level factors associated with likelihood of perforated appendicitis both pre-pandemic and during the COVID-19 pandemic. Mixed effects modeling was employed to control for unmeasured hospital characteristics and correlation due to clustering of patients within hospitals that may confound any associations [20,21]. Effect modification was evaluated by including 2-way interaction terms for intra-pandemic period and race/ethnicity, COI, and insurance type. These interaction terms were included in our model and used to produce post-hoc estimations for all children and sub-analyses of Hispanic children only. Covariates included pandemic period, COI ranking, race and ethnicity, sex, patient age, insurance, and hospital region. Covariate selection was based on co-author consensus, availability from PHIS, and variables with a significant bivariate association. All statistical significance tests were conducted with a 2-sided $\alpha = 0.05$. Data were analyzed by using SAS software (SAS Institute, Inc., Cary, North Carolina).

Results

Demographics and baseline characteristics

Overall, 33,727 children who underwent appendectomy were identified (Fig. 1) of which 13,430(39.8 %) were female and 20,297(60.2 %) were male. Non-Hispanic White children were the largest group in our cohort ($N = 16{,}048$, 47.6 %) followed by Hispanic children ($N = 12{,}709$, 37.7 %) (Table 1). The most common insurance type was public insurance (N = 16,528, 49 %). The most common COI category was very low ($N = 7377$, 21.9 %). On bivariate comparison, sex, race and ethnicity, insurance type, and hospital length of stay did not change significantly between pre-pandemic and intra-pandemic periods ($p > 0.05$). Children were slightly younger at time of admission pre-pandemic compared to intra-pandemic (10.5 ± 3.9 years vs 10.8 ± 3.9 years, $p < 0.001$). COI did change significantly intra-pandemic compared to pre-pandemic ($p = 0.003$) with more children from the high and very high levels having increased presentation with appendicitis and children from the very low levels having decreased presentation with appendicitis (Table 1).

Of the 25 states included in our analysis, 8 (32 %) were in Midwest region of the United States. The Northeast had 4 (16 %) states included. The South had 10 (40 %) states included, and the West had 3 (12 %) states included. Of the 43 hospitals included in our analysis, 12 (27.9 %) were in the Midwest, 6 (14 %) were in the Northeast, 16 (37.2 %) were in the South, and 9 (20.9 %) were in the West.

Perforated appendicitis

The overall proportion of children presenting with perforated appendicitis did not significantly increase intra-pandemic (36.4 % vs. 37.4 %, $p = 0.06$). Intra-pandemic, there was an increased prevalence of perforated appendicitis among male children (52.1 % vs 47.9 %, $p = 0.007$), Hispanic children (52.9 % vs 47.1 %, $p = 0.03$), and children with public insurance (51.9 % vs 48.1 %, $p = 0.004$). There was not a statistically significant difference in presentation with perforated appendicitis for children with private or other insurance ($p > 0.05$)

Table 1
Demographics, characteristics, and outcomes of children with appendicitis before and during the COVID-19 pandemic.

	Total	Pre-pandemic	Intra-pandemic	*p*-Value
	N = 33,727	N = 16,500	*N* = 17,227	
	N (%)	N (%)	N (%)	
Age at admission, years (mean, SD)	10.7 (3.9)	10.5 (3.9)	10.8 (3.9)	<0.001
Sex				0.26
Female	13,430 (39.8)	6520 (39.5)	6910 (40.1)	
Male	20,297 (60.2)	9980 (60.5)	10,317 (59.9)	
Race and ethnicity				0.19
Asian	960 (2.8)	481 (2.9)	479 (2.8)	
Hispanic	12,709 (37.7)	6144 (37.2)	6565 (38.1)	
Non-Hispanic Black	2261 (6.7)	1151 (7.0)	1110 (6.4)	
Non-Hispanic White	16,048 (47.6)	7877 (47.7)	8171 (47.4)	
Other[a]	1749 (5.2)	847 (5.1)	902 (5.2)	
Insurance				0.07
Private	15,173 (45.0)	7363 (44.6)	7810 (45.3)	
Public	16,528 (49.0)	8179 (49.6)	8349 (48.3)	
Other	2026 (6.0)	958 (5.8)	1068 (6.2)	
Child Opportunity Index (COI)				0.003
Very low	7377 (21.9)	3678 (22.3)	3699 (21.5)	
Low	6954 (20.6)	3491 (21.2)	3463 (20.1)	
Moderate	6227 (10.5)	3049 (18.5)	3178 (18.5)	
High	5923 (17.6)	2859 (17.3)	3064 (17.8)	
Very high	7246 (21.5)	3423 (20.8)	3823 (22.2)	
United States region				0.05
Midwest	6455 (19.1)	3257 (19.7)	3198 (18.6)	
Northeast	3245 (9.6)	1572 (9.5)	1673 (9.7)	
South	15,397 (45.7)	7494 (45.4)	7903 (45.9)	
West	8630 (25.6)	4177 (25.3)	4453 (25.9)	
Perforated appendicitis	12,453 (36.9)	6010 (36.4)	6443 (37.4)	0.06
Length of stay (mean, SD)	1 (1–3)	1 (1–3)	1 (1–3)	0.31

