National Trends in Adolescent Bariatric Surgical Procedures and Implications for Surgical Centers of Excellence

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BACKGROUND: Bariatric surgery is indicated for severely obese adolescents who have failed nonsurgical treatment. Our objective was to examine national trends in the use of bariatric operations among adolescents.

STUDY DESIGN: The Kids' Inpatient Database was used to identify bariatric surgery patients in the pediatric population (age younger than 18 years) for 1997, 2000, and 2003. Patients were identified by procedure codes for bariatric operations with confirmatory diagnosis codes for obesity. Nationally representative estimates of trends in bariatric procedures, patient characteristics, hospital characteristics, and in-hospital complication rates were calculated. We augmented our analysis with the 2003 Nationwide Inpatient Sample, to ascertain hospitals' overall bariatric surgical volume (adolescents and adults).

RESULTS: From 1997 to 2003, the estimated number of adolescent bariatric procedures performed nationally increased 5-fold from 51 to 282 ($p < 0.01$). More than 100 hospitals performed bariatric procedures on adolescents in 2003, most of which (87%) performed 4 or fewer adolescent bariatric operations annually. Operations were predominantly performed in adult hospitals (85%). Although most hospitals had high overall bariatric operation volumes (> 200 bariatric procedures for patients of any age), 39% of adolescent bariatric procedures were performed at lower-volume centers. Patients were predominantly Caucasian (68%) and female (72%), with a mean age of 16 years (minimum age 12 years). In-hospital complications occurred in 6% of patients. There were no in-hospital deaths.

CONCLUSIONS: Our findings indicate a recent, rapid increase in the frequency of adolescent bariatric procedures. Most hospitals that performed bariatric procedures on adolescents had limited experience with adolescent bariatric patients, although many of these hospitals appear to have been experienced adult centers with high overall bariatric volume (adolescents and adults). Future research must better clarify the institutional qualifications considered mandatory for treatