Pediatric RESEARCH

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CLINICAL RESEARCH ARTICLE

Socioeconomic disparities in the comorbidities and surgical management of pediatric Crohn's disease

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BACKGROUND: To examine differences in comorbidities and surgical management based on socioeconomics in hospitalized children with Crohn's disease (CD).

METHODS: Using the Kids' Inpatient Database for 2006–2012, we identified patients (<21 years) with a CD diagnosis. Cases were analyzed and stratified by median parental income by zip code. Multivariable logistic regression was performed.

RESULTS: Of the 28,337 pediatric CD hospitalizations identified, patients were more likely male (51.1%), non-Hispanic white (71.3%), and had a mean age of 15.9 years. The proportion of minority patients increased as income quartile declined. Higher income quartile patients were more likely to be coded with anxiety and less likely with anemia. The highest income quartile was more likely to have a bowel obstruction, and peritoneal/intestinal abscess and was also 28% more likely to undergo a major surgical procedure.

CONCLUSIONS: Significant variability exists in the reported comorbidities and surgical interventions associated with CD by income quartile. Lower income quartile patients are more likely to be of minority ethnicity and anemic, but less likely to undergo a major surgical procedure. Further investigation is warranted to determine whether these differences represent disease variability, differences in healthcare resource allocation, or implicit bias in management.

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IMPACT:

- There is a disparity in the care of children and young adults with Crohn's disease based on parental income. Links between parental income and the treatment of Crohn's disease in children and young adults has not been assessed in national datasets in the United States.
- Children in the highest income quartile were more likely to undergo a major surgical procedure.
- The variations in healthcare for hospitalized children and young adults with CD found in this study may represent variability in patient disease, implicit bias, or a disparity in healthcare delivery across the United States.

INTRODUCTION

Research on the association between parental levels of income with the management and outcomes of pediatric inflammatory bowel disease (IBD) in the United States is limited. The prevalence of Crohn's disease (CD) in patients younger than 20 years old has been increasing,[1] and it is estimated that between 20% and 30% of patients with CD are diagnosed before the age of 20 years.[1–3] Compared with adults, pediatric patients with CD have a more extensive and severe disease course,[4] increasing their risks of hospitalization. A limited number of studies have shown a link between wealth and CD, with one comprehensive study of hospitalized IBD patients revealing a higher prevalence of IBD among affluent populations.[5] Nevertheless, little is known about how socioeconomic status (SES) of children with CD in the United States may impact their management and disease outcomes.

Parental income has shown to be an important factor influencing patient management and outcomes for a myriad of other disease conditions, including respiratory complications in obese children undergoing tonsillectomy,[6] increased mortality in pediatric lymphoma patients undergoing a major surgical procedure,[7] and lower rates of procedures in childhood traumatic brain injury.[8]

Parental income may also be a factor in patient outcomes of IBD internationally. In a large Canadian study, pediatric patients in low-income zip codes diagnosed with IBD were more likely to be hospitalized for IBD-related complications when compared to patients with higher income zip codes.[9] However, the single-payer system within Canada's healthcare system, regardless of employment or SES, limits the applicability of such findings to a multi-payer country, such as the United States. To the best of our knowledge, there have been no observational studies that have

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examined the relationship between parental incomes in the United States with associated comorbidities, disease-related complications, and interventions in pediatric CD.

Using data from the large, nationally representative Kids' Inpatient Database (KID), we examined the relationship between hospitalized pediatric patients with CD and income in the United States, and disparities in the inpatient treatment and management of CD in the pediatric population, which may be based on parental income.

METHODS

Study design and data source

After combining the KID for the years 2006, 2009, and 2012 into a single dataset, a cross-sectional analysis was performed. At the time this study was conducted, 2012 was the most recent year available; however, the 2016 KID (utilizing International Classification of Diseases, Tenth Revision, ICD-10 codes) was subsequently released. Due to concerns about comparisons between ICD-9 and ICD-10 coding, the 2016 data were not included in this study. Managed as part of the Healthcare Cost and Utilization Project (HCUP) by the Agency for Healthcare Research and Quality (AHRQ), the KID is produced triennially and is the largest publicly available administrative all-payer national sampling of pediatric and young adult (<21 years of age) inpatient discharges.[10] With 38, 44, and 44 states participating in 2006, 2009, and 2012 respectively, the KID represents ~80% of all pediatric and young adult discharges during the study period and 6.7–7.6 million national discharges among children and adolescents aged <21 years old.

Case selection

Patients were identified using ICD-9 diagnosis codes related to CD of 555, 555.0, 555.1, 555.2, and 555.9 in either the primary or any of the secondary diagnoses. We identified procedures and comorbidities by ICD-9 and single-level Clinical Classifications Software (CCS). The CCS, developed by AHRQ as part of HCUP, is a diagnosis and procedure categorization scheme. A major surgical procedure is defined in the KID as the presence of a major diagnostic or therapeutic procedure that occurred in the operating room. An emergent admission was determined by whether the hospitalization was elective or not.

Cases were excluded if there were concerns for indeterminate colitis (ICD-9 codes for both ulcerative colitis and CD) or if there were a trauma involved in the hospitalization (as defined by ICD-9 E-codes). Additionally, cases were excluded if there were missing data from critical variables, including age, sex, race, primary payer, mortality, total hospital charges (THCs), length of stay, and median income quartile per zip code. Finally, cases were excluded if there were coding errors within the ICD-9 codes using a built-in STATA 15.0 feature (College Station, TX). These exclusion criteria eliminated 20.5% of the possible cases. The primary reasons for exclusion were a missing race (76.0%) and THCs (8.9%).

Independent and dependent variables

Median parental income, the independent variable, was classified according to HCUP documentation for zip codes into quartiles and was used to stratify variables in this study. This income quartile has been used in a multitude of other studies investigating the relationship between outcomes and SES.[11,12] Patient characteristics included age, sex, race, and elective admission. Health insurance payer was evaluated in three categories—private pay (including HMO), government (Medicare, Medicaid), and others. Four age groups were defined—elementary school (<10 years), middle school (11–13 years), high school (14–18 years), and post-high school (19–20 years). Hospital regions were defined by US census bureau definitions.[13] Patient location was described as urban (central and fringe counties of metro areas ≥1 million population), suburban (counties in metro areas of 50,000–999,999 population), and rural (micropolitan counties, non-core counties). Hospitalization information assessed included length of stay (LOS) and THCs in USD. THC is reported in USD$ and were standardized to 2018 US Dollar values.[14] The comorbidities and interventions were defined using ICD-9 and CCS codes, and the definitions are listed in Supplementary I. The selection of the comorbidities and interventions were made a priori by the study team based on our clinical experience. The comorbidities assessed included anxiety, anemia, depression, nutritional deficiency (including cachexia, protein-calorie malnutrition, and deficiencies of vitamin A, thiamine, niacin, B-complex vitamins, vitamin C and D) treatment noncompliance, intestinal obstruction, perianal disease, peritonitis, peritoneal or intestinal abscess, presence of an ostomy, complication with an ostomy, and the presence of an enteroenteric fistula. The interventions assessed utilized the HCUP-defined variable of a major surgical procedure, which is based on the presence of a major therapeutic or diagnostic procedure that occurred during the hospitalization.[15] Additionally, we utilized ICD-9 procedure-based definitions for total abdominal colectomy, small or large bowel resection, vascular catheterization, blood transfusion, and use of supplementary enteral or parental nutrition (Supplementary I).

Data analysis

National estimates for hospitalizations of pediatric and young adult with CD were generated using the HCUP-provided weighting and svy function in STATA. In order to generate national estimates using the KID, HCUP provides a weighting variable which when used in conjunction with the svy function in STATA allows users to generate numbers that are nationally reflective. Pearson's χ^2 and Student's t tests were used in analyzing categorical and continuous variables, respectively, and all statistical tests were two sided. Statistical significance was considered with a p value < 0.05. Independent multiple multivariable logistic regression analysis was performed to assess the relationship between income quartile and comorbidities or interventions while controlling for potential confounders. The dependent variable was the comorbidity or intervention of interest, and the independent variable was income quartile. The confounders controlled for included age (by category), sex, race, patient location, payer, and hospital region. Confounders were selected based on the findings presented in Table 1. A total of 17 models were run in both crude and adjusted forms (Tables 3, 4). All analyses were performed using STATA 15.0 statistical software.

