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# Postoperative complications after gastrointestinal pediatric surgical procedures: outcomes and socio-demographic risk factors

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## Abstract

**Background:** Several socio-demographic characteristics are associated with complications following certain pediatric surgical procedures. In this comprehensive study, we sought to determine socio-demographic risk factors and resource utilization of children with complications after common pediatric surgical procedures.

**Methods:** We performed a population-based cohort study utilizing the 2016 Healthcare Cost and Use Project Kids' Inpatient Database (KID) to identify and characterize pediatric patients (age 0–21 years) in the United States with common inpatient pediatric gastrointestinal surgical procedures: appendectomy, cholecystectomy, colonic resection, pyloromyotomy and small bowel resection. Multivariable logistic regression modeling was used to identify socio-demographic predictors of postoperative complications. Length of stay and hospitalization costs for patients with and without postoperative complications were compared.

**Results:** A total of 66,157 pediatric surgical hospitalizations were identified. Of these patients, 2,009 had postoperative complications. Male sex, young age, African American and Native American race and treatment in a rural hospital were associated with significantly greater odds of postoperative complications. Mean length of stay was 4.58 days greater and mean total costs were \$11,151 (US dollars) higher in the complication cohort compared with patients without complications.

**Conclusions:** Postoperative complications following inpatient pediatric gastrointestinal surgery were linked to elevated healthcare-related expenditure. The identified socio-demographic risk factors should be considered in the risk stratification before pediatric surgical procedures. Targeted interventions are required to reduce preventable complications and surgical disparities.

**Keywords:** Pediatric gastrointestinal surgery, Postoperative complications, Surgical disparities, Gender, Income, Race

## Introduction

Surgery can be a high-risk, resource-intensive therapy and postoperative complications contribute significantly to disease burden and healthcare expenditure in countries around the world [1]. Postoperative complications in pediatric patients are distinct from typical complications seen in adults due to the challenges of operating on smaller anatomical structures and specific age-related

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pathophysiologic processes [2]. Therefore, focused research efforts are needed to evaluate underlying risk factors of postoperative complications in the unique population of pediatric surgical patients.

Previous studies indicate that there are substantial differences in odds of postoperative complications depending on socio-demographic variables in pediatric surgical patients [3–10]. Socio-economically disadvantaged groups and rural populations are likely to experience worse surgical outcomes [11]. Such inequalities are often referred to as *surgical disparities* [11]. In the literature documenting surgical disparities in adults, both patient and provider factors have been identified and are strongly interconnected [12]. Among the recognized socio-demographic patient factors are race, ethnicity, sex and socio-economic status, while provider factors include implicit or unconscious biases, differences in clinical decision-making, and years of training [11]. In pediatric studies of tonsillectomy, female sex and greater household income were associated with a decreased rate of post-tonsillectomy hemorrhage [3] whereas respiratory complications were greater among African-American patients [4]. In the US, African American and Hispanic children were more likely to experience a complication and had longer hospital stays than Caucasian patients after undergoing an appendectomy for acute appendicitis [5]. Insurance status [6–8], hospital location (urban vs. rural) [9], and geographic region [10] are other factors that have demonstrated associations with postoperative outcomes.

A detailed understanding of the interplay of specific factors contributing to postoperative complications is crucial for targeted preventive approaches. However, this interplay remains poorly elucidated for pediatric surgical patients. Most previous studies have had a small sample size or have had a narrowed focus of contributing factors that may lead to complications. Thus, we conducted a comprehensive population-based cohort study to evaluate the role of socio-demographic and center factors on postoperative complications and healthcare costs in inpatient pediatric gastrointestinal surgical patients. We hypothesized that both patient and center characteristics are significantly associated with post-surgical outcomes in this setting.

## Methods

### Study population and data source

In this retrospective cohort study, we used the 2016 Kids' Inpatient Database (KID) of the Healthcare Cost and Utilization Project (HCUP) to evaluate the characteristics and outcomes of postoperative complications in children undergoing pediatric gastrointestinal surgery. The 2016 KID, released in September 2018, is a nationally

representative database of pediatric hospitalizations in the United States and contains data on 3,117,413 pediatric hospital stays from 4,200 hospitals in 47 states [13]. HCUP provides weighting factors based upon census data which can be used to produce national estimates. We used the *International Classification of Diseases – 10th revision – Procedure Coding System* (ICD-10-PCS) to identify pediatric patients aged 0–21 years in the United States undergoing the following common inpatient pediatric gastrointestinal surgical procedures: appendectomy, cholecystectomy, colonic resection, pyloromyotomy and small bowel resection. These procedures were selected to achieve a broad representation of both infant and childhood gastrointestinal disorders across a spectrum of complication risk. Incidences of a wide range of postoperative complications were determined utilizing codes from the ICD-10 section *Complications – surgical procedure*. Analyzed diagnoses included post-procedural endocrine and metabolic complications and disorders (ICD-10 code E89), intraoperative and post-procedural complications and disorders of the nervous system (G97), eye and adnexa (H59), ear and mastoid process (H95), circulatory system (I97), respiratory system (J95), digestive system (K91), musculoskeletal system (M96) and genitourinary system (N99) as well as not elsewhere classified complications of procedures (T81) and other complications of surgical and medical care (T88). In health administrative data, this approach of identifying postoperative complications based on ICD-10 codes has been shown to have high negative predictive value (0.93) relative to prospectively identified surgical complications [14]. ICD-10 diagnostic codes were also used to exclude patients with chronic conditions such as chromosomal aberrations, congenital malformations and metabolic disorders [15]. Patients with necrotizing enterocolitis (NEC; ICD-10 P77) were also excluded from analyses, since the KID does not provide any distinction between preexisting and postoperative NEC [16]. Children were categorized as either having no postoperative complications or having any complication during the admission.

### Statistical analysis

Summaries of the variables were computed for each group prior to significance tests and model construction. Weighted numbers of procedures and complications were used for frequency estimates and unweighted numbers were used in the outcome models in accordance with HCUP data structure and use. Groups were compared with t-tests and proportions were compared with chi-squared testing. Admission trends over the study period were assessed with the Mann-Kendall trend test. Our primary outcome was to identify factors associated with increased risk of postoperative complications.

We constructed a binomial logistic regression model for the occurrence of complications. Procedure type, socio-demographic characteristics, hospital factors and admission features were included as a priori confounders. Socio-demographic characteristics included age, sex (male/female), race (Caucasian/African American/Hispanic/Asian and Pacific Islander/Native American/other), expected primary payer (Medicare/Medicaid/private insurance/self-pay/no charge/other) and household income national quartile based on ZIP code. Patient's age at admission was categorized into the following four age groups similar to prior methods [17]: neonates (<1 month), infants (1 month to 2 years), children (2 to 12 years) and adolescents (12 years or older). Hospital factors were hospital region (Northeast/Midwest/South/West), hospital location and teaching status (rural/urban non-teaching/urban teaching) and hospital size. Categories of hospital size were assigned by the HCUP as small (1 to 99 beds), medium (100 to 399 beds), and large ( $\geq 400$  beds). Elective admission, weekend admission and admission month were included as admission features. Gestational age and BMI were included as comorbid conditions. Gestational age categories were extremely premature (<28 weeks, ICD-10 code P07.2), premature (28 to 36 weeks, P07.3), mature (37 to 42 weeks) and post-term (>42 weeks, P08.2). BMI was categorized into less than 5th (Z68.51), 5th to 84th (Z68.52), 85th to 94th (Z68.53) and greater than or equal to 95th (Z68.54) percentile for age. Intestinal perforation status (K35.2 and K35.3) was also included in the outcome models. We conducted a subgroup analysis for the outcomes of persons who underwent appendectomy as it was the most common procedure either in isolation or in combination with other surgical procedures.

The secondary outcomes of the study were length of stay (LOS) in days and hospitalization costs in US dollars. Hospitalization costs were computed with the KID Cost-to-Charge Ratio Files. Multivariable linear regression models were constructed to determine the LOS and costs for persons with and without complications. The models were adjusted for the patient and hospital characteristics as above. A second set of models was constructed for procedure-specific results. *A priori* selected covariates with missing values less than 10% were incorporated into the final models. A *p* value less than 0.05 was considered statistically significant for all tests. Analyses were conducted with R 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria).

## Results

A total of 48,022 unweighted corresponding to 66,157 weighted inpatient pediatric gastrointestinal surgical admissions were analyzed. Baseline characteristics for

patients with and without postoperative complications are detailed in Table 1. The mean age at admission was 12.1 (SD 5.8) years. There were greater proportions of males (54.7%), of non-Caucasian race (53.8%), on Medicaid (51.0%), in the first (lowest) household income national quartile (31.0%), admitted in the South region (35.2%), and in urban teaching centers (73.5%) at large hospitals (62.9%). Most admissions were non-elective (93.0%) and occurred on a weekday (74.7%).

Of these, 51,168 underwent an appendectomy, 9,959 had a cholecystectomy, 4,575 had a pyloromyotomy, 382 had a colonic resection and 331 had a small bowel resection. The complication rates were 3.3% for appendectomy, 2.5% for cholecystectomy, 0.6% for pyloromyotomy, 11.2% for colonic resection and 12.1% for small bowel resection ( $p < 0.001$ ). 65,904 patients underwent one procedure, 248 patients two different procedures and 5 patients three different procedures in the same admission. The complication rate for undergoing one procedure was 3.0%, for two procedures 10.1% and for three procedures 25.1%. A total of 2,009 patients (3.0%) had at least one postoperative complication. Of those, 1,918 had one, 84 had two and 7 had three complications. The most common complications were post-procedural disorders of the digestive system ( $n = 1,492$ ). Other complications affected the respiratory system ( $n = 175$ ), circulatory system ( $n = 40$ ), genitourinary system ( $n = 39$ ), musculoskeletal system ( $n = 4$ ) and nervous system ( $n = 1$ ).

The results of our multivariable model for examining the factors associated with postoperative complications are presented in Table 2. Female sex (OR 0.67, 95% CI 0.60–0.76) and receiving treatment in urban teaching hospitals (OR 0.74, 95% CI 0.60–0.92) were associated with significantly reduced odds of postoperative complications. In contrast, being of African American (OR 1.38, 95% CI 1.13–1.69), Native American (OR 1.71, 95% CI 1.08–2.71) and other (OR 1.30, 95% CI 1.03–1.65) race was associated with a significantly elevated complication risk when compared with Caucasian race. Other significantly associated factors with increased risk of complications were age less than one month (OR 3.71, 95% CI 1.57–8.77) and between one month and two years (OR 2.11, 95% CI 1.32–3.35) as well as having an elective admission (OR 1.51, 95% CI 1.24–1.84).

In the multivariable model for those who underwent appendectomy procedures, female sex (OR 0.70, 95% CI 0.62–0.80) and treatment in urban teaching hospitals (OR 0.74, 95% CI 0.58–0.94) were similarly associated with a significant reduction of the postoperative complication odds in this cohort. Being of African American (OR 1.36, 95% CI 1.08–1.73) or other race (OR 1.42, 95% CI 1.11–1.83), age less than one month (OR 17.03, 95% CI 7.70–37.68), having an intestinal perforation (OR

**Table 1** Baseline characteristics of inpatient pediatric gastrointestinal surgical patients in the United States in 2016

Variable	Total (n = 66,157)	No Complication (n = 64,148)	Complication (n = 2,009)
Procedure			
Appendectomy	50,947 (77.0)	49,290 (96.7)	1,657 (3.3)
Cholecystectomy	9,796 (14.8)	9,561 (97.6)	235 (2.4)
Colonic Resection	333 (0.5)	297 (89.2)	36 (10.8)
Pyloromyotomy	4,574 (6.9)	4,546 (99.4)	28 (0.6)
Small Bowel Resection	254 (0.4)	228 (89.8)	26 (10.2)
Combination of 2 Procedures	--	--	--
Combination of 3 Procedures	--	--	--
Age in Years mean (SD)	12.2 (5.8)	12.1 (5.8)	12.1 (5.6)
Age Group			
< 1 month	1,694 (2.6)	1,669 (98.5)	25 (1.5)
1–24 months	3,544 (5.4)	3,486 (98.4)	58 (1.6)
2–12 years	27,239 (41.2)	26,312 (96.6)	928 (3.4)
>12 years	33,679 (50.9)	32,681 (97.0)	998 (3.0)
Sex			
Male	36,172 (54.7)	34,896 (96.5)	1,276 (3.5)
Female	29,980 (45.3)	29,249 (97.6)	731 (2.4)
Race			
White	28,619 (46.3)	27,758 (97.0)	860 (3.0)
Black	4,794 (7.7)	4,606 (96.1)	188 (3.9)
Hispanic	22,807 (36.9)	22,189 (97.3)	619 (2.7)
Asian/Pacific Islander	1,729 (2.8)	1,679 (97.1)	50 (2.9)
Native American	588 (1.0)	554 (94.3)	34 (5.7)
Other	3,338 (5.4)	3,225 (96.6)	113 (3.4)
Insurance Status			
Medicare	161 (0.2)	--	--
Medicaid	33,729 (51.0)	32,740 (97.1)	989 (2.9)
Private Insurance	26,916 (40.7)	26,092 (96.9)	824 (3.1)
Self-pay	3,209 (4.9)	3,105 (96.8)	104 (3.2)
No Charge	149 (0.2)	--	--
Other	1,916 (2.9)	1,844 (96.2)	72 (3.8)
Median Income for ZIP Code			
First Quartile	20,238 (31.0)	19,628 (97.0)	610 (3.0)
Second Quartile	16,243 (24.9)	15,706 (96.7)	536 (3.3)
Third Quartile	15,829 (24.2)	15,339 (96.9)	490 (3.1)
Fourth Quartile	13,003 (19.9)	12,655 (97.3)	348 (2.7)
Geographic Region of Hospital			
Northeast	11,245 (17.0)	10,965 (97.5)	280 (2.5)
Midwest	10,568 (16.0)	10,175 (96.3)	393 (3.7)
South	23,308 (35.2)	22,525 (96.6)	784 (3.4)
West	21,036 (31.8)	20,484 (97.4)	552 (2.6)
Hospital Location and Teaching Status			
Rural	4,265 (6.4)	4,086 (95.8)	179 (4.2)
Urban Nonteaching	13,236 (20.0)	12,813 (96.8)	423 (3.2)
Urban teaching	48,656 (73.5)	47,249 (97.1)	1,406 (2.9)
Hospital Size			
Small (1 to 99 beds)	8,706 (13.2)	8,410 (96.6)	296 (3.4)
Medium (100 to 399 beds)	15,818 (23.9)	15,361 (97.1)	457 (2.9)
Large ( $\geq$ 400 beds)	41,633 (62.9)	40,377 (97.0)	1,256 (3.0)

