National Trends in Pediatric Metabolic and Bariatric Surgery: 2010–2017

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abstract

BACKGROUND: The childhood obesity epidemic has grown exponentially and is known to disproportionately affect minority groups. Successful treatment of this complex health issue requires a multidisciplinary approach including metabolic and bariatric surgery (MBS) for qualifying pediatric patients. This study examines current national trends in pediatric bariatric surgery from 2010 to 2017 using the National Inpatient Sample.

METHODS: This study analyzed MBS among pediatric patients <19 years old using weighted discharge data from 2010 to 2017. The primary outcome was national procedure rates. Secondary analyses included procedure type, demographics, BMI, comorbidities, length of stay, and complication rates.

RESULTS: From 2010 to 2017, annual bariatric procedure rates increased from 2.29 to 4.62 per 100 000 ($P < .001$). Laparoscopic sleeve gastrectomy outpaced Roux-en-Y gastric bypass and laparoscopic adjustable gastric band over time (0.31–3.99 per 100 000, $P < .0001$). The mean age was stable over time 18.10–17.96 ($P = .78$). The cohort was primarily female (76.5% to 75.4%), white (54.0% to 45.0%), and privately-insured (59.9% to 53.4%). Preoperative BMI increased from 2010 to 2017 ($P < .001$), whereas number of obesity-related comorbidities was stable ($P > .05$). Length of stay was <2 days (2.02–1.75, $P = .04$) and in-hospital complication rates were low (7.2% to 6.45%, $P = .88$).

CONCLUSIONS: Pediatric MBS is underutilized nationally with disproportionately lower rates among minority groups. Despite incremental progress, further investigation into the racial and social determinants that limit access to pediatric weight loss surgery is critical.

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WHAT'S KNOWN ON THIS SUBJECT: The childhood obesity epidemic has grown exponentially and is known to disproportionately affect minority and low socioeconomic groups. This complex health issue requires an equitable, multidisciplinary approach to successful treatment including weight loss surgery for qualifying pediatric patients.

WHAT THIS STUDY ADDS: Population-based pediatric bariatric procedure rates grew from 2010 to 2017. These patients are predominantly older, female, white, and privately-insured. Despite increasing preoperative BMI across the study period, obesity-related comorbidities remained stable. Length of stay and in-hospital complication rates remain acceptably low.

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The pediatric obesity epidemic has grown exponentially in recent decades. From 2017 to 2018, the prevalence of obesity among US adolescents was reported to be 19.3%, with rates as high as 20.3% and 21.2% in ages 6 to 11 and 12 to 19, respectively.[1–4] Importantly, Hispanic and non-Hispanic Black children are disproportionately affected when compared with non-Hispanic white and Asian peers.[2] Several studies have shown that obesity in childhood portends increased morbidity and mortality as an adult, with early onset of chronic and progressive obesity-related conditions (ORCs), such as cardiovascular disease, insulin resistance, nonalcoholic fatty liver disease, and osteoarthritis diagnosed at earlier ages. This translates to a threefold increase in healthcare expenditures and estimated costs of over 14 billion dollars annually.[3] Moreover, weight gain trajectory in adolescents is a particularly important intervention target, as even sustained weight loss later in life is unlikely to fully reverse cardiometabolic risk.[5]

Pediatric obesity is a complex health issue that requires a multidisciplinary approach to successful treatment. Only recently has surgical intervention become an integral part of this algorithm for children, owed to well-replicated safety and efficacy data from landmark studies.[6–8] In 2019, both the American Society for Metabolic and Bariatric Surgery (ASMBS) Pediatric Committee and the American Academy of Pediatrics (AAP) updated evidence-based guidelines to expand recommendations for weight loss surgery to qualifying pediatric patients with obesity.[9,10] Subsequent acceptance among consensus groups led to a broader adoption with commensurate growth in annual procedure rates.[11]

Although adoption of pediatric metabolic and bariatric surgery (MBS) has improved over time, race and low socioeconomic status have repeatedly been identified as primary contributors to discrepancies in access and coverage.[12] Racial and ethnic minorities experience disproportionately higher rates of severe obesity and ORCs, leading to increased health care expenditures and early mortality.[9,13] Yet, dramatic underutilization of surgical weight loss treatment has persisted among Black and Hispanic children in particular, despite irrefutable indications and multiple studies reporting favorable postsurgical outcomes and complication rates.[14–16] In response, the AAP issued a statement in 2019 calling for "increased access to multidisciplinary, pediatric-focused bariatric surgery centers regardless of income, race, or ethnicity"[9].

This study provides a current examination of national trends in pediatric MBS from 2010 to 2017 using the National Inpatient Sample (NIS). NIS is 1 of the largest publicly available all-payer inpatient healthcare databases in the United States.[17] Whereas the primary outcome was population-based procedure rates, secondary analyses included procedure type, demographics, preoperative BMI, comorbidities, hospital characteristics, length of stay (LOS), and in-hospital complication rates.

METHODS

The present cohort study evaluated MBS utilization rates among pediatric patients using weighted discharge data from 2010 to 2017 NIS. NIS is released annually and approximates a 20% stratified sample of inpatient hospital discharges. Samples are weighted to produce national estimates by the Agency for Healthcare Research and Quality Healthcare Cost and Utilization project (HCUP).

This study analyzed MBS among adolescents between the ages of 12 and 19 years. Supplemental Table 4 displays ICD-9 and ICD-10 diagnosis and procedure codes used to define key conditions, procedures, and exclusions. A bariatric procedure code and confirmatory diagnosis code for obesity were required as inclusion criteria. Nonelective procedures, as defined by emergency admissions or transfers, were excluded, as were admissions with diagnoses not intended for weight loss.

The primary outcome was national population-based bariatric procedure rate. Secondary analyses included procedure type, surgical approach, demographics, payer status, BMI, ORCs, hospital type, LOS, and in-hospital complication rates. Groups for primary payer were condensed into Medicaid and Medicare, private insurance, and "other," which included self-pay, no charge, missing, and other. Both Medicare and "no charge" had frequencies of <11 and could not be reported separately. BMI was included as a categorical variable based on commonly used criteria for class (35–39, 40–45, 45–49, and 50+) as well as codes specific for "morbid obesity" and "Ped 95th," defined as pediatric BMI-for-age at or above the 95th percentile for age and sex. Ped 95th includes BMI >120% of the 95th percentile as there is no stand-alone *International Classification of Disease* (ICD-9 or ICD-10) code for that specific classification of obesity. This accounts for the discrepancy between the clinical guideline set forth by the ASMBS and the Centers for Medicare and Medicaid Services requirements for procedural reimbursement. Complication rates were collapsed into binary "yes" or "no" groups because of low annual frequencies by system and severity (Table 3).

The ASMBS eligibility criteria for pediatric MBS are BMI > 40 kg/m^2 or BMI > 35 kg/m^2 with at least 1 comorbid disease.[18] As such, these specific ORCs were included in the trend analyses, as defined by *International Classification of Disease, Clinical Modification* (ICD-9-CM and ICD-10-CM) diagnosis codes.

Hospitals were classified as "pediatric" if the weighted volume of admissions for patients aged 0 to 21 was ≥90% of the hospital's total weighted admissions. Of note, this did not include adult centers with pediatric designation per the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Project. Estimates of national pediatric population were obtained from the US Census Bureau[19] and used to calculate rates of MBS utilization overall.

Descriptive statistics were reported overall and by year for the target population. To account for design change of NIS in 2012,[17] updated trend weights were used for observations and national estimates with 95% confidence intervals.

All analyses were performed using statistical procedures that account for the complex sampling design, as recommended by HCUP. Categorical variables were compared using Rao-Scott χ-Square test. Continuous variables were compared using analysis of variance. Trends for overall MBS and surgery type were analyzed using analysis of variance and regression. All analyses were performed in SAS version 9.4 software (SAS Institute Inc, Cary, NC). In compliance with the HCUP data use agreement, data were not reported when tabulated frequency of observations for a given variable was <11.

RESULTS

Overall Procedure Rate and Procedure Type

There were 9014 index records from NIS included in the analysis. Overall, annual procedure rates increased from 2.29 (1.62–2.96) to 4.62 (3.70–5.54) per 100 000 ($P < .001$) between 2010 and 2017 (Fig 1).

The type of procedure performed evolved considerably from 2010 to 2017. Rates of Roux-en-Y gastric bypass (RYGB) (1.68 [1.21–2.15] to 0.61 [0.42–0.80] procedures per 100 000; $P = .25$) and adjustable gastric band (AGB) (0.53 [0.33–0.73] to 0.07 [0.01–0.13] per 100 000, $P = .17$) decreased, whereas sleeve gastrectomy (SG) gained significant popularity (0.31 [0.12–0.50] to 3.99 [3.33–4.65] procedures per 100 000; $P < .001$). The rate of open procedures was exceedingly low and decreased over time (0.08 [0.00–0.16] to 0.045 [0.00–0.08] procedures per 100 000); with a frequency too small to report after 2015 (Fig 2). This represents a major shift in operative technique to favor minimally invasive approaches.

Patient Demographics

The mean age did not differ significantly between 2010 and 2017 (18.10 [17.88–18.32] and 17.96 [17.70–18.22]; $P = .78$) At each time point, the cohort was predominantly female (76.5% to 75.4%, $P = .56$). Although all racial groups showed increased total number of procedures over time, a slight but statistically significant shift in racial trends was noted (Fig 3). Whereby white children comprised 54.0% to 45.0% of the cohort from 2010 to 2017 ($P = .05$), the percentage of Black children undergoing MBS decreased over time from 18.2% to 14.6% ($P = .05$), whereas numbers among Hispanic children saw a slight growth (17.2% to 25.9%, $P = .05$) (Table 1). Insurance status was predominated by private payers (59.9% to 53.4%, $P = .06$), though there was a trend toward increased proportions of Medicaid and Medicare increased from 24.5% to 36.3% ($P = .06$) during the study period.

BMI and Obesity-related Comorbidities

Overall, children had increasing preoperative BMI across the study period ($P < .001$). Between 2010 and 2017, the percentage of children with BMI greater than 50 grew from 4.2% to 16.2% ($P < .001$). The only group to show the opposite trend was "morbidly obese," which decreased from 48.4% to 17.2% over time. Hypertension (HTN) was the most common obesity-related comorbidity (21.2% to 16.2%), followed by obstructive sleep apnea (20.3% to 25.0%), gastroesophageal reflux disease (16.2% to 24.6%), diabetes mellitus (15.2% to 11.3%) and nonalcoholic steatohepatitis (12.6% to 18.5%). The only significant trend in ORCs was for HTN, which decreased over time ($P < .001$, Table 2).

Hospital Characteristics, LOS, and In-hospital Complications

Of the procedures that were occurring at adult hospitals during the study period, 93.5% to 90.0% ($P = .99$) were pediatric bariatric procedures. There was a significant decrease in LOS from 2.02 (1.63–2.40) to 1.75 (1.58–1.91) between 2010 and 2017 ($P = .04$). In-hospital complications were uncommon with weighted frequencies <11 in several system-based categories necessitating cohort analysis for any complication. Overall, the rate of having any complication was stable at 7.2% to 6.5% between 2010 and 2017 ($P = .88$, Table 3). The only measurable subcategory in NIS was rates of minor surgical complications (ie, no additional procedural or surgical intervention) which ranged from 3.6% to 5.5% (Supplemental Table 4).

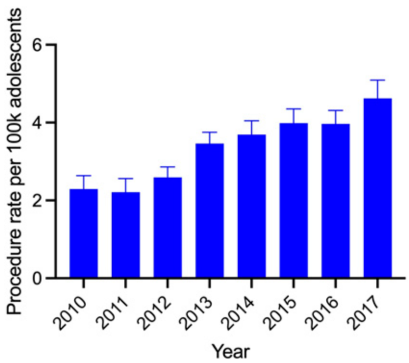

FIGURE 1
Total bariatric procedure rates by year. This figure represents national trends in annual bariatric procedure rates per 100 000 adolescents. Error bars represent SE.

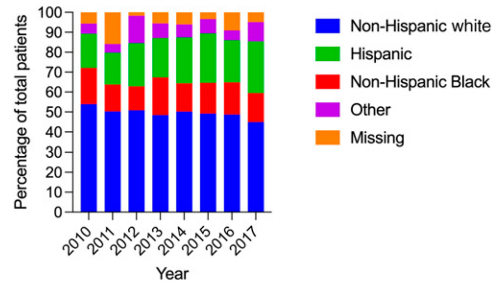

FIGURE 3
Race and ethnicity by year. This figure represents national trends in race and ethnicity. Numbers are reported as percentages of total patient undergoing MBS per year. Legend: blue = non-Hispanic white; green = Hispanic; red = non-Hispanic Black; purple = other, orange = missing.

DISCUSSION

MBS, though a safe and effective intervention for severe pediatric obesity, and the only treatment known to reverse ORCs including insulin resistance, hypertension, and early renal disease, is underutilized nationally.[5] The present analysis uses 1 of the largest national inpatient databases, NIS, to examine current trends in pediatric MBS among US hospitals between 2010 and 2017, a period in which rates of severe obesity increased in US adolescents.[4] Overall, a significant growth in annual pediatric bariatric procedure rates was observed. There was a notable shift toward minimally invasive approaches with a strong predilection of SG over RYGB and AGB. Patients undergoing pediatric MBS were largely older, female, white, and privately insured, although trends suggestive of increased utilization among disproportionately affected groups was detected, particularly in Black and publicly insured youth. Despite higher preoperative BMIs across the study period, hospital LOS and complication rates remained acceptably low. These data highlight the limited function of prevention efforts and further underscore the need for this effective and durable obesity treatment of children. To this end, the AAP issued a consensus statement in October 2019 urging universal access to pediatric bariatric surgery "regardless of income, race, or ethnicity," thus setting the stage to rectify such inequities in the future.[9]

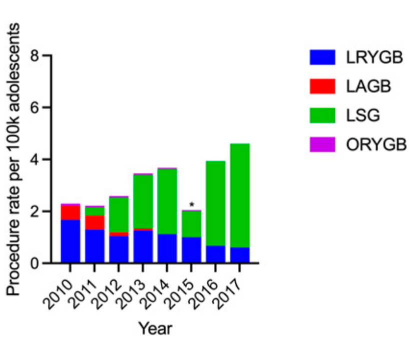

FIGURE 2
Types of bariatric surgical procedure performed by year. This figure represents national trends in type of bariatric surgical procedure performed displayed as rate per 100 000 adolescents. Legend: blue = laparoscopic Roux-en-Y gastric bypass; red = laparoscopic adjustable gastric band; green = laparoscopic sleeve gastrectomy; purple = open Roux-en-Y gastric bypass. *2015 is the year that the United States transitioned from ICD-9 to ICD-10 code sets. LAGB, laparoscopic adjustable gastric band; LRYGB, laparoscopic Roux-en-Y gastric bypass; LSG, laparoscopic sleeve gastrectomy; ORYGB, open Roux-en-Y gastric bypass.

Few studies have reported previous trends in utilization of MBS in the pediatric population. Schilling et al found that from 1997 to 2003 the estimated number of pediatric weight loss procedures increased fivefold from 51 to 282.[11] This growth was primarily attributed to increased rates of RYGB in the early 2000s which, at the time, was considered the most appropriate procedural approach in adolescents.[20] More recently, Kelleher et al examined trends from 2000 to 2009 and demonstrated a plateau in pediatric bariatric procedure rates after 2003, hovering between 2.2 and 2.4 procedures per 100 000 adolescents. By 2010, AGB comprised nearly one-third of all pediatric procedures and rates of open surgery fell dramatically in favor of minimally invasive techniques.[21] This current study showed significant increases in annual bariatric procedure rates from 2.29 to 4.62 per 100 000 patients from 2010 to 2017, with a notable surge in SG rates and a concurrent decline in RYGB. No AGB procedures were reported after 2013. These results mirror adult ASMBS data, which shows SG outpacing RYGB by 2013 at 59.4%, compared with 17.8% RYGB and 0.6% AGB in 2019.[22] Of note, longitudinal analyses have demonstrated no difference in weight loss between children undergoing SG or RYGB, but inferior BMI reduction after AGB.[8,23] These findings represent exponential growth after a period of stagnancy with regard to annual procedural rates and an evolving surgical approach that parallels trends seen in the adult population. Although this may suggest broader acceptance, it still falls well short of