Ethical consideration

The Institutional Review Board at the University of Massachusetts Medical School (Worcester, MA) reviewed this study and deemed it exempt. Following the data use agreement with AHRQ for the use of the KID, this study does not report information where the number of observations is ≤10.

RESULTS

There were 28,337 hospitalizations for children and young adults involving CD identified in 2006, 2009, and 2012. Patients with CD were predominately non-Hispanic white (71.3%), male (51.1%), admitted in the South (35.6%), residents of urban environments (60.3%), privately insured (64.8%), with a mean age of 15.9 years (±4.6 years) (Table 1).

Patient characteristics according to parental income

Females were predominant in the lowest income quartile (51.6%), but this changed as income quartile increased, with males predominating in the highest quartiles. Non-Hispanic white and Asian patients were seen at growing proportions from lowest to highest quartiles. Black and Hispanic patients were seen in

Table 1. Patient characteristics according to income quartile.

	1st *N* (%)	2nd *N* (%)	3rd *N* (%)	4th *N* (%)	Total *N* (%)	*p* Value
Total	6111 (21.6)	6062 (21.4)	6910 (24.4)	9254 (32.7)	28,377	
Age, mean ± SD	16.2 (4.5)	16.0 (4.6)	15.8 (4.7)	15.8 (4.5)	15.9 (4.6)	
Age groupings						
Elementary (0–10)	490 (8.0)	529 (8.7)	678 (9.8)	864 (9.3)	2562 (9.0)	0.11
Middle school (11–13)	740 (12.1)	831 (13.7)	945 (13.7)	1305 (14.1)	3820 (13.5)	0.19
High school (14–18)	2846 (46.6)	2777 (45.8)	3199 (46.3)	4497 (48.6)	13,319 (47.0)	0.11
Post-high school (19+)	2035 (33.3)	1926 (31.8)	2087 (30.2)	2588 (28.0)	2588 (30.5)	<0.01
Male sex	2956 (48.4)	3009 (49.6)	3589 (51.9)	4931 (53.3)	14,485 (51.1)	<0.01
Race						
Non-Hispanic white	3170 (51.9)	4329 (71.4)	5179 (75.0)	7530 (81.4)	20,208 (71.3)	<0.01
Black	1892 (31.0)	1035 (17.1)	805 (11.6)	668 (7.2)	4399 (15.5)	<0.01
Hispanic	734 (12.0)	428 (7.1)	558 (8.1)	479 (5.2)	2,198 (7.8)	<0.01
Asian or Pacific Islander	50 (0.8)	44 (0.7)	80 (1.2)	162 (1.8)	336 (1.2)	<0.01
Native American	35 (0.6)	18 (0.3)	15 (0.2)	19 (0.2)	87 (0.3)	0.12
Other	231 (3.8)	207 (3.4)	274 (4.0)	397 (4.3)	1,109 (3.9)	0.40
Region						
Northeast	1483 (24.3)	1377 (22.7)	1774 (25.7)	3553 (38.4)	8186 (28.9)	<0.01
Midwest	1163 (19.0)	1299 (21.4)	1472 (21.3)	1408 (15.2)	5341 (18.9)	<0.01
South	2856 (46.7)	2487 (41.0)	2334 (33.8)	2408 (26.0)	10,085 (35.6)	<0.01
West	496 (8.1)	786 (13.0)	1206 (17.5)	1805 (19.5)	4923 (15.2)	<0.01
Elective admission	1016 (16.7)	1034 (17.1)	1270 (18.4)	1737 (18.8)	5058 (17.9)	0.06
Patient location						
Urban	2846 (46.6)	2588 (42.7)	4107 (59.4)	7535 (81.4)	17,076 (60.3)	<0.01
Suburban	1513 (24.8)	2135 (35.2)	2270 (32.9)	1393 (15.1)	7311 (25.8)	<0.01
Rural	1699 (28.8)	1289 (21.3)	418 (6.1)	91 (1.0)	3497 (12.3)	<0.01
Type of primary insurance						
Private	2616 (42.8)	3411 (56.3)	4719 (68.3)	7627 (82.4)	18,373 (64.8)	<0.01
Government	2783 (45.5)	1903 (31.4)	1570 (22.7)	1087 (11.7)	7342 (25.9)	<0.01
Other	712 (11.7)	749 (12.4)	620 (9.0)	540 (5.8)	540 (9.3)	<0.01

