Economic Trends of Racial Disparities in Pediatric Postappendectomy Complications

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abstract

BACKGROUND: Despite unparalleled advances in perioperative medicine, surgical outcomes remain poor for racial minority patients relative to their white counterparts. Little is known about the excess costs to the health care system related to these disparities.

METHODS: We performed a retrospective analysis of data from the Nationwide Inpatient Sample between 2001 and 2018. We included children younger than 18 years admitted with appendicitis who underwent an appendectomy during their hospital stay. We examined the inflation-adjusted hospital costs attributable to the racial disparities in surgical complications and perforation status, focusing on differences between non-Hispanic white patients and non-Hispanic Black patients.

RESULTS: We included 100 639 children who underwent appendectomy, of whom 89.9% were non-Hispanic white and 10.1% were non-Hispanic Black. Irrespective of perforation status at presentation, surgical complications were consistently higher for Black compared with white children, with no evidence of narrowing of the racial disparity gap over time. Black children consistently incurred higher hospital costs (median difference: $629 [95% confidence interval: $500–$758; $P < .01$). The total inflation-adjusted hospital costs for Black children were $518 658 984, and $59 372 044 (11.41%) represented the excess because of the racial disparities in perforation rates.

CONCLUSIONS: Although all patients had a progressive decline in post appendectomy complications, Black children consistently had higher rates of complications and perforation, imposing a significant economic burden. We provide an empirical economic argument for sustained efforts to reduce racial disparities in pediatric surgical outcomes, notwithstanding that eliminating these disparities is simply the right thing to do.

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WHAT'S KNOWN ON THIS SUBJECT: Nearly every metric indicates that minority pediatric patients have poor surgical outcomes compared with their white counterparts. However, little is known about the excess costs to the health care system related to these disparities.

WHAT THIS STUDY ADDS: In an era of renewed attention to systematic inequalities in the United States, we outlined a two-decade trend of racial disparities in appendectomy outcomes and its attendant economic impact on our health care system.

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Despite unparalleled advances in perioperative medicine over the last 20 years, surgical outcomes remain poor for racial minority pediatric patients compared with that of their white counterparts. Indeed, staggering inequalities exist for Black children, compared with white children, in the risk of surgical morbidity and mortality across several pediatric surgical procedures, including abdominal surgery,[1–5] cardiac surgery,[6–9] hematopoietic stem cell transplant,[10,11] urologic surgery,[12–14] neurosurgery,[15] pediatric oncology,[16] trauma,[17] and appendectomy care.[1,18] These disparities persist even in apparently healthy children who are expected to develop few complications.[19]

Concordant with the disparity in surgical outcomes for Black children is the exponential increase in surgical cost, driven partly by advances in surgical techniques but principally by complications.[20–23] However, little is known about the excess costs to the health care system related to disparities based on race. Further research or new policies to reduce the disparity gap would likely require a sustained commitment to achieving the desired outcome. Therefore, exploring the costs to the health care system attributable to the racial disparities in surgical outcomes is critically important. Such data should address skeptical counter argument to acting on even the most morally imperative issue, sometimes questioning, "how are we going to pay for it?"

Quantifying the excess costs to the health care system associated with disparities for Black children in surgical outcomes requires selecting a surgical practice that is common, is random in occurrence, and has variability in measured outcomes by race. Pediatric appendectomy fulfills these criteria for several reasons. Between 60 000 to 80 000 appendectomies are performed in the United States annually, making it one of the most common general surgery procedures.[24–27] Furthermore, Black children undergoing appendectomy have a higher risk of surgical complications, readmissions, and longer hospital stay than their white peers do.[28] Because inequities in pediatric surgical outcomes are well documented[29] yet their economic ramifications unknown, our overarching goal was to quantify the economic dimensions of disparity in appendectomy outcomes over an 18-year period.

This study builds on our previous work demonstrating disparities between Black and white children undergoing surgery, including the use of do-not-resuscitate orders,[30] pain management,[31] and risk of death.[19,32] To identify interventions to address disparities between Black and white children, we decided a priori to focus specifically on the trends in pediatric appendectomy outcomes and the related health care system costs attributable to disparities in postappendectomy complications among Black and white children.