TABLE 1 Patient Demographics by Year

	2010	2011	2012	2013	2014	2015	2016	2017	*P*
Age									
Mean (95% CI)	18.1 (17.9–18.3)	18.1 (17.8–18.3)	17.8 (17.6–18.0)	17.9 (17.7–18.1)	18.1 (17.8–18.3)	18.0 (17.7–18.2)	18.0 (17.8–18.2)	18.0 (17.7–18.2)	.78
Gender									
Male	184.8 (23.5)	164.1 (21.8)	255.0 (29.1)	245.0 (21.0)	270.0 (21.9)	305.0 (22.9)	285.0 (21.5)	380.0 (24.6)	.56
Female	601.8 (76.5)	588.5 (78.2)	629.0 (70.9)	920.0 (79.0)	965.0 (78.1)	1025.0 (77.1)	1040.0 (78.5)	1165.0 (75.4)	
Race and ethnicity									
Non-Hispanic white	424.3 (54.0)	378.7(50.3)	445.0 (50.9)	565.0 (48.5)	620.0 (50.2)	655.0 (49.3)	645.0 (48.7)	695.0 (45.0)	.05
Non-Hispanic Black	142.9 (18.2)	101.7 (13.5)	105.0 (12.0)	220.0 (18.9)	175.0 (14.2)	205.0 (15.1)	215.0 (16.2)	225.0 (14.6)	
Hispanic	134.9 (17.2)	120.2 (16.0)	190.0 (21.7)	230.0 (19.7)	285.0 (23.1)	330.0 (24.8)	280.0 (21.1)	400.0 (25.9)	
Other	40.1 (5.1)	32.9 (4.4)	120.0 (13.7)	85.0(7.3)	80.0 (6.5)	95.0 (7.1)	65.0 (4.9)	150.0 (9.7)	
Missing	44.5 (5.7)	119.2 (15.8)	15.0 (1.7)	65.0(5.6)	75.0 (6.1)	45.0 (3.4)	120.0 (9.1)	75.0 (4.9)	
Type of insurance									
Medicare or Medicaid	192.5 (24.5)	242.3 (32.2)	175.0 (20.0)	260.0 (22.3)	300.0 (24.3)	455.0 (34.2)	420.0 (31.7)	560.0 (36.3)	.06
Private	470.9 (59.9)	449.6 (59.8)	570.0 (65.1)	790.0 (67.8)	805.0 (65.2)	735.0 (55.3)	790.0 (59.6)	825.0 (53.4)	
Other	123.3 (15.7)	60.5 (8.0)	130.0 (14.9)	115.0 (9.9)	130.0 (10.5)	140.0 (10.5)	115.0 (8.7)	160.0 (10.4)	

Data presented as *n* (%) unless otherwise noted. CI, confidence interval.

the childhood obesity epidemic trajectory. Lastly, there was a marked gender gap in the pediatric MBS population with a strong female predominance. This skewed distribution is also reported in the adult bariatric literature and suggests a potential underuse of MBS among males with obesity at all ages.[24] Further analysis of the effects of gender-based differences on childhood obesity intervention is warranted.

Rates of pediatric obesity are highest among minority groups. From 2017 to 2018, the obesity prevalence for Hispanic and Black children ages 2 to 19 years was 25.6% and 24.2% compared with 16.1% in white children.[2] Despite this, the majority of pediatric patients undergoing MBS were white with near stagnant underrepresentation of Black children and negligible increases in the proportion of Hispanic youth. This racial and ethnic breakdown is consistently observed in the extant literature.[13,15,16,25] Nunez et al investigated health disparities in pediatric MBS from 2007 to 2014 and found that despite higher preoperative BMI and ORCs among minority youth, only 11% of the cohort was Black and 13% was Hispanic.[13] Moreover, there have been no differences in weight loss trajectory or complication rates observed between racial groups.[6–8,13,15,16] Several barriers have been identified that potentially explain this incongruity, including geographic limitations, socioeconomic status, insurance coverage, provider concerns, societal misconceptions, systemic racism, and perceived impact on quality of life.[9,13,15,26] It is imperative that healthcare providers work with families, especially the most vulnerable and high-risk, to expand equitable access to comprehensive, multidisciplinary, pediatric-specific bariatric programs.[9]