[a] Native Hawaiian/Pacific Islander, American Indian, and Alaskan Native.

(Table 2).

Unadjusted and adjusted logistic regression model with post-hoc estimations

Results of our unadjusted and adjusted multivariable logistic regression models are presented in Table 3.

Post-hoc estimation for likelihood of perforated appendicitis intra-pandemic when compared to the same group before the pre-pandemic

After controlling for covariates, Hispanic children were more likely to present with perforated appendicitis intra-pandemic compared to Hispanic children presenting pre-pandemic (OR 1.18, 95%CI: 1.07, 1.30, $p = 0.001$). Publicly-insured children were more likely to present with perforated appendicitis intra-pandemic compared to publicly-insured children pre-pandemic (OR 1.14, 95%CI: 1.03, 1.25, $p = 0.01$). When analyzing only Hispanic children, publicly-insured children were more likely to present with perforated appendicitis intra-pandemic (OR 1.26, 95%CI: 1.13, 1.40, $p < 0.001$) compared to publicly-insured children pre-pandemic. Hispanic children with moderate (OR 1.24, 95%CI: 1.02, 1.51, $p = 0.03$) and high COI (OR 1.27, 95%CI: 1.01, 1.60, $p = 0.04$) were more likely to present with perforated appendicitis intra-pandemic when compared to themselves pre-pandemic (Table 4).

Table 2
Prevalence of Perforated Appendicitis Before and During the COVID-19 Pandemic.

	Pre-pandemic	Intra-pandemic	p-Value
	N = 16,500	N = 17,227	
	N (%)	N (%)	
Sex			
Female	2433 (48.8)	2555 (51.2)	0.68
Male	3577 (47.9)	3888 (52.1)	0.007
Race and ethnicity			
Asian	203 (50.5)	199 (49.5)	0.84
Hispanic	2380 (47.1)	2669 (52.9)	0.03
Non-Hispanic Black	459 (52.0)	424 (48.0)	0.41
Non-Hispanic White	2655 (48.6)	2806 (51.4)	0.40
Other[a]	313 (47.6)	345 (52.4)	0.58
Insurance			
Private	2428 (48.6)	2567 (51.4)	0.89
Public	3233 (48.1)	3482 (51.9)	0.004
Other	349 (47.0)	394 (53.0)	0.83
Child Opportunity Index (COI)			
Very low	1478 (48.7)	1555 (51.3)	0.11
Low	1347 (50.8)	1307 (49.2)	0.47
Moderate	1118 (47.6)	1231 (52.4)	0.09
High	986 (46.9)	1118 (53.1)	0.11
Very high	1081 (46.7)	1232 (53.3)	0.56
Region			
Midwest	1375 (49.4)	1407 (50.6)	0.15
Northeast	431 (46.9)	488 (53.1)	0.27
South	2644 (48.2)	2841 (51.8)	0.39
West	1560 (47.7)	1707 (52.3)	0.35

[a] Native Hawaiian/Pacific Islander, American Indian, and Alaskan Native.

Post-hoc estimation of perforated appendicitis partitioned by COVID-19 pandemic presentation

The odds of a Hispanic child presenting with perforated appendicitis relative to a non-Hispanic White child increased intra-pandemic (pre-pandemic OR 1.10, 95%CI: 1.0, 1.2; p = 0.04; intra-pandemic OR 1.19, 95%CI: 1.09, 1.30, $p < 0.001$) Publicly-insured children also had higher odds of presentation with perforated appendicitis relative to privately-insured children (pre-pandemic OR 1.12, 95%CI: 1.04, 1.22, $p = 0.005$; intra-pandemic OR 1.26, 95%CI: 1.16, 1.36, p < 0.001). When analyzing only Hispanic children, the odds of publicly-insured Hispanic children presenting with perforated appendicitis relative to privately-insured Hispanic children was significant intra-pandemic (OR 1.22, 95%CI: 1.07, 1.39 $p = 0.003$) while pre-pandemic were elevated but insignificant (OR 1.14, 95%CI: 0.99, 1.31; $p = 0.07$). Hispanic children with very low or low COI had an increased risk of presenting with perforated appendicitis relative to Hispanic children with very high COI pre-pandemic, this was non-significant intra-pandemic (Table 5).

Additional analyses

There were no significant differences in length of stay intra-pandemic compared to pre-pandemic when analyzed by race (all $p > 0.05$) (Table 6). Supplemental Table 1 shows absolute risk of presentation with perforated appendicitis during the pre-pandemic and intra-pandemic periods. Supplemental Table 2 compares children with complete and incomplete data. Supplemental Table 3 compares characteristics children with incomplete data between the pre-pandemic and intra-pandemic periods. Supplemental Table 4 compares data from the

Table 3
Unadjusted and adjusted multivariable logistic regression.

	Unadjusted		Adjusted	
	OR (95 % CI)	p-Value	OR (95 % CI)	p-Value
Race and ethnicity				
Asian	1.38 (1.20, 1.59)	<0.001	1.40 (1.15, 1.72)	0.001
Hispanic	1.39 (1.31, 1.47)	<0.001	1.10 (1.00, 1.20)	0.04
Non-Hispanic Black	1.26 (1.14, 1.39)	<0.001	1.23 (1.07, 1.42)	0.004
Other[a]	1.21 (1.08, 1.35)	<0.001	1.08 (0.92, 1.26)	0.34
Non-Hispanic White	Ref	Ref	Ref	Ref
Intra-pandemic vs pre-pandemic	1.07 (1.02, 1.12)	0.007	1.05 (0.94, 1.18)	0.36
Childhood Opportunity Index				
Very low	1.53 (1.42, 1.65)	<0.001	1.29 (1.14, 1.45)	<0.001
Low	1.40 (1.30, 1.50)	<0.001	1.27 (1.13, 1.42)	<0.001
Moderate	1.34 (1.24, 1.44)	<0.001	1.18 (1.05, 1.32)	0.005
High	1.19 (1.10, 1.29)	<0.001	1.10 (0.99, 1.24)	0.09
Very high	Ref	Ref	Ref	Ref
Female vs male	1.02 (0.98, 1.07)	0.32	0.98 (0.93, 1.02)	0.32
Insurance				0.005
Public	1.41 (1.34, 1.48)	<0.001	1.13 (1.04, 1.22)	0.16
Other	1.25 (1.13, 1.38)	<0.001	1.11 (0.96, 1.30)	
Private	Ref	Ref	Ref	Ref
Admit age (years)	0.91 (0.90, 0.91)	<0.001	0.91 (0.90, 0.91)	<0.001
Hospital region				
Midwest	3.11 (1.32, 7.36)	0.01	3.04 (1.32, 7.00)	0.01
South	1.65 (0.70, 3.85)	0.24	1.50 (0.66, 3.42)	0.33
West	1.74 (0.69, 4.36)	0.23	1.48 (0.61, 3.62)	0.38
Northeast	Ref	Ref	Ref	Ref
Interaction terms				
Intra-pandemic * Asian			0.95 (0.72, 1.26)	0.72
Intra-pandemic * Hispanic			1.09 (0.97, 1.22)	0.15
Intra-pandemic * Non-Hispanic Black			0.89 (0.73, 1.09)	0.27
Intra-pandemic * Other[a]			1.04 (0.84, 1.29)	0.73
Intra-pandemic * Non-Hispanic White			Ref	Ref
Intra-pandemic * Very Low COI			0.95 (0.80, 1.11)	0.49
Intra-pandemic * Low			0.87 (0.74, 1.02)	0.08
Intra-pandemic * Moderate			1.03 (0.88, 1.21)	0.69
Intra-pandemic * High			1.03 (0.88, 1.21)	0.68
Intra-pandemic * Very High COI			Ref	Ref
Intra-pandemic * Public Insurance			1.12 (1.00, 1.25)	0.05
Intra-pandemic * Other Insurance			1.05 (0.85, 1.29)	0.66
Intra-pandemic * Private Insurance			Ref	Ref

[a] Native Hawaiian/Pacific Islander, American Indian, and Alaskan Native.

Table 4
Post-hoc estimation[a] for likelihood of perforated appendicitis during the COVID-19 pandemic when compared to the same group before the COVID-19 pandemic.

A. All children (N = 33,727)		
	Odds ratio (95 % confidence interval)	p-Value
Race and ethnicity		
Asian	1.03 (0.78, 1.36)	0.85
Hispanic	1.18 (1.07, 1.30)	0.001
Non-Hispanic Black	0.97 (0.80, 1.17)	0.72
Non-Hispanic White	1.08 (0.99, 1.18)	0.09
Other[b]	1.12 (0.91, 1.39)	0.28
Insurance type		
Private insurance	1.02 (0.92, 1.13)	0.74
Public insurance	1.14 (1.03, 1.25)	0.01
Other insurance	1.07 (0.87, 1.31)	0.54
COI		
Very low COI	1.04 (0.91, 1.19)	0.56
Low COI	0.96 (0.84, 1.09)	0.51
Moderate COI	1.14 (0.99, 1.30)	0.07
High COI	1.14 (0.99, 1.31)	0.08
Very high COI	1.10 (0.96, 1.26)	0.17
B. Hispanic children alone (n = 12,709)		
Insurance type		
Private insurance	1.17 (0.99, 1.38)	0.07
Public insurance	1.26 (1.13, 1.40)	<0.001
Other insurance	1.12 (0.83, 1.52)	0.44
COI		
Very low COI	1.09 (0.93, 1.28)	0.28
Low COI	1.07 (0.90, 1.27)	0.46
Moderate COI	1.24 (1.02, 1.51)	0.03
High COI	1.27 (1.01, 1.60)	0.04
Very high COI	1.26 (0.94, 1.69)	0.13

[a] Adjusted for sex, age, region, and hospital clustering.
[b] Native Hawaiian/Pacific Islander, American Indian, and Alaskan Native.

four excluded hospitals to data from the included hospitals.

Discussion

In this multicenter study of children with appendicitis, we identified worsening healthcare disparities, as demonstrated by increased odds of perforated appendicitis, for Hispanic children during the COVID-19 pandemic. This difference was most prominent for publicly insured Hispanic children. Our findings highlight potential targets for intervention to improve healthcare access for underserved children and their families during the COVID-19 pandemic.

This information can assist pediatric healthcare providers and public health professionals to anticipate specific populations most at risk for worsening health outcomes in future pandemics and disasters.

Our results showed that Hispanic children had increased likelihood of presenting perforated appendicitis during the COVID-19 pandemic. Hispanic children also had increased odds of presentation with perforated appendicitis relative to non-White Hispanic children pre-pandemic and intra-pandemic. Larson et al. demonstrated that Hispanic children have decreased healthcare utilization and increased unmet healthcare needs compared to non-Hispanic Black and non-Hispanic White children [22]. Of the previous studies done in the U.S. assessing the impact of COVID-19 on perforated appendicitis in children, Theodorou et al.'s multicenter study in California was the only one that specifically analyzed perforated appendicitis in the context of race. They found that overall perforation rates did not change significantly, but among children with perforated appendicitis (n = 494), there was a significant change in demographics: White and Asian children had increased rates of perforated appendicitis while children identified as Black or "Other" had decreased rates of perforated appendicitis [13]. We did not observe a change in perforation rates among any of these groups, but Theodorou et al. did not account for Hispanic ethnicity in their analyses. This is significant as nearly 50 % of children in California are Hispanic [23].

Table 5
Post-hoc estimation[a] for perforated appendicitis partitioned[b] by COVID-19 pandemic presentation.