METHODS

Study Design and Data Source

We performed a retrospective analysis of data from Nationwide Inpatient Sample (NIS) data spanning 18 years, between 2001 and 2018.[33] In brief, the NIS is a large, nationally representative hospital inpatient stay database maintained by the Healthcare Cost and Utilization Project (HCUP) and sponsored by the Agency for Healthcare Research and Quality. The NIS collects all-payer data on 7 to 8 million hospital stays annually across participating states, including an array of individual-level sociodemographic characteristics, payer information, and *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM), and *International Classification of Diseases, 10th Revision, Clinical Modification*, (ICD-10-CM), diagnostic and procedural codes. In 2012, the NIS was drawn from a frame of 44 states, representing >95% of the US population.[34] In 2018, the NIS comprises data from 47 states plus Washington, DC, covering 97% of the US population. The NIS is a publicly available deidentified data set and does not constitute human subject research.

Study Population

We studied children younger than 18 years who were admitted with appendicitis and underwent an appendectomy. We used the primary diagnostic codes 540.0, 540.1, 540.9, 541, or 542 (ICD-9), and K35.80, K35.89, K36, K37, K35.2, or K35.3 (ICD-10), to identify children with a final primary diagnosis of appendicitis.[35,36] We identified children who underwent appendectomy during the same admission by using the procedure codes 47.01, 47.09, 54.11, 54.21 (ICD-9-CM) and 0DTJ0ZZ and 0DTJ4ZZ (ICD-10).

Outcomes

Our primary outcome was the hospital costs attributable to the racial disparities in surgical complications and perforation rates. Costs and charges have different definitions, with charges referring to the amount billed to patients or payers for a service provided. Specific to the NIS data set, hospital charges refer to the amount, excluding professional and noncovered fees, billed for the entire hospital stay. Hospital costs represent the total amount spent by hospitals to deliver care, including

wages, supplies, and utilities. We obtained hospital costs by using hospital-specific cost-to-charge ratios based on hospital accounting reports from the Centers for Medicare and Medicaid Services.[37] We also inflated the costs to 2018 US dollars using the Consumer Price Index for the gross domestic products.[38]

Primary Exposure

Our primary exposure was the racial disparities in surgical complications and perforation rates defined as the difference in the risk-adjusted rates across racial groups, controlling for sex, age, median income for zip code, location and teaching status of the hospital, insurance status, laparoscopy status, and number of comorbidities. We defined race according to the HCUP data element that follows a categorization based on the 1977 Office of Management and Budget directive (separate groups for Hispanic and 5 non-Hispanic racial groups: white, Black, Asian and Pacific Islander, American Indian or Alaska Native, and other) and included subjects that were either non-Hispanic white or non-Hispanic Black.[20] We used ICD-9-CM and ICD-10-CM, diagnosis codes to identify surgical complications, as defined by the Pediatric Health Information System and used in previous studies.[39–41] The complete list of ICD codes flagged as surgical complications can be found through the children's hospital association Web site.[42] In Supplemental Table 3, we include the ICD codes of findings that were flagged as surgical complications in our study population.

Statistical Analysis

We accounted for survey design complexity by incorporating sampling weights according to HCUP recommendations, thereby producing population estimates of proportions and regression coefficients. We estimated the costs attributable to the racial disparities in perforation rates by multiplying the difference in risk-adjusted rates of perforation between Black and white children with the number of perforations in Black and white children and the excess hospitalization costs because of perforation.[43] We obtained the risk-adjusted difference in perforation rates between Black and white children using Poisson regression, adjusting for sex, age, median income for zip code, location and teaching status of the hospital, insurance status, laparoscopy status, and number of comorbidities. We obtained the excess hospitalization costs because of perforation using quantile regression, estimating the median difference in costs comparing hospitalization with and without perforation. With this approach, the estimated costs attributable to the racial disparities would reflect the avoidable hospital costs, assuming perforation rates were similar between Black and white children, while adjusting for individual and hospital-level covariates.

We used quantile regression analysis, accounting for intrahospital clustering of costs, with a two-way interaction term between race and discharge year to examine trends in hospital costs and evaluate whether the costs in Black and white children were converging or diverging across years. We chose the quantile regression models because of their appropriateness for skewed health care costs data and asymptotic validity under heteroskedasticity and model misspecification.[44] We also examined the trends in surgical complications using Poisson regression models, with an interaction term for race and discharge year.[45] To produce stable estimates from the trend analyses, we pooled data into nine 2-year cycles: 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, 2011–2012, 2013–2014, 2015–2016, and 2017–2018. We performed all analyses using Stata version 15 (Stata Corp, College Station, TX) and considered a P value $<.05$ to be statistically significant.

RESULTS

Characteristics of the Study Population

We included 100 639 children who underwent appendectomy between 2001 and 2018, corresponding to a weighted study population of 483 813 children. The study subjects were 89.9% (95% confidence interval [CI]: 89.3% to 90.5%) non-Hispanic white children and 10.1% (95% CI: 9.5% to 10.7%) non-Hispanic Black children. There were no differences between Black and white children regarding sex and age at the time of surgery. Overall, Black children were more likely to be living in the South (51.5% vs 35.8%), belong to families with a lower median income for zip code (<$39 000 per year: 41.9% vs 17.6%), be cared for in urban teaching hospitals (67.5% vs 48.7%), and be enrolled in Medicaid (53.5% vs 24.2%) (Table 1). Black and white children were comparable with regards to the use of laparoscopic surgery and timing of surgery within 48 hours of admission.

Race-Specific Trends in Surgical Complications

Figure 1 summarizes the risk-adjusted rates of overall surgical complications. Overall, the rates decreased for both Black and white children over time, but the rates were always higher for Black children. Although the rates of surgical complications were decreasing for both Black and white patients, we found no statistically significant evidence of narrowing of the racial difference in surgical complications over time (adjusted

relative risk [RR]: 1.00; 95% CI: 0.97 to 1.03; $P = .96$). The largest difference in surgical complication rates was observed in 2001–2002, when Black children, compared with their white peers, were estimated to be 63% more likely to develop surgical complications (adjusted RR: 1.63; 95% CI: 1.34 to 1.99; $P < .01$).

Next, we examined surgical complications by perforated appendicitis status. Expectedly, surgical complication rates were higher for children with a perforated appendicitis (Fig 2). Similar to the pattern for the overall complication rates, the rates of surgical complications decreased for Black and white children over the study period. However, irrespective of perforation status at presentation, surgical complications were consistently higher for Black children versus their white peers throughout the study period (Fig 2).

Race-Specific Trends of Hospital Costs

The median hospital costs for appendectomy have risen steadily and were consistently higher in Black children than in their white peers throughout the study period (adjusted median difference: $629 (95% CI: $500 to $758; $P < .01$) (Fig 3). The median annual changes in hospital costs were $401 (95% CI: $370 to $432; $P < .01$) in white children and $383 (95% CI: $332–$435; $P < .01$) in Black children (Fig 3). However, we found no evidence of narrowing of the racial gap in hospital costs throughout the study period: $−17 (95% CI: $−60 to $26; $P = .28$) (Fig 3).

Economic Burden of the Racial Differences in Perforation Rates

Table 2 displays the hospital costs attributable to the racial disparities in perforation rates. Over the 18-year study period, the total hospital costs for Black children were $518 658 984,

TABLE 1 Characteristics of Children <18 Years of Age Who Underwent an Inpatient Appendectomy (2001–2018)