**Table 1** (continued)

Variable	Total (n = 66,157)	No Complication (n = 64,148)	Complication (n = 2,009)
Admission Modality			
Non-elective	61,336 (93.0)	59,532 (97.1)	1,804 (2.9)
Elective	4,635 (7.0)	4,433 (95.6)	202 (4.4)
Admission Day			
Weekday	49,401 (74.7)	47,884 (96.9)	1,517 (3.1)
Weekend	16,756 (25.3)	16,264 (97.1)	492 (2.9)
Admission Season			
Winter	16,473 (24.9)	15,982 (97.0)	491 (3.0)
Spring	16,645 (25.2)	16,135 (96.9)	510 (3.1)
Summer	17,437 (26.4)	16,890 (96.9)	547 (3.1)
Fall	15,599 (23.6)	15,138 (97.0)	460 (3.0)
Perforation			
No	42,618 (64.4)	41,868 (98.2)	750 (1.8)
Yes	23,539 (35.6)	22,281 (94.7)	1,258 (5.3)
Gestational Age			
Extremely Immature < 28 Weeks	18 (0.0)	--	--
Immature 28–37 Weeks	64 (0.1)	--	--
Post-term > 42 Weeks	--	--	--
Body Mass Index			
< 5th Percentile for Age	62 (0.1)	--	--
5th – 85th Percentile for Age	174 (0.3)	163 (93.7)	11 (6.3)
85th – 95th Percentile for Age	159 (0.2)	--	--
≥ 95th Percentile for Age	778 (1.2)	748 (96.1)	30 (3.9)
Not available	64,982 (98.2)	63,022 (97.0)	1,961 (3.0)

Column 1 represents column/block based %s; Column 2 and 3 contain row based frequencies and %s. Frequencies that are < 11 and related frequencies were not reported based on HCUP policy

4.27, 95% CI 3.69–4.94) and having one (OR 4.75, 95% CI 2.40–9.38) or two (OR 25.71, 95% CI 2.73–242.38) more procedures had significantly greater odds of postoperative complications.

Postoperative complication rates were also compared between household income national quartiles for patient ZIP code, geographic regions and between months in separate tests. Complication rates differed significantly among income quartiles for patient ZIP code ( $p = 0.02$ ) and were lowest in patients from fourth (highest) quartiles. Analysis by hospital region showed significant regional differences ( $p < 0.001$ ) with greater case frequencies in the South and Midwest compared with the Northeast and West of the United States. No significant time trend was present in pediatric surgical admissions with or without complications (Fig. 1).

For our secondary outcomes, the mean LOS was 8.30 (SD = 10.01) days in patients with complications and 2.86 (SD = 3.73) days in patients without complications. In the multivariable model, the LOS was significantly greater in the cohort with complications by 4.58 days (95% CI 4.05–5.10). Total hospitalization costs in the presence

of at least one complication amounted to an average of \$23,674 (SD = 31,116), while the mean costs in the complication-free control group were \$10,835 (SD = 13,285). Procedure-specific LOS and costs are presented in Table 3. The adjusted multivariable model revealed a significant difference of \$11,151 (95% CI 9,470–12,832) in costs between the two groups. Procedure-specific models are presented in Table 4. The strongest effects of postoperative complications on LOS and costs were found in small bowel resection and colonic resection. Since there were only 15 deaths in the total cohort related to pediatric gastrointestinal surgical procedures, no regression models for mortality were constructed.

## Discussion

Our study of 66,157 admissions representing a national estimate of children undergoing selected gastrointestinal surgical procedures is one of the largest cohorts of pediatric surgical hospitalizations. Our data indicated that infants, males, persons of racial minorities and those treated in rural hospitals had greater odds of experiencing complications following pediatric gastrointestinal

**Table 2** Multivariable logistic regression model to evaluate factors associated with postoperative complications

Variable	All procedures		Appendectomy	
	OR	95% CI	OR	95% CI
<b>Procedure</b>				
Small bowel resection	Ref	...		
Appendectomy	0.17	0.10–0.29	Ref	...
Cholecystectomy	0.31	0.17–0.54		
Colonic resection	0.82	0.41–1.65		
Pyloromyotomy	0.02	0.01–0.05		
Combination of two procedures	0.8	0.36–1.76	4.75	2.40–9.38
Combination of three procedures	4.22	0.42–42.95	25.71	2.73–242.38
<b>Age group</b>				
>12 years	Ref	...	Ref	...
< 1 month	3.71	1.57–8.77	17.03	7.70–37.68
1–24 months	2.11	1.32–3.35	1.77	0.99–3.17
2–12 years	0.92	0.82–1.05	0.88	0.77–1.00
<b>Sex</b>				
Male	Ref	...	Ref	...
Female	0.67	0.60–0.76	0.7	0.62–0.80
<b>Race</b>				
Caucasian	Ref	...	Ref	...
African American	1.38	1.13–1.69	1.36	1.08–1.73
Hispanic	0.97	0.84–1.12	0.98	0.84–1.14
Asian and Pacific Islander	1.08	0.76–1.52	1.09	0.76–1.57
Native American	1.71	1.08–2.71	1.43	0.82–2.50
Other	1.3	1.03–1.65	1.42	1.11–1.83
<b>Insurance Status</b>				
Medicare	Ref	...	Ref	...
Medicaid	0.51	0.23–1.13	0.58	0.23–1.47
Private Insurance	0.55	0.25–1.20	0.62	0.24–1.57
Self-pay	0.58	0.25–1.31	0.65	0.25–1.72
No Charge	0.89	0.27–2.95	1	0.25–1.72
Other	0.69	0.30–1.60	0.79	0.30–2.13
<b>Median Income for ZIP code</b>				
First Quartile	Ref	...	Ref	...
Second Quartile	1.09	0.94–1.26	1.16	0.99–1.37
Third Quartile	1.08	0.93–1.27	1.09	0.92–1.29
Fourth Quartile	0.91	0.76–1.10	0.93	0.76–1.13
<b>Geographic Region of Hospital</b>				
Northeast	Ref	...	Ref	...
Midwest	1.22	1.00–1.49	1.16	0.93–1.44
South	1.18	0.99–1.41	1.21	1.00–1.47
West	1.01	0.84–1.21	1	0.82–1.21
<b>Hospital Location and Teaching Status</b>				
Rural	Ref	...	Ref	...
Urban Non-teaching	0.94	0.74–1.18	0.96	0.75–1.24
Urban Teaching	0.74	0.60–0.92	0.74	0.58–0.94
<b>Hospital Size</b>				