	Pre-pandemic		Intra-pandemic	
A. All children (N = 33,727)				
	Odds ratio (95 % CI)	p-Value	Odds radio (95 % CI)	p-Value
Race and ethnicity				
Asian	1.40 (1.15, 1.72)	0.001	1.33 (1.09, 1.63)	0.01
Hispanic	1.10 (1.00, 1.20)	0.04	1.19 (1.09, 1.30)	<0.001
Non-Hispanic Black	1.23 (1.07, 1.42)	0.004	1.10 (0.95, 1.28)	0.18
Other[c]	1.08 (0.92, 1.26)	0.35	1.12 (0.96, 1.30)	0.14
Non-Hispanic White	Ref	Ref	Ref	Ref
Insurance type				
Public	1.13 (1.04, 1.22)	0.005	1.26 (1.16, 1.36)	<0.001
Other	1.11 (0.96, 1.30)	0.16	1.17 (1.01, 1.35)	0.04
Private insurance	Ref	Ref	Ref	Ref
COI				
Very low	1.29 (1.14, 1.45)	<0.001	1.22 (1.08, 1.37)	0.001
Low	1.27 (1.13, 1.42)	<0.001	1.10 (0.99, 1.23)	0.08
Moderate	1.18 (1.05, 1.32)	0.005	1.22 (1.09, 1.36)	<0.001
High	1.11 (0.99, 1.24)	0.09	1.14 (1.02, 1.27)	0.02
Very high	Ref	Ref	Ref	Ref
B. Hispanic children alone (N = 12,709)				
Insurance type				
Public	1.14 (0.99, 1.31)	0.07	1.22 (1.07, 1.39)	0.003
Other	1.09 (0.84, 1.40)	0.51	1.05 (0.83, 1.32)	0.70
Private insurance	Ref	Ref	Ref	Ref
COI				
Very low	1.37 (1.08, 1.73)	0.01	1.19 (0.96, 1.48)	0.11
Low	1.37 (1.08, 1.73)	0.01	1.16 (0.93, 1.45)	0.19
Moderate	1.25 (0.98, 1.61)	0.07	1.24 (0.99, 1.56)	0.06
High	1.11 (0.85, 1.45)	0.42	1.13 (0.88, 1.43)	0.34
Very high	Ref	Ref	Ref	Ref

[a] Adjusted for sex, age, region, and hospital clustering.
[b] Odds ratios are comparing with the pre-pandemic and intra-pandemic periods, not between periods.
[c] Native Hawaiian/Pacific Islander, American Indian, and Alaskan Native.

Table 6
Length of stay stratified by COVID-19 pandemic presentation.

	Pre-pandemic	Intra-pandemic	p-Value
	N = 16,500	N = 17,227	
	Median (IQR)	Median (IQR)	
Race and ethnicity			
Asian	1 (1.0–4.0)	1 (1.0–4.0)	0.57
Hispanic	1 (1.0–3.0)	1 (1.0–4.0)	0.63
Non-Hispanic Black	2 (1.0–4.0)	2 (1.0–4.0)	0.25
Non-Hispanic White	1 (1.0–3.0)	1 (1.0–3.0)	0.15
Other[a]	1 (1.0–3.0)	1 (1.0–3.0)	0.82

[a] Native Hawaiian/Pacific Islander, American Indian, and Alaskan Native.

Additionally their study was performed within a single state and included a mix of hospital types. The complex effects of racism as a barrier to seeking healthcare have been well established, including discrimination, segregation, and association with socioeconomic status [24]. For Hispanic patients specifically, language barrier has been shown to lead to delays in accessing healthcare [25–27]. Hispanic children and their families continue to face the difficulties of discrimination and language barriers in seeking healthcare in the setting of exacerbated healthcare disparities during the COVID-19 pandemic.

Public insurance is associated with perforated appendicitis in children [2–4,6], and lack of insurance has been associated worsening healthcare disparities during the COVID-19 pandemic [9]. Our findings support that children with public insurance were more likely to present with perforated appendicitis, which increased intra-pandemic compared to pre-pandemic. This pattern was consistent throughout the analysis of only Hispanic children. Over half of Hispanic children in the U.S. are publicly-insured, but Black children have a similar proportion of public insurance [28]. In a 2021 analysis of Hispanic children's access to health insurance and health care, Perreira et al. reported that while 95 % of Hispanic children are U.S. citizens, 34 % of those children live in households where their parents are not U.S. citizens. The non-citizen parents may not be eligible for healthcare coverage and therefore less likely to utilize healthcare services for reasons including cost and fear of having to disclose citizenship status [29]. Children's healthcare utilization is largely determined by their parents or adult caretakers. If most Hispanic children's parents are less likely to seek care due to insurance status and fear of having to disclose citizenship status, this compounded with worsening healthcare disparities during COVID-19 could be a factor in our study's findings.