Characteristics	Overall, Weighed Prevalence, % (95% CI)	Non-Hispanic White, Weighed Prevalence, % (95% CI)	Non-Hispanic Black, Weighed Prevalence, % (95% CI)
Study population	100	89.9 (89.3 to 90.5)	10.1 (9.5 to 10.7)
Male sex	60.5 (60.2 to 60.9)	60.2 (59.9 to 60.6)	63.3 (62.3 to 64.3)
Age, y			
≥13	45.7 (44.9 to 46.5)	45.5 (44.6 to 46.4)	47.5 (46.2 to 48.8)
6–12	48.2 (47.4 to 48.9)	48.4 (47.7 to 49.2)	45.9 (44.6 to 47.1)
≤5	6.1 (5.9 to 6.4)	6.1 (5.8 to 6.4)	6.6 (6.1 to 7.2)
Median income for zip code, $			
>63 000	32.0 (30.1 to 33.9)	33.8 (31.9 to 35.8)	15.3 (13.7 to 17.1)
39 000–63 000	48.0 (46.6 to 49.4)	48.6 (47.1 to 50.1)	42.8 (41.0 to 44.6)
<39 000	20.0 (19.0 to 21.2)	17.6 (16.5 to 18.7)	41.9 (39.6 to 44.3)
Insurance status			
Commercial	65.4 (64.3 to 66.4)	68.5 (67.4 to 69.5)	38.1 (36.5 to 39.8)
Medicaid	27.1 (26.2 to 28.1)	24.2 (23.3 to 25.1)	53.5 (51.9 to 55.0)
Other	3.5 (3.3 to 3.8)	3.5 (3.3 to 3.8)	3.6 (3.1 to 4.1)
None	3.9 (3.7 to 4.2)	3.8 (3.6 to 4.1)	4.8 (4.2 to 5.6)
Census region			
Midwest	24.6 (22.3 to 27.1)	24.6 (22.2 to 27.2)	24.8 (21.9 to 28.0)
Northeast	19.3 (17.7 to 21.0)	19.8 (18.2 to 21.5)	15.2 (13.0 to 17.8)
South	37.4 (34.7 to 40.1)	35.8 (33.1 to 38.5)	51.5 (47.8 to 55.3)
West	18.7 (16.9 to 20.6)	19.8 (18.0 to 21.9)	8.4 (7.2 to 9.7)
Perforated appendicitis	31.4 (30.7 to 32.0)	30.8 (30.1 to 31.4)	36.9 (35.7 to 38.0)
Laparoscopy	63.7 (62.2 to 65.2)	63.9 (62.3 to 65.4)	62.3 (60.0 to 64.6)
Surgery within 48 h	98.4 (98.3 to 98.5)	98.6 (98.5 to 98.6)	97.0 (96.5 to 97.4)
Location and teaching status			
Rural	14.5 (13.5 to 15.6)	15.4 (14.3 to 16.5)	7.3 (6.2 to 8.6)
Urban and nonteaching	34.8 (32.5 to 37.2)	35.9 (33.5 to 38.4)	25.2 (22.7 to 27.9)
Urban and teaching	50.6 (48.0 to 53.2)	48.7 (46.0 to 51.4)	67.5 (64.4 to 70.3)
Year			
2001–2002	11.3 (10.2 to 12.5)	11.4 (10.3 to 12.6)	10.6 (9.2 to 12.3)
2003–2004	11.8 (10.7 to 13.0)	11.7 (10.7 to 12.9)	12.5 (10.5 to 14.8)
2005–2006	12.6 (11.3 to 14.1)	12.8 (11.5 to 14.3)	10.9 (9.3 to 12.8)
2007–2008	12.9 (11.8 to 14.1)	12.9 (11.8 to 14.1)	12.7 (11.0 to 14.5)
2009–2010	14.1 (12.5 to 15.9)	14.3 (12.7 to 16.0)	13.0 (10.9 to 15.4)
2011–2012	12.1 (11.1 to 13.2)	12.1 (11.1 to 13.3)	12.0 (10.4 to 13.7)
2013–2014	10.0 (9.2 to 10.8)	9.8 (9.0 to 10.7)	11.3 (10.0 to 12.7)
2015–2016	8.4 (7.7 to 9.1)	8.2 (7.5 to 8.9)	9.9 (8.8 to 11.2)
2017–2018	6.7 (6.2 to 7.4)	6.7 (6.1 to 7.3)	7.1 (6.2 to 8.1)

We retained children admitted for appendicitis and underwent appendectomy during the hospital stay between 2001 and 2018 and were entered in the NIS database.

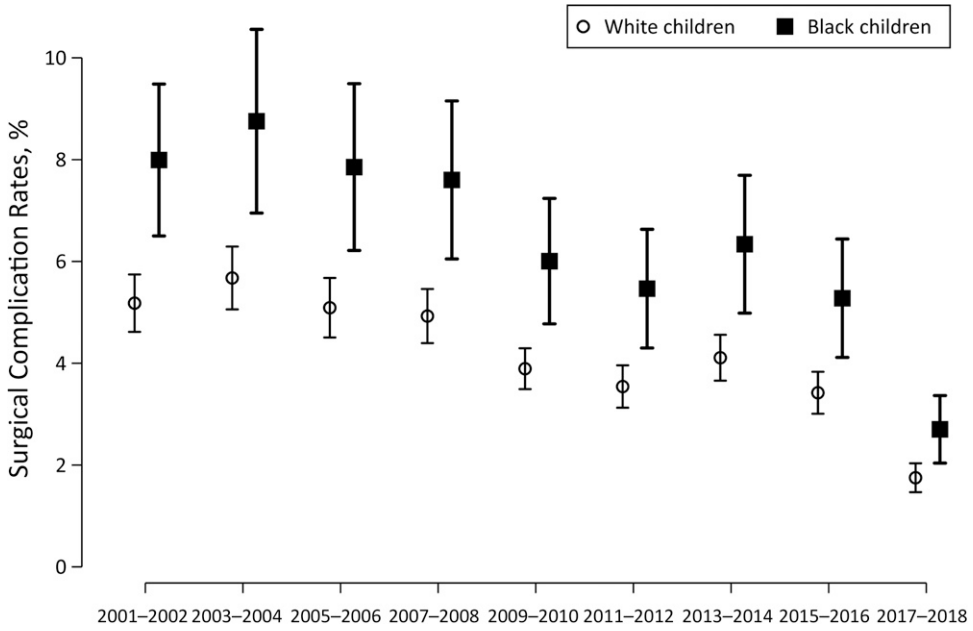

FIGURE 1

Race-specific trends in surgical complications in children who were admitted for appendicitis and underwent appendectomy, controlling for sex, age, median income for zip code, location and teaching status of hospital, insurance status, perforated appendicitis status, laparoscopy status, and number of comorbidities (NIS 2001–2018). Each additional cycle was associated with a relative decrease in the risk of surgical complications in both white (adjusted RR: 0.91; 95% CI: 0.88 to 0.94; $P < .01$) and Black children (adjusted RR: 0.91; 95% CI: 0.89 to 0.92; $P < .01$). There was no evidence of narrowing of the disparity gap over time because the 2-way interaction term between cycle and race was not statistically significant at the alpha level of 0.05 (adjusted RR: 1.00; 95% CI: 0.97 to 1.03; $P = .96$).

and $59 372 044 (11.4%) represented the excess because of the racial disparities. The largest economic impact of the racial disparities occurred in 2015–2016, when $11 969 801 reflects the spending that would have been avoidable if Black and white children had comparable perforation rates.

DISCUSSION

We sought to outline a two-decade trend of disparities for Black children in appendectomy outcomes and its attendant economic impact on our health care system. Although both Black and white children had a progressive decline in appendectomy complications, there was no significant decrease in the disparity gap, leading to Black children consistently having higher rates of complications. These persisting disparities exist even with uncomplicated appendicitis. The excess risk of perforation in Black patients was associated with a significant financial burden to the

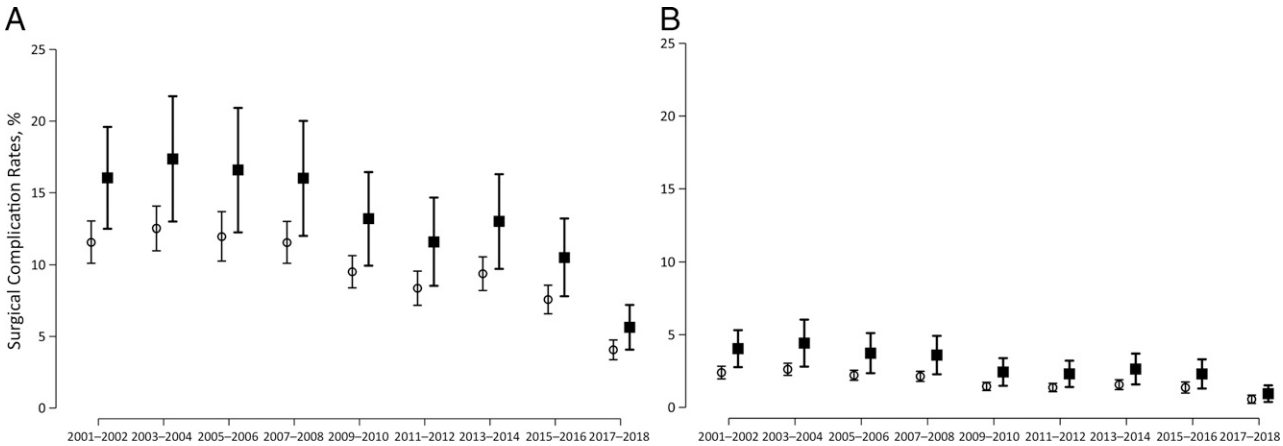

FIGURE 2

Race-specific trends in surgical complications in children who were admitted for (A) perforated and (B) nonperforated and appendicitis and underwent appendectomy, controlling for sex, age, median income for zip code, census region, location and teaching status of hospital, insurance status, perforated appendicitis status, laparoscopy status, and number of comorbidities (NIS 2001–2018).

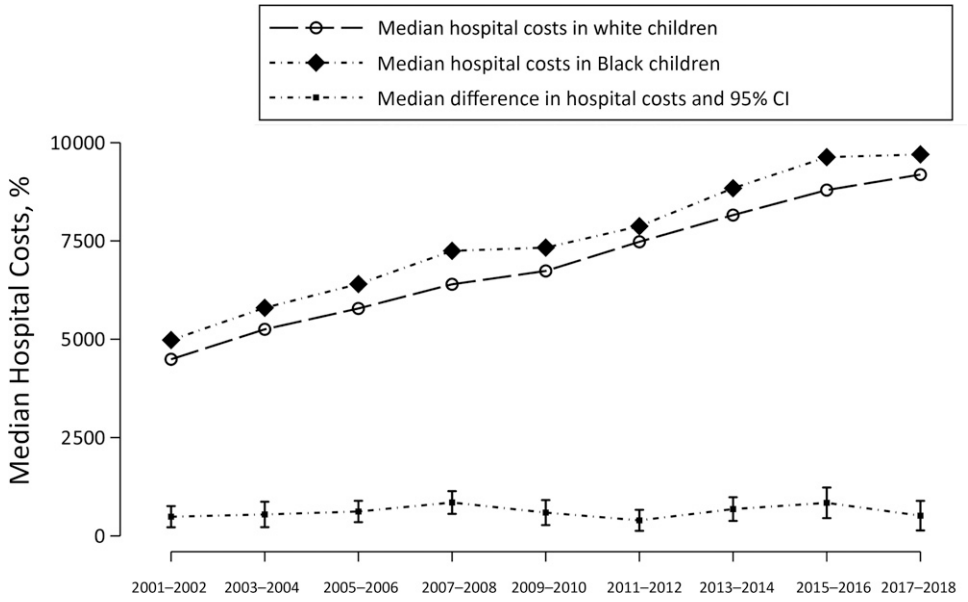

FIGURE 3

Race-specific trends in median hospital costs in children who were admitted for appendicitis and underwent appendectomy, controlling for sex, age, median income for zip code, location and teaching status of hospital, insurance status, perforated appendicitis status, laparoscopy status, and number of comorbidities (NIS 2001–2018). Overall, the median hospital costs comparing Black children with white children was $629 (95% CI: $500–$758; $P < .01$) throughout the study period. The median annual changes in hospital costs were $401 (95% CI: $370 to $432; $P < .01$) in White children and $383 (95% CI: $332 to $435; $P < .01$) in Black children. The interaction term between cycle and race was not statistically significant (median difference: −$17; 95% CI: −$60 to $26; $P = .28$).

health care system because of consistently higher costs incurred by Black children.

The persisting disparity gap that is occurring against the overall improvement in surgical complications implies that the progress achieved throughout almost 2 decades did not address the structural racism that may explain the excess risk of surgical complications in Black children. The surgical practice has improved over time with uptake in laparoscopic approach, and several policy changes have encouraged hospitals and providers to enact quality improvement initiatives, including value-based surgical care and Enhanced Recovery After Surgery protocols.[46,47] Our findings imply that intervening is not only fair but also likely cost-effective and may procure larger benefits. In an era of renewed attention to systematic inequalities in the United States,[48] our study demonstrates the economic impact on our health care system of persisting inequalities in

TABLE 2 Inflation-Adjusted Hospital Costs Attributable to the Racial Disparities in Perforation Rates.

	Rates of Surgical Complications					
Year	White, %	Black, %	Median Excess Cost Due to Perforation, $	Excess Cost Attributable to the Higher Risk of Perforation in Black Children, $	Total Hospital Cost in Black Children, $	Fraction of Hospital Cost in Black Children That is Excess, %
2001–2002	5.2	8.0	4393	4 130 923	46 556 610	8.9
2003–2004	5.7	8.8	5185	4 939 751	61 781 049	8.0
2005–2006	5.1	7.9	5191	4 842 720	57 276 967	8.5
2007–2008	4.9	7.6	4700	4 433 107	65 855 370	6.7
2009–2010	3.9	6.0	4324	4 729 631	61 339 210	7.7
2011–2012	3.5	5.5	5935	7 303 323	60 942 388	12.0
2013–2014	4.1	6.3	4853	7 591 212	62 302 973	12.2
2015–2016	3.4	5.3	5245	11 969 801	62 471 128	19.2
2017–2018	1.8	2.7	3825	9 431 576	40 133 289	23.5
Total	—	—	—	59 372 044	518 658 984	11.4

We inflated the costs to 2018 United States dollars using the Consumer Price Index for the gross domestic products. Adjusted for sex, age, median income for zip code, census region, location and teaching status of hospital, insurance status, perforated appendicitis status, laparoscopy status, and number of comorbidities (NIS 2001–2018).

pediatric surgical outcomes. As the most common pediatric abdominal surgical emergency in the United States,[28] appendectomy offers a unique opportunity to evaluate value-based care as well as differences across groups in the incidence and economic implications of group-specific excess risk of postoperative complications.

It is intuitive to assume that racial variation in perforation rates is the main contributor to the differential costs of surgery for Black patients. However, even in children with nonperforated appendicitis, Black children compared with white children were more likely to develop surgical complications and incur higher hospital costs. This implies that perforated appendicitis may only partly explain the persisting racial disparities in surgical outcomes and their economic impact on our health care system. On the other hand, it is not realistic to discard the role of presurgical factors that may explain the racial differences in perforation rates. Indeed, acute appendicitis is a "delay-sensitive" condition, meaning that the natural history of the disease in the absence of treatment is predictable and involves progression to perforation, systemic infection, bleeding, and death.[49,50] The disparities in appendicitis outcomes may be related to the delay in disease milestones, such as a patient complaint of abdominal pain, parental recognition of condition urgency, initial presentation for care, obtaining appropriate time-sensitive diagnostic laboratories and imaging studies, accurate diagnosis, and then ultimately surgical intervention.[25,49,51,52] The need for sustained commitment to reducing the human and economic impact of the racial differences in surgical outcomes implicates everyone, upstream or downstream from surgery.

This study should be interpreted in the context of its limitations. Race can be misclassified in administrative databases. The outcome data are also subject to misclassification bias and coding errors, but this is unlikely to be differential on the basis of child race. This study is focused only on the difference in economic burden between non-Hispanic Black and non-Hispanic white children with appendicitis because of the well-recognized disparities in surgical outcomes.[26,53] We also recognize that the study database does not measure pediatric hospital status, which may play a role in surgical complication rates. Furthermore, the NIS does not capture readmission and only captures complications that occur during a single stay. The burden of postsurgical complications also depends on other factors, such as hospital quality and volume, individual surgeon's experience, and other intraoperative variables not available in administrative databases. Additionally, some of the ICD code descriptions lack specificity (eg, "digestive system complications") Finally, this study was conducted from the perspective of the health care system, so factors such as parental lost productivity, work-related losses, or illness-related school absenteeism are not included.

CONCLUSIONS

Compared with non-Hispanic white children, Black children have higher perforation rates of postappendectomy complications, contributing to a higher cost of surgical care for Black children. This disparity has barely changed in the last 2 decades. Although many factors determine surgical outcomes and cost, our estimates underscore the substantial economic consequences of complications-related disparities in the United States and call for targeted efforts to reduce these complications in Black children. To inspire action on even the most morally pressing issues, it is sometimes necessary to spotlight material justification as to why intervention is warranted. We identified a long-standing disparity that requires sustained commitment to reducing the excess risk of surgical complications in Black children that is not only morally but also economically the expedient thing to do.

ABBREVIATIONS

CI: confidence interval
HCUP: Healthcare Cost and Utilization Project
ICD: *International Classification of Diseases*
NIS: Nationwide Inpatient Sample
RR: relative risk

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