**Table 2** (continued)

Variable	All procedures		Appendectomy	
	OR	95% CI	OR	95% CI
Small (1 to 99 beds)	Ref	...	Ref	...
Medium (100 to 399 beds)	0.89	0.73–1.07	0.93	0.76–1.14
Large (≥ 400 beds)	0.9	0.77–1.06	0.9	0.76–1.08
<b>Admission Modality</b>				
Non-elective	Ref	...	Ref	...
Elective	1.51	1.24–1.84	1.3	1.00–1.69
<b>Admission Day</b>				
Weekday	Ref	...	Ref	...
Weekend	0.97	0.85–1.10	0.94	0.82–1.08
<b>Admission Month</b>				
Month	1.00	0.99–1.02	1.00	0.98–1.02
<b>Intestinal Perforation</b>				
No	Ref	...	Ref	...
Yes	4.12	3.57–4.75	4.27	3.69–4.94

CI Confidence Interval, OR Odds Ratio, Ref Reference Group

surgery. Accordingly, the presence of complications was associated with longer hospitalization stays and higher costs.

We pooled procedures with distinct age-related frequency peaks. Controlling for procedure type in the models enabled the identification of young age as a factor for increased risk of complications after pediatric gastrointestinal procedures. This finding is similar to others that have reported age-related differences in postoperative complication rates in children undergoing adenotonsillectomy or appendectomy [18–20]. We identified that female sex was associated with reduced complication risk across a spectrum of pediatric gastrointestinal surgeries similar to another study of tonsillectomies [3]. While a large body of medical literature addresses sex inequalities in adults, underlying mechanisms in pediatric surgery are unknown. It is possible that differences in postoperative risk especially in the youngest age groups may relate to biological differences in sex but there may also be gendered differences on the part of parents and caregivers that are worthy of further study.

Race is the most commonly investigated patient factor in this research area and racial disparities in outcomes have been demonstrated in a variety of pediatric surgical procedures [4, 5, 21, 22]. Racial health inequity has been linked to inadequate care processes, such as choice of procedure and specialty referral, and may be reinforced by structural racism both within communities and within the healthcare system [23, 24], as well as other socio-cultural factors that are challenging to measure. Accordingly, our data showed increased complication rates among African Americans, Native Americans and

Complication Rate (%)