For all children with appendicitis (perforated and non-perforated), we observed an overall increase in children with higher COI presenting with appendicitis and decrease in children with lower COI presenting with appendicitis during the pandemic (Table 1). Fritz et al. found that acute care utilization has decreased during the COVID-19 pandemic in children with the lowest COI [30], which could be a factor in our findings regarding COI in children with appendicitis. In a 2022 study, Bouchard et al. found that the odds of children with very low, low, moderate, and high COI presenting with perforated appendicitis were increased when compared to children with very high COI as the reference group, with the odds ratio increasing as the COI level being compared decreased [16]. These findings are consistent with our pre-pandemic observations for the entire cohort and for only Hispanic children, which demonstrate the odds of presentation with perforated appendicitis increasing as COI level decreases when compared to the reference category of very high COI. Table 5 also demonstrated an apparent intra-pandemic improvement in odds of presentation with perforated appendicitis for Hispanic children with lower COI levels when compared to Hispanic children with a very high COI level. Our findings could be secondary to changing presentation patterns at tertiary care centers during the COVID-19 pandemic. Additionally, insurance type may have had a greater effect on odds on presentation for Hispanic children than COI level during the pandemic. Also, more Hispanic children of very high COI level presenting with perforated appendicitis relative to Hispanic children of lower COI levels could also explain the improvement in intra-pandemic odds ratios. The analysis of the associations between COI and perforated appendicitis in Hispanic children should be explored in further research, possibly into which of the 3 subdomains of COI are associated with presentation with perforated appendicitis. This research could lead to actionable interventions to increase healthcare access for patients and their families who are medically underserved.

Our study has limitations. Our data reflects the experience of 43 Children's hospitals across 25 states which may limit generalizability to states not included in our analysis. We did observe some differences in characteristics of children and hospitals that were excluded from the analysis, suggesting some biased estimates in our cohort. The excluded hospitals have a higher percentage of non-White patients and patients with public insurance compared to our cohort, suggesting that our estimates of presentation with perforated appendicitis may be conservative. The retrospective nature of the PHIS database also puts our study at risk of potential misclassification bias. PHIS is an administrative database, and we used ICD-10 coding to categorize simple versus perforated appendicitis, which is limited by lack of pathologic confirmation of diagnosis. However, the rates of perforation we found are similar to other published rates using other data sources [4–6,31]. We were unable to accurately quantify how many children were transfers to the hospital and if transfer status was associated with presentation with perforated appendicitis. Similarly we were unable to quantify days of symptoms

prior to presentation and if diagnostic delay was associated with perforated appendicitis. Also, families may have avoided driving longer distances to a children's hospital during the COVID-19 pandemic which may limit the generalizability of our results. Finally, the COI was used at the zip code level, as the more granular census tract measure is not available in PHIS. This may have resulted in the misclassification of the COI for some observations, but it has been shown that using zip code instead of census tract data results in minimal if any difference in estimates, especially when using large datasets that represent several zip codes [32–34].

Conclusion

The COVID-19 pandemic exacerbated existing disparities in healthcare access for children with appendicitis. Specifically Hispanic children were more likely to present with perforated appendicitis, a marker of worsening healthcare disparities, during the COVID-19 pandemic. This difference was largely driven by increased rates observed for publicly insured Hispanic children. Future pandemic response efforts aimed at mitigating healthcare disparities must focus on increasing healthcare access for minority and publicly insured children and specifically address the systemic effects of bias and racism that may prevent families who are medically underserved from seeking care.

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This study was approved by the Children's Hospital Los Angeles Institutional Review Board.

CRediT authorship contribution statement

Marjorie N. Odegard: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Shadassa A. Ourshalimian:** Data curation, Formal analysis, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Stephanie Y. Chen:** Conceptualization, Validation, Writing – review & editing. **Christopher J. Russell:** Conceptualization, Methodology, Writing – review & editing. **Adaeze U. Obinelo:** Project administration, Writing – review & editing. **Cameron M. Kaplan:** Formal analysis, Methodology, Writing – review & editing. **Lorraine I. Kelley-Quon:** Conceptualization, Formal analysis, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

None.

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