TABLE 2 Obesity-related Comorbidities by Year

	2010	2011	2012	2013	2014	2015	2016	2017	*P*
Diabetes									
Yes	119.3 (15.2)	89.11 (11.8)	130.0 (14.9)	120.0 (10.3)	170.0 (13.8)	120.0 (9.0)	135.0 (10.2)	175.0 (11.3)	.40
No	667.4 (84.8)	663.5 (88.2)	745.0 (85.1)	1045.0 (89.7)	1065.0 (86.2)	1210.0 (91.0)	1190.0 (89.8)	1370.0 (88.7)	
Hypertension									
Yes	167.1 (21.2)	220.8 (29.3)	155.0 (17.7)	240.0 (20.6)	175.0 (14.2)	200.0 (15.0)	180.0 (13.6)	250.0 (16.2)	.01
No	619.6 (78.8)	531.9 (70.7)	720.0 (82.3)	925.0 (79.4)	1060.0 (85.8)	1130.0 (85.0)	1145.0 (86.4)	1295.0 (83.8)	
Sleep apnea									
Yes	159.7 (20.3)	174.0 (23.1)	190.0 (21.7)	245.0 (21.0)	240.0 (19.4)	300.0 (22.6)	280.0 (21.1)	385.0 (24.9)	.53
No	627.0 (79.7)	578.6 (76.9)	685.0 (78.3)	920.0 (79.0)	995.0 (80.6)	1030.0 (77.4)	1045.0 (78.9)	1160.0 (75.1)	
NASH									
Yes	98.9 (12.6)	72.1 (9.6%)	100.0 (11.4)	115.0 (9.9)	120.0 (9.7)	185.0 (13.9)	175.0 (13.2)	285.0 (18.5)	.13
No	687.8 (87.4)	680.5 (90.4)	775.0 (88.6)	1050.0 (90.1)	1115.0 (90.3)	1145.0 (86.1)	1150.0 (86.8)	1260.0 (81.6)	
GERD									
Yes	127.0 (16.2)	145.4 (19.3)	195.0 (22.3)	240.0 (20.6)	260.0 (21.1)	310.0 (23.3)	275.0 (20.8)	380.0 (24.6)	.65
No	659.6 (83.9)	607.2 (80.7)	680.0 (77.7)	925.0 (79.4)	975.0 (79.0)	1020.0 (76.7)	1050.0 (79.3)	1165.0 (75.4)	

Data presented as *n* (%) unless otherwise noted. GERD, gastroesophageal reflux disease; NASH, nonalcoholic steatohepatitis.

TABLE 3 In-hospital Postoperative Complication Rates by Year

	2010	2011	2012	2013	2014	2015	2016	2017	*P* value
Any complication									
Yes	56.8 (7.2)	45.2 (6.0)	45.0 (5.1)	75.0 (6.4)	50.0 (4.1)	70.0 (5.3)	60.0 (4.5)	100.0 (6.5)	.88
No	729.9 (92.8)	707.4 (94.0)	830.0 (94.9)	1090.0 (93.6)	1185.0 (96.0)	1260.0 (94.7)	1265.0 (95.5)	1445.0 (93.5)	

Data presented as *n* (%) unless otherwise noted.

The current data only underscores the point that obesity-related health disparities disproportionately impact minority groups, and that said minority groups are still less likely to receive surgical weight loss treatment than their white counterparts.

In the present analysis, children undergoing MBS were predominantly privately-insured. However, enrollment in government-funded insurance programs such as Medicaid and Medicare increased over the study period, representing incremental progress in improving access to publicly insured youth. This data are consistent with several reports showing that the majority of pediatric bariatric patients are private payers from higher-income areas.[21,27] A previous study from Teen Longitudinal Assessment of Bariatric Surgery reported that 53% of adolescents meeting criteria for MBS were denied authorization for insurance coverage, compared with 15% in adults. An age less than 18 was the most cited reason for denial of coverage in youth. It is important to note that 80% of adolescents ultimately received insurance approval, but this required multiple time-consuming appeals.[28] Such disparities in utilization and access have been primarily attributed to socioeconomic status as race and ethnicity were not shown to be independently associated with the decision to undergo MBS.[9,29,30] This problem is further exacerbated by known inconsistencies in eligibility criteria for pediatric MBS among government insurance programs.[9] The data herein are consistent with previous estimates and again highlights a major and persistent barrier to access for families with low socioeconomic status and public insurance.

Preoperative BMI increased across the study period. Although variations in categorical coding of BMI groups made standardization and interpretation somewhat challenging, the overall national trend was irrefutable. Furthermore, the decrease in the "morbidly obese" group over time likely reflects a clearer use of BMI classification and avoidance of stigmatizing terminology. Meanwhile, rates of ORCs were relatively stable from 2010 to 2017. HTN and obstructive sleep apnea were the most common comorbidities, though rates of HTN decreased across the study period. Although Kelleher et al reported increased prevalence of all comorbidities between 2003 to 2009, this trend was not observed in the current study.[21] LOS was less than 2 days, with a significant decrease in LOS over time. Peri-operative complication rates were low at 6% to 7% and driven primarily by minor surgical complications that did not require reintervention or reoperation at the index encounter. This is comparable to figures reported in prior studies.[11,21] Lastly, these surgeries are largely being performed at adult hospitals, based on age of weighted admissions and not Metabolic and Bariatric Surgery Accreditation and Quality Improvement Project designation. This recapitulates the need both for more pediatric-only bariatric centers of excellence and adult centers with pediatric designation where in children and adolescents can receive high-quality, multidisciplinary care that is focused on their unique needs.