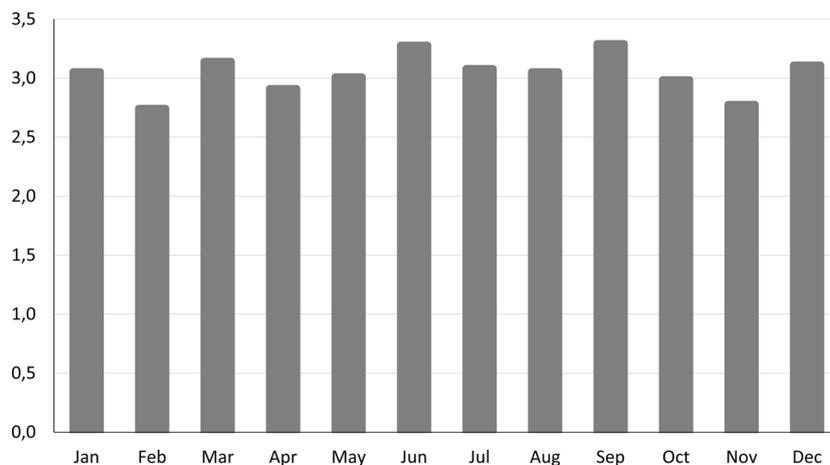


Fig. 1 Postoperative complication rate over time in total cohort

**Table 3** Length of stay and hospitalization costs stratified by procedure type and complication

Procedure		Length of stay		Hospitalization costs	
		mean	(SD)	mean	(SD)
All procedures	No complication	2.86	(3.73)	10,835	(13,285)
	Complication	8.30	(10.01)	23,674	(31,117)
Appendectomy	No complication	2.77	(3.17)	10,522	(8,085)
	Complication	7.85	(7.41)	21,231	(24,413)
Cholecystectomy	No complication	3.15	(3.83)	12,598	(24,436)
	Complication	9.66	(19.65)	33,436	(52,209)
Colonic resection	No complication	9.43	(16.35)	32,719	(47,642)
	Complication	17.71	(10.04)	60,431	(50,716)
Pyloromyotomy	No complication	2.42	(3.70)	7,865	(12,551)
	Complication	4.85	(3.62)	14,585	(12,470)
Small bowel resection	No complication	10.82	(17.63)	34,714	(50,135)
	Complication	23.03	(41.15)	64,371	(81,317)

patients classified as *other race* compared with Caucasian children. In the few available studies including Native American children, no increased likelihood of postoperative complications was observed [5, 22] whereas we did identify an increased risk suggestive of disparities in surgical access and care. For Hispanic children, the existing evidence on postoperative complication risk is conflicting [4, 5, 8, 22]. Our results support the observations from a recent large cross-sectional study, which did not find an elevated risk for Hispanic children [4] and they did encompass 37% of the cohort.

Consistent with existing evidence, we identified that the hospital location and teaching status were

**Table 4** Multivariable model of length of stay and hospitalization costs by procedure type

Procedure		Length of stay	Hospitalization costs
		Coefficient (95% CI)	Coefficient (95% CI)
All procedures			
No complication	Ref		Ref
	Complication	<b>4.58 (4.05–5.10)</b>	<b>11,151 (9,470–12,832)</b>
Appendectomy			
No complication	Ref		Ref
	Complication	<b>4.25 (3.81–4.68)</b>	<b>9,281 (7,777–10,784)</b>
Cholecystectomy			
No complication	Ref		Ref
	Complication	<b>5.48 (2.69–8.27)</b>	<b>16,722 (10,128–23,316)</b>
Colonic resection			
No complication	Ref		Ref
	Complication	<b>7.73 (2.84–12.62)</b>	<b>34,653 (11,592–57,715)</b>
Pyloromyotomy			
No complication	Ref		Ref
	Complication	0.62 (-1.80–3.03)	2,875 (-5,478–11,228)
Small bowel resection			
No complication	Ref		Ref
	Complication	<b>16.57 (0.18–32.97)</b>	<b>37,417 (6,952–67,882)</b>

associated with post-surgical complication rates [9]. Our analyses further identified that elective admission was associated with increased odds of complications and may relate to higher complexity of elective procedures compared with typical nonelective procedures; as elective admissions only comprised 7% of the cohort, the accuracy of this result is not clear.

When we examined socio-economic factors, consistent with earlier studies, we noted that there was a trend to lower postoperative complication rates in the highest income groups [3, 25, 26], but this was not significant in the adjusted model. One reason may be the interplay between income and other socio-demographic variables such as race or other unknown confounders [12]. More recent studies have identified primary payer status and hospital region as predictors of postoperative complications [6–8, 10]. Although we did note differences in these factors relative to complications, they were not significant in our multivariable models. Regarding admission features, prior studies have identified weekend admission as a risk factor for complications after pediatric surgery [27, 28] although this was not the case in our cohort. In accordance with previous findings, admission month and hospital size had no effect on complication frequency [29, 30].

Despite this being one of the largest cohorts to evaluate factors of postoperative complications, there are some limitations to consider. As the KID database is an administrative database, there is potential for information bias including misclassification and missingness. However, as the database is rigorous on data accuracy, and we utilized a similar approach to identifying surgery and complications to prior HCUP studies to maintain consistency and ensure inclusion of relevant admissions. As the unit of measure was an admission, it is possible that a patient was discharged before a complication occurred and readmissions were not recorded as linked to the index hospitalization. However, as our focus was on the risk factors and healthcare utilization, a proportion of the cohort having repeated admissions would not have largely affected the results. For missingness, there was minimal to no missingness in the cohort data in the covariates incorporated into the outcome models. BMI and gestational age, potential relevant patient characteristics, were not included in the models due to missingness. As the diagnosis and procedure information is limited to the admission unit of data, the timing and causality of complications to a surgical procedure cannot be definitively determined, but this would have affected the cohort non-selectively and thus likely did not skew the results significantly. Severity of complications was not specifically assessed based on data granularity but encouragingly, less than 4% of the cohort had multiple surgical procedures. Although we did not include all surgical procedures, we focused on the group of surgical procedures with the greatest volume [31], and also thought it would focus the evaluation and maintain our ability to be sufficiently powered for the analyses. We used postoperative complications as an indicator of poor surgical outcome which has

some challenges given the lack of agreement in the definition of complications and the grading of the severity. However, we attempted to be comprehensive and our evaluation of associated factors being consistent with earlier studies lends credence to our findings.