gradually lower percentages as income quartiles increased. There was no difference in income quartile distribution for elementary, middle, and high schoolers, but post-high school patients were seen at lower rates, from 33.3% to 28.0%, as income quartile increased. Private insurance status predominated in the highest three income quartiles with an upward trend from lowest to highest. A parallel decline in government payer status was seen as income quartile increased. There was no difference in elective admission, or mortality during the hospitalization based on income quartile distribution (Table 1).

Prevalence of comorbidities, complications, and interventions according to parental income

There was a significantly higher proportion of patients with a diagnosis of anxiety in the highest income quartiles, with a considerably lower proportion with diagnoses of anemia, obesity, or noncompliance in the same income quartiles (Table 2). There was an increased proportion of patients with diagnoses of bowel obstruction, peritoneal or intestinal abscesses, or ostomy in the highest income quartile, with a significantly lower percentage of each seen in each successive lower quartile (Table 2). There were fewer major surgical procedures, small or large bowel resections performed, and less administration of parenteral or enteral nutrition in lower income quartiles patients when compared to the higher income quartiles (Table 2). However, there were higher rates of blood transfusions administered within the lower income quartile compared to the higher quartile.

Logistic regression evaluating parental income association with interventions and comorbidities

Crude (Table 3) and adjusted (Table 4) logistic regressions were performed to evaluate for the association of income quartile on the diagnosis of associated comorbidities, disease-related complications, and interventions. After performing adjusted logistic regression, the highest income quartiles were associated with increased likelihood of having a peritoneal or intestinal abscesses (adjusted odds ratio (aOR) 1.37; 95% confidence interval (CI) 1.08–1.37), having an ostomy (aOR 1.69; 95% CI 1.16–2.46), having a small bowel (aOR 1.68; 95% CI 1.25–2.26) or large bowel resection (aOR 1.21; 95% CI 1.02–1.43), and having any major surgical procedure performed (aOR 1.28; 95% CI 1.12–1.45). The highest income quartile was 37% less likely to be diagnosed with noncompliance (aOR 0.63; 0.48–0.83) compared to the lowest income quartile (Table 4).

DISCUSSION

Prior research has demonstrated the increased prevalence of CD within non-Hispanic white and affluent communities within North America and Europe.[5,16] Our findings mirror the existing literature

Table 2. Comorbidities, complications, and interventions associated with Crohn's disease according to parental income.

	1st *N* (%)	2nd *N* (%)	3rd *N* (%)	4th *N* (%)	Total *N* (%)	*p* Value
Associated comorbidities						
Anxiety	197 (3.2)	192 (3.2)	287 (4.2)	410 (4.4)	1,086 (3.8)	0.01
Anemia	1620 (26.5)	1537 (25.4)	1702 (24.6)	2074 (22.4)	6933 (24.5)	<0.01
Depression	276 (4.5)	258 (4.3)	291 (4.2)	369 (4.0)	1,193 (4.2)	0.71
Nutritional deficiency	497 (8.1)	510 (8.4)	652 (9.4)	690 (7.5)	2,348 (8.3)	0.01
Treatment noncompliance	349 (5.7)	217 (3.6)	249 (3.6)	214 (2.3)	1,028 (3.6)	<0.01
Complications						
Bowel obstruction	324 (5.3)	377 (6.2)	417 (6.0)	638 (6.9)	1756 (6.2)	0.02
Perianal disease	256 (4.2)	294 (4.8)	319 (4.6)	381 (4.1)	1250 (4.4)	0.37
Peritonitis	64 (1.1)	56 (0.9)	85 (1.2)	124 (1.3)	330 (1.2)	0.34
Peritoneal/intestinal abscess	261 (4.3)	352 (5.8)	421 (6.1)	582 (6.3)	1616 (5.7)	<0.01
Ostomy	172 (2.8)	248 (4.1)	327 (4.7)	409 (4.4)	1157 (4.1)	<0.01
Complication with ostomy	32 (0.5)	26 (0.4)	69 (1.0)	63 (0.7)	189 (0.7)	0.03
Enteroenteric fistula	193 (3.2)	252 (4.2)	272 (3.9)	337 (3.6)	1055 (3.7)	0.17
Interventions						
Major surgical procedure	1046 (17.1)	1197 (19.7)	1445 (20.9)	2058 (22.2)	5745 (20.3)	<0.01
Total abdominal colectomy	11 (0.2)	18 (0.3)	27 (0.4)	43 (0.5)	99 (0.4)	0.10
Small bowel resection	105 (1.7)	170 (2.8)	197 (2.8)	296 (3.2)	768 (2.7)	<0.01
Large bowel resection	462 (7.6)	517 (8.5)	617 (8.9)	922 (10.0)	2519 (8.9)	<0.01
Vascular catheterization	685 (11.2)	751 (12.4)	888 (12.9)	1196 (12.9)	3520 (12.4)	0.07
Blood transfusion	426 (7.0)	376 (6.2)	397 (5.7)	508 (5.5)	1706 (6.0)	0.03
Enteral/parenteral nutrition use	570 (9.3)	634 (10.5)	873 (12.6)	1152 (12.5)	3229 (11.4)	<0.01

by finding that the majority of hospitalized children and young adults with CD were non-Hispanic white (71.3%) and privately insured (64.8%), with approximately one-third of children and young adult inpatients in the highest income quartile.[5,17–22] The income distribution of the children and young adults with CD in our study is in sharp contrast to the income distribution in the overall population in the KID. Only 20.5% of the total population in the KID were in the highest income quartile. Existing research has demonstrated that Black and Hispanic children with CD had longer LOS than white children[23] and that Black children had more anemia, more vitamin D deficiency, and more blood transfusions.[24] Our study, the first to our knowledge to look at income level in the United States, demonstrated that hospitalized children in the United States with CD in higher income quartiles underwent major surgical procedures, including ileostomy creation, small bowel resection, and large bowel resection at higher rates than those in lower income quartiles. In addition, we found differences in comorbidities, disease-related complications, and interventions based on income.

Differences in surgical management

The difference in surgery rates seen across the income quartiles of this study may be due to several factors. One possibility is that differences exist in the disease spectrum of CD within different socioeconomic strata. A second possibility is that those in lower income quartiles receive fewer surgeries despite needing them and that the inverse might also be true—that those in higher income quartiles receive unwarranted surgeries. An additional alternative is that provider implicit bias plays a role in clinical management. Implicit bias occurs when attitudes or stereotypes affect our understanding, actions, and decisions in an unconscious manner.[25] Disparities in treatment recommendations, expectations, management of pain, and levels of provider empathy has been associated with implicit bias among providers.[26] Existing research demonstrates that non-Hispanic whites undergo higher rates of IBD-related abdominal surgery than other racial groups,[20,23] and in this study, we saw a higher predominance of non-Hispanic whites in the highest income quartile. While the racial distribution might explain the higher rates of surgery in the highest quartile, the reasons why non-Hispanic whites undergo higher rates of surgery than other races are not evident based on the available information. In turn, it is challenging to exclude implicit bias by income or another related demographic. Future research on the potential role of implicit bias in the management of children with CD is needed to elucidate this further, and to investigate the role that SES plays in the management of children with CD.