There were several limitations in this study. First, though the NIS data are released annually, and therefore boasts 1 of the most complete large-scale national datasets, it only samples 20% of weighted admissions and therefore may be less representative of pediatric healthcare delivery. Approximately 5% to 10% of race data were missing from NIS, which could lead to unintentionally biased estimates of racial distribution in cohorts. Furthermore, the nomenclature and coding of BMI groups is different across institutions making standardization and interpretation of trends somewhat challenging. Lastly, the structure of NIS restricts the data to the index inpatient admission because of lack of patient-level identifiers. As such, weight loss trajectories, complication rates, and subsequent readmissions were not analyzed and thus, could under-represent peri-operative outcomes.

CONCLUSIONS

National pediatric bariatric procedure rates have experienced an increase from 2010 to 2017. The cohort is primarily older, female, white, and privately-insured. Preoperative BMI has increased, whereas individual ORCs have remained stable. Though a proven safe and effective weight loss intervention, pediatric MBS is underutilized with disproportionately lower rates among minority groups. Further investigation into the racial and social determinants that limit access to MBS is essential to combat this growing public health crisis.

ABBREVIATIONS

AAP: American Academic of Pediatrics
AGB: adjustable gastric band
ASMBS: American Society for Metabolic and Bariatric Surgery
CI: confidence interval
GERD: gastroesophageal reflux disease
HCUP: Healthcare Cost and Utilization project
HTN: hypertension
ICD: *International Classification of Disease*
LOS: length of stay
MBS: metabolic and bariatric surgery
NIS: National Inpatient Sample
ORC: obesity-related comorbidities
RYGB: Roux-en-Y gastric bypass
SG: sleeve gastrectomy

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REFERENCES

1. Hales CM, Fryar CD, Carroll MD, Freedman DS, Ogden CL. Trends in obesity and severe obesity prevalence in US youth and adults by sex and age, 2007-2008 to 2015-2016. *JAMA*. 2018;319(16):1723–1725
2. Ogden CL, Fryar CD, Martin CB, et al. Trends in obesity prevalence by race and hispanic origin-1999-2000 to 2017-2018. *JAMA*. 2020;324(12):1208–1210
3. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of obesity among adults and youth: United States, 2015-2016. *NCHS Data Brief*. 2017;(288):1–8
4. Fryar CD, Carroll MD, Afful JA; Centers for Disease Control and Prevention. Prevalence of overweight, obesity, and severe obesity among children and adolescents aged 2–19 years: United States, 1963–1965 through 2017–2018. Available at: https://www.cdc.gov/nchs/data/hestat/obesity-child-17-18/obesity-child.htm. Accessed June 1, 2021
5. Alley DE, Chang VW. Metabolic syndrome and weight gain in adulthood. *J Gerontol A Biol Sci Med Sci*. 2010;65(1):111–117
6. Inge TH, Zeller MH, Jenkins TM, et al; Teen-LABS Consortium. Perioperative outcomes of adolescents undergoing bariatric surgery: the Teen-Longitudinal Assessment of Bariatric Surgery (Teen-LABS) study. *JAMA Pediatr*. 2014;168(1):47–53
7. Inge TH, Jenkins TM, Xanthakos SA, et al. Long-term outcomes of bariatric surgery in adolescents with severe obesity (FABS-5+): a prospective follow-up analysis. *Lancet Diabetes Endocrinol*. 2017;5(3):165–173
8. Inge TH, Coley RY, Bazzano LA, et al; PCORnet Bariatric Study Collaborative. Comparative effectiveness of bariatric procedures among adolescents: the