The increased use of healthcare resources in patients with complications from our cohort reinforces the relevance of postoperative complications not only to the patients and their families, but also to the healthcare system. To our knowledge, this study provides the most comprehensive analysis of socio-demographic predictors causing disparities in pediatric gastrointestinal surgical outcomes. There is a crucial need for effective and context-sensitive risk stratification algorithms to reduce preventable postoperative complications in pediatric surgical patients from health and socio-economic perspectives. Despite the known impacts of socio-demographic disparities in surgical outcomes, only a minority of surgeons account for these factors in their practice [32] highlighting the need for enhanced education across the medical spectrum as well as quality improvement and health system post-surgical surveillance initiatives.

## Conclusions

In our large population-based cohort study of children undergoing gastrointestinal surgical procedures, we identified a number of patient and system related factors that were associated with disparate outcomes. Young age, male sex, belonging to racial minorities including African Americans and Native Americans as well as receiving treatment in a rural hospital were associated with increased risk of postoperative complications. Only with greater education regarding social determinants of health of medical professionals, healthcare allocation reforms, and optimizing postoperative care pathways can we hope to mitigate outcome disparities in children undergoing surgery.

## Abbreviations

BMI: body mass index; HCUP: Healthcare Cost and Utilization Project; ICD-10: International Classification of Diseases – 10th revision; KID: Kids' Inpatient Database; LOS: length of stay; NEC: necrotizing enterocolitis.

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## Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by RB, SL and RS. The first draft of the manuscript was written by RB and RS. AC and MB were major contributors in writing the manuscript. All authors read and approved the final manuscript.

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#### Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available due to restrictions but are available from the corresponding author Robert Brock on reasonable request and with permission of the HCUP KIDS' Inpatient Database (KID), 2016. <https://www.hcup-us.ahrq.gov/kidoverview.jsp>.

#### Declarations

##### Ethics approval and consent to participate

All methods were carried out in accordance with the guidelines and regulations of the Nationwide Databases from the Healthcare Cost and Utilization Project (HCUP). Therefore, the study was approved by the Agency for Healthcare Research and Quality (AHRQ). The need for informed consent was waived by the AHRQ, because of the retrospective nature of the study. Details relating to an individual person were not reported based on the HCUP policy.

##### Consent for publication

Not applicable.

##### Competing interests

The authors declare that they have no competing interests.