Our study found that rates of surgery differ by income quartile contradicts two existing studies.[9,27] There are several possible reasons for the discrepancies between our findings on the impact of parental income on pediatric and adolescent IBD and previously published reports. First, these two studies were completed before widespread tumor necrosis factor-α (TNF-α) antibody therapy was in use for pediatric patients with CD, while our research looked at the period after their introduction (2006–2012). Anti-TNF-α therapy (Remicade/Infliximab, first approved for pediatric CD in the United States in 2006) has significantly altered the management of CD with increased disease remission rates both in short-term[28,29] and long-term management.[30–32] While one recent study found no overall impact on the rate of bowel resections following the approval of TNF-α inhibitors,[18] it could not assess for the specific use of TNF-α antibody therapy use in this population. Second, differences in the healthcare systems of these studies (Canada and France) may impact the management of CD in this population.[33] Finally, there may be differences in the management of CD between the United States and Canada or France with rates of surgery and differing outcomes, as has been demonstrated in other unrelated disease states.[34]

Table 3. Crude logistic regressions according to parental income evaluating comorbidities, complications, and interventions.

Reference group = 1st quartile	2nd			3rd			4th		
	Odds ratio	95% CI	*p* Value	Odds ratio	95% CI	*p* Value	Odds ratio	95% CI	*p* Value
Associated comorbidities									
Anxiety	0.99	0.75, 1.30	0.99	1.31	1.01, 1.69	0.04	1.40	1.09, 1.78	0.01
Anemia	0.94	0.84, 1.05	0.94	0.91	0.81, 1.02	0.09	0.80	0.71, 0.90	<0.01
Depression	0.94	0.74. 1.18	0.94	0.93	0.74, 1.17	0.53	0.88	0.70, 1.11	0.27
Nutritional deficiency	1.04	0.88, 1.23	1.04	1.18	0.99, 1.96	0.06	0.91	0.76, 1.09	0.30
Noncompliance	0.61	0.49, 0.76	0.61	0.62	0.49, 0.78	<0.01	0.39	0.31, 0.49	<0.01
Complications									
Bowel obstruction	1.18	0.97, 1.45	1.18	1.15	0.94, 1.39	0.17	1.32	1.11, 1.58	<0.01
Peritoneal/intestinal abscess	1.38	1.12, 1.71	1.38	1.46	1.17, 1.81	<0.01	1.50	1.22, 1.85	<0.01
Ostomy	1.47	1.11, 1.94	1.47	1.71	1.25, 2.34	<0.01	1.59	1.20, 2.12	<0.01
Complication with ostomy	0.83	0.41, 1.67	0.83	1.94	1.03, 3.65	0.04	1.31	0.74, 2.29	0.35
Enteroenteric fistula	1.33	1.03, 1.72	1.33	1.26	0.99, 1.59	0.06	1.16	0.91, 1.48	0.25
Interventions									
Major surgical procedure	1.19	1.06, 1.34	1.19	1.28	1.14, 1.44	<0.01	1.39	1.24, 1.55	<0.01
Total abdominal colectomy	1.67	0.66, 4.19	1.67	2.12	0.95, 4.72	0.07	2.55	1.16, 5.61	0.02
Small bowel resection	1.66	1.23, 2.24	1.66	1.68	1.26, 2.24	<0.01	1.90	1.44, 2.51	<0.01
Large bowel resection	1.14	0.96, 1.35	1.14	1.20	1.03, 1.40	0.02	1.35	1.16, 1.57	<0.01
Vascular catheterization	1.12	0.98, 1.28	1.12	1.17	1.02, 1.34	0.03	1.18	1.02, 1.35	0.02
Blood transfusion	0.88	0.73, 1.06	0.88	0.81	0.67, 0.99	0.04	0.77	0.64, 0.93	0.01
Enteral/parenteral nutrition use	1.13	0.98, 1.32	1.13	1.41	1.76, 1.68	<0.01	1.38	1.18, 1.68	<0.01