PCORnet bariatric study. *Surg Obes Relat Dis.* 2018;14(9):1374–1386

9. Armstrong SC, Bolling CF, Michalsky MP, Reichard KW, Section On Obesity SOS; Section on Obesity, Section on Surgery. Pediatric metabolic and bariatric surgery: evidence, barriers, and best practices. *Pediatrics.* 2019;144(6):e20193223
10. Michalsky M, Reichard K, Inge T, Pratt J, Lenders C; American Society for Metabolic and Bariatric Surgery. ASMBS pediatric committee best practice guidelines. *Surg Obes Relat Dis.* 2012; 8(1):1–7
11. Schilling PL, Davis MM, Albanese CT, Dutta S, Morton J. National trends in adolescent bariatric surgical procedures and implications for surgical centers of excellence. *J Am Coll Surg.* 2008;206(1):1–12
12. Martin M, Beekley A, Kjorstad R, Sebesta J. Socioeconomic disparities in eligibility and access to bariatric surgery: a national population-based analysis. *Surg Obes Relat Dis.* 2010;6(1):8–15
13. Nunez Lopez O, Jupiter DC, Bohanon FJ, Radhakrishnan RS, Bowen-Jallow KA. Health disparities in adolescent bariatric surgery: nationwide outcomes and utilization. *J Adolesc Health.* 2017; 61(5):649–656
14. Messiah SE, Lopez-Mitnik G, Winegar D, et al. Changes in weight and co-morbidities among adolescents undergoing bariatric surgery: 1-year results from the Bariatric Outcomes Longitudinal Database. *Surg Obes Relat Dis.* 2013; 9(4):503–513
15. Messiah SE, Lopez-Mitnik G, Winegar D, et al. Effect of ethnicity on weight loss among adolescents 1 year after bariatric surgery. *World J Diabetes.* 2013; 4(5):202–209
16. Steinberger AE, Youngwirth LM, Kim SE, et al. Adolescent bariatric surgery: racial disparities in 30-day outcomes using the MBSAQIP from 2015 to 2018. *Obes Surg.* 2021;31(8):3776–3785
17. Quality AfHRa. *HCUP National Inpatient Sample (NIS).* Rockville, MD: Healthcare Cost and Utilization Project (HCUP); 2017
18. Pratt JSA, Browne A, Browne NT, et al. ASMBS pediatric metabolic and bariatric surgery guidelines, 2018. *Surg Obes Relat Dis.* 2018;14(7):882–901
19. Bureau USC. National population by characteristics. Available at: www.census.gov/data/datasets/time-series/demo/popest/2010s-national-detail.html. Accessed July 27, 2021
20. Inge TH, Krebs NF, Garcia VF, et al. Bariatric surgery for severely overweight adolescents: concerns and recommendations. *Pediatrics.* 2004;114(1):217–223
21. Kelleher DC, Merrill CT, Cottrell LT, Nadler EP, Burd RS. Recent national trends in the use of adolescent inpatient bariatric surgery: 2000 through 2009. *JAMA Pediatr.* 2013;167(2):126–132
22. (ASMBS) ASfMaBS. Estimate of bariatric surgery numbers, 2011-2019. Published. Available at: https://asmbs.org/resources/estimate-of-bariatric-surgery-numbers. Accessed June 1, 2021
23. Khidir N, El-Matbouly MA, Sargsyan D, Al-Kuwari M, Bashah M, Gagner M. Five-year outcomes of laparoscopic sleeve gastrectomy: a comparison between adults and adolescents. *Obes Surg.* 2018;28(7):2040–2045
24. Fuchs HF, Broderick RC, Harnsberger CR, et al. Benefits of bariatric surgery do not reach obese men. *J Laparoendosc Adv Surg Tech A.* 2015;25(3): 196–201
25. Perez NP, Westfal ML, Stapleton SM, et al. Beyond insurance: race-based disparities in the use of metabolic and bariatric surgery for the management of severe pediatric obesity. *Surg Obes Relat Dis.* 2020;16(3):414–419
26. Johnson VR, Acholonu NO, Dolan AC, Krishnan A, Wang EH, Stanford FC. Racial disparities in obesity treatment among children and adolescents. *Curr Obes Rep.* 2021;10(3):342–350
27. Hennings DL, Baimas-George M, Al-Quarayshi Z, Moore R, Kandil E, DuCoin CG. The inequity of bariatric surgery: publicly insured patients undergo lower rates of bariatric surgery with worse outcomes. *Obes Surg.* 2018;28(1):44–51
28. Inge TH, Boyce TW, Lee M, et al. Access to care for adolescents seeking weight loss surgery. *Obesity (Silver Spring).* 2014;22(12):2593–2597
29. Stanford FC, Jones DB, Schneider BE, et al. Patient race and the likelihood of undergoing bariatric surgery among patients seeking surgery. *Surg Endosc.* 2015;29(9):2794–2799
30. Byrd AS, Toth AT, Stanford FC. Racial disparities in obesity treatment. *Curr Obes Rep.* 2018;7(2):130–138