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#### References

- Daodu OO, Zondervan N, Urban D, MacRobie A, Brindle M. Deriving Literature-Based Benchmarks for Pediatric Appendectomy and Cholecystectomy Complications from National Databases in High-Income Countries: A Systematic Review and Meta-Analysis. *J Pediatr Surg*. 2019;54(12):2528–38.
- Linnaus ME, Ostlie DJ. Complications in common general pediatric surgery procedures. *Semin Pediatr Surg*. 2016;25(6):404–11.
- Bhattacharyya N, Shapiro NL. Associations between socioeconomic status and race with complications after tonsillectomy in children. *Otolaryngol Head Neck Surg*. 2014;151(6):1055–60.
- Kou YF, Sakai M, Shah GB, Mitchell RB, Johnson RF. Postoperative respiratory complications and racial disparities following inpatient pediatric tonsillectomy: A cross-sectional study. *Laryngoscope*. 2019;129(4):995–1000.
- Zwintscher NP, Steele SR, Martin MJ, Newton CR. The effect of race on outcomes for appendicitis in children: a nationwide analysis. *Am J Surg*. 2014;207(5):748–53.
- Stone ML, LaPar DJ, Mulloy DP, Rasmussen SK, Kane BJ, McGahren ED, et al. Primary payer status is significantly associated with postoperative mortality, morbidity, and hospital resource utilization in pediatric surgical patients within the United States. *J Pediatr Surg*. 2013;48(1):81–7.
- Mowrer AR, Esparaz JR, Nierstedt RT, Zumpf KB, Chakraborty SR, Pearl RH, et al. Failure to thrive: the socioeconomics of pediatric gastrostomy complications. *J Pediatr Surg*. 2020;55(5):855–60.
- Duval M, Wilkes J, Korgenski K, Srivastava R, Meier J. Causes, costs, and risk factors for unplanned return visits after adenotonsillectomy in children. *Int J Pediatr Otorhinolaryngol*. 2015;79(10):1640–6.
- McAteer JP, Richards MK, Stergachis A, Abdullah F, Rangel SJ, Oldham KT, et al. Influence of hospital and patient location on early postoperative outcomes after appendectomy and pyloromyotomy. *J Pediatr Surg*. 2015;50(9):1549–55.
- Harounian JA, Schaefer E, Schubart J, Carr MM. Pediatric adenotonsillectomy and postoperative hemorrhage: Demographic and geographic variation in the US. *Int J Pediatr Otorhinolaryngol*. 2016;87:50–4.
- Torain MJ, Maragh-Bass AC, Dankwa-Mullen I, Hisam B, Kodadek LM, Lilley EJ, et al. Surgical Disparities: A Comprehensive Review and New Conceptual Framework. *J Am Coll Surg*. 2016;223(2):408–18.
- Haider AH, Scott VK, Rehman KA, Velopulos C, Bentley JM, Cornwell EE, III, et al. Racial Disparities in Surgical Care and Outcomes in the United States: A Comprehensive Review of Patient, Provider, and Systemic Factors. *J Am Coll Surg*. 2013;216(3):482–92.
- HCUP Kids' Inpatient Database (KID). Healthcare Cost and Utilization Project (HCUP). [Internet]. 2016 [cited November 15, 2020]. Available from: [www.hcup-us.ahrq.gov/kidoverview.jsp](http://www.hcup-us.ahrq.gov/kidoverview.jsp).
- McIsaac DI, Hamilton GM, Abdulla K, Lavallée LT, Moloo H, Pysyk C, et al. Validation of new ICD-10-based patient safety indicators for identification of in-hospital complications in surgical patients: a study of diagnostic accuracy. *BMJ Qual Saf*. 2020;29(3):209–16.
- Feudtner C, Christakis DA, Connell FA. Pediatric deaths attributable to complex chronic conditions: a population-based study of Washington State, 1980–1997. *Pediatrics*. 2000;106(1 Pt 2):205–9.
- Bazaclicu C, Neu J. Necrotizing Enterocolitis: Long Term Complications. *Curr Pediatr Rev*. 2019;15(2):115–24.
- Faraoni D, Gardella KM, Odegard KC, Emani SM, DiNardo JA. Incidence and Predictors for Postoperative Thrombotic Complications in Children With Surgical and Nonsurgical Heart Disease. *Ann Thorac Surg*. 2016;102(4):1360–7.
- Gehrke T, Scherzad A, Hagen R, Hackenberg S. Risk factors for children requiring adenotonsillectomy and their impact on postoperative complications: a retrospective analysis of 2000 patients. *Anaesthesia*. 2019;74(12):1572–9.
- Julien-Marsollier F, Salis P, Abdat R, Diallo T, Van Den Abbelle T, Dahmani S. Predictive factors of early postoperative respiratory complications after tonsillectomy in children with unidentified risks for this complication. *Anaesth Crit Care Pain Med*. 2018;37(5):439–45.
- Aneiros B, Cano I, García A, Yuste P, Ferrero E, Gómez A. Pediatric appendicitis: Age does make a difference. *Rev Paul Pediatr*. 2019;37(3):318–24.
- Akbulgic O, Langham MR, Davis RL. Race, preoperative risk factors, and death after surgery. *Pediatrics*. 2018;141(2):e20172221.
- Stone ML, LaPar DJ, Kane BJ, Rasmussen SK, McGahren ED, Rodgers BM. The effect of race and gender on pediatric surgical outcomes within the United States. *J Pediatr Surg*. 2013;48(8):1650–6.
- Bailey ZD, Krieger N, Agénor M, Graves J, Linos N, Bassett MT. Structural racism and health inequities in the USA: evidence and interventions. *Lancet*. 2017;389(10077):1453–63.
- Wallace M, Crear-Perry J, Richardson L, Tarver M, Theall K. Separate and unequal: Structural racism and infant mortality in the US. *Health Place*. 2017;45:140–4.
- Rubinger L, Chan C, Andrade D, Go C, Smith ML, Snead OC, et al. Socio-economic status influences time to surgery and surgical outcome in pediatric epilepsy surgery. *Epilepsy Behav*. 2016;55:133–8.
- Ingram ME, Calabro K, Polites S, McCracken C, Aspelund G, Rich BS, et al. Systematic Review of Disparities in Care and Outcomes in Pediatric Appendectomy. *J Surg Res*. 2020;249:42–9.
- Egberg MD, Galanko JA, Kappelman MD. Weekend Surgical Admissions of Pediatric IBD Patients Have a Higher Risk of Complication in Hospitals Across the US. *Inflamm Bowel Dis*. 2020;26(2):254–60.
- Goldstein SD, Papandria DJ, Aboagye J, Salazar JH, Van Arendonk K, Al-Omar K, et al. The “weekend effect” in pediatric surgery - increased mortality for children undergoing urgent surgery during the weekend. *J Pediatr Surg*. 2014;49(7):1087–91.
- Lin Y, Mayer RR, Verla T, Raskin JS, Lam S. Is there a “July effect” in pediatric neurosurgery? *Childs Nerv Syst*. 2017;33(8):1367–71.
- Wang H-HS, Tejwani R, Zhang H, Wiener JS, Routh JC. Hospital Surgical Volume and Associated Postoperative Complications of Pediatric Urological Surgery in the United States. *J Urol*. 2015;194(2):506–11.

31. Tzong KY, Han S, Roh A, Ing C. Epidemiology of pediatric surgical admissions in US children: data from the HCUP kids inpatient database. *J Neurosurg Anesthesiol.* 2012;24(4):391–5.
32. Britton BV, Nagarajan N, Zogg CK, Selvarajah S, Schupper AJ, Kironji AG, et al. Awareness of racial/ethnic disparities in surgical outcomes and care: factors affecting acknowledgment and action. *Am J Surg.* 2016;212(1):102–8.

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