Differences in comorbidities and disease-related complications

Limited studies have looked at the comorbidities associated with CD within the hospitalized pediatric and young adult population, and none to our knowledge have examined differences in the prevalence of comorbidities based on socioeconomic status. Although it is plausible that patients within lower income quartiles would have higher severity of illness (e.g., increased prevalence of comorbidities and disease complications), due to limited access to care and inability to afford the cost of their care, our findings suggest otherwise. We found higher rates of anemia and noncompliance in hospitalized children and young adults in the lower income quartile compared to the highest quartile. Conversely, we also found this population to have a lower prevalence of bowel obstructions and peritoneal or intestinal abscesses. After performing adjusted logistic regression, the likelihood of peritoneal or intestinal abscesses was significantly increased by 37–42% in all income quartiles compared to the lowest quartile. Overall, we observed the anticipated higher comorbidity incidence within the lowest income quartile, although complications of CD were higher among the higher income quartiles. It is possible that these complications are postoperative and therefore seen with higher frequency in higher income quartiles because they undergo more major surgical procedures. On the other hand, it is possible that these complications of CD are indications to proceed with surgical intervention in this patient population.

The rate of anemia in this study of hospitalized children and young adults ranged from 22.4% to 26.5% with the highest rate seen in the lowest income quartile. Our rate is lower than those seen in other studies, but our population differs in that it was neither a purely surgical cohort[35] nor was the data captured explicitly upon the initial presentation of CD.[36] The relative difference in the rate of anemia was small, so conclusions about anemia differences based on income quartile are limited. The rate of blood transfusions administered mirrored the trend seen in anemia in that the lowest income quartile was the most frequent recipients. The reason for the higher anemia rates in lower income patients is not apparent, but may be related to reduced access to healthcare resources, and thus lower disease remission rates, rather than a difference in disease severity related to racial variation. Since patients from lower income have fewer major procedures, it might also follow that they are admitted to the hospital more frequently for flares of their CD. It is not uncommon for a CD flare patient to experience intestinal hemorrhage with associated anemia. Limited access to specialists such as pediatric gastroenterologists or surgeons, and inability to afford or acquire medications could lead to the observed higher rates of anemia if the individual is experiencing more symptoms. The KID does not capture iron transfusions and it is possible that supplemental iron influences blood transfusion rate. Other potential explanations include other potential comorbidities or inadequate medical therapy. Additionally, it has been shown that while there are differences in rates of IBD-related surgeries, rates of hospitalization, length of stay, and IBD-related morbidity[20,23]—there appears to be mixed evidence on disease severity based on race.[37,38] Therefore, it seems unlikely that the higher prevalence of black and Hispanic patients with CD in the lowest income quartile explains the higher rates of anemia and the need for blood transfusions.

Study strengths and limitations

The major strength of this study is the size and nature of the KID. It is the single largest national all-payer administrative dataset of children and adolescents <21 years of age within the United States. The size of the KID, with more than 6.5 million hospitalizations collected tri-annually, allows for a robust analysis of the nature and management of a variety of rare and common conditions.

There are several limitations associated with this study. Primarily is the use of median income quartiles by zip code. Income levels have been associated with longer life expectancy,[39] but the best variable for measuring socioeconomic status depends on both the population and the outcome under investigation.[40] Secondly, ICD-9 codes were utilized to determine the presence of the

Table 4. Multivariate logistic regressions according to parental income evaluating comorbidities, complications, and interventions[a].

Reference group = 1st quartile	2nd			3rd			4th		
	Odds ratio	95% CI	*p* Value	Odds ratio	95% CI	*p* Value	Odds ratio	95% CI	*p* Value
Associated comorbidities									
Anxiety	0.89	0.67, 1.18	0.41	1.16	0.87, 1.55	0.30	1.28	0.96, 1.70	0.09
Anemia	1.03	0.92, 1.16	0.59	1.02	0.90, 1.15	0.79	0.96	0.85, 1.09	0.55
Depression	0.96	0.75, 1.22	0.72	1.00	0.77, 1.30	1.00	1.02	0.76, 1.38	0.90
Nutritional deficiency	1.09	0.92, 1.29	0.30	1.28	1.07, 1.52	0.01	1.02	0.84, 1.24	0.82
Noncompliance	0.83	0.66, 1.05	0.12	0.93	0.73, 1.19	0.58	0.63	0.48, 0.83	<0.01
Complications									
Bowel obstruction	1.14	0.93, 1.41	0.22	1.05	0.85, 1.30	0.64	1.18	0.96, 1.46	0.12
Peritoneal/intestinal abscess	1.42	1.14, 1.77	<0.01	1.43	1.13, 1.81	<0.01	1.37	1.08, 1.73	0.01
Ostomy	1.47	1.11, 1.95	0.01	1.74	1.28, 2.35	<0.01	1.63	1.20, 2.21	<0.01
Complication with ostomy	0.85	0.41, 1.74	0.65	2.15	1.10, 4.19	0.03	1.45	0.76, 2.77	0.26
Enteroenteric fistula	1.38	1.05, 1.82	0.02	1.29	1.00, 1.67	0.05	1.17	0.87, 1.56	0.30
Interventions									
Major surgical procedure	1.16	1.03, 1.30	0.02	1.22	1.08, 1.37	<0.01	1.28	1.12, 1.45	<0.01
Total abdominal colectomy	1.81	0.66, 4.95	0.25	2.19	0.91, 5.26	0.08	2.69	0.95, 7.60	0.06
Small bowel resection	1.56	1.15, 2.11	0.01	1.53	1.14, 2.06	0.01	1.68	1.25, 2.26	<0.01
Large bowel resection	1.09	0.92, 1.29	0.33	1.11	0.95, 1.31	0.19	1.21	1.02, 1.43	0.03
Vascular catheterization	1.13	0.98, 1.30	0.08	1.12	0.96, 1.30	0.15	1.09	0.93, 1.27	0.29
Blood transfusion	0.99	0.82, 1.20	0.92	0.96	0.78, 1.19	0.73	0.94	0.77, 1.16	0.59
Enteral/parenteral nutrition use	1.13	0.97, 1.33	0.12	1.31	1.08, 1.58	0.01	1.15	0.96, 1.38	0.13

[a]Adjusted for sex, race, hospital region, age, patient location, and insurance status.

comorbidities of interest, and we are unable to determine if these were present on admission or if they manifested during the hospitalization. It cannot be determined how thoroughly these comorbidities and procedures were documented over time, and the rise in prevalence observed may be more reflective of increased documentation and awareness as opposed to increased prevalence. Missing data represents a significant challenge and is predominately due to individual state's choice not to include variables, particularly race, which accounted for 76.0% of the excluded patients. Each state was given the choice to provide race information as part of their data upload to HCUP to create the KID, and this is the predominant reason for missing race in the KID. There are disease-specific variables, which would further our understanding of this work but are not available in the dataset. There is a robust body of literature indicating a link between ileal involvement and complications of both medical and surgical management. However, due to the limitations of ICD-9 coding, it is not possible to investigate these children independently from other children with CD. The KID is an inpatient only database and any same-day or outpatient procedures, such as an EGD, would not be fully captured. Finally, the KID is not a longitudinal patient-level database, and it is not possible to determine whether patients had one or multiple hospitalizations or to track if there were changes in their care over time.

CONCLUSIONS

We have demonstrated a significant variance in the prevalence and likelihood of comorbidities associated with CD for hospitalized children and young adults in the United States based on median household income quartile. Anxiety was most prevalent in the highest income quartile, whereas anemia was most prevalent among the lowest income. There was a higher likelihood of undergoing a major surgical procedure for patients in the highest income quartile. Additional research should be focused on eliciting whether the variations in healthcare for hospitalized children and young adults with CD found in this study represent variability in patient disease, implicit bias, or a disparity in healthcare delivery across the United States.

AUTHOR CONTRIBUTIONS

Substantial contributions to conception, design, acquisition of data, or analysis and interpretation of data: R.J.M., A.K., M.A.C., J.R.L., and J.T.A. Drafting the article or revising it critically for important intellectual content: R.J.M., A.K., M.P.H., M.A.C., J.R.L., and J.T.A. Final approval of the version to be published: R.J.M., A.K., M.P.H., M.A.C., J.R.L., and J.T.A.

ADDITIONAL INFORMATION

The online version of this article (https://doi.org/10.1038/s41390-020-0830-9) contains supplementary material, which is available to authorized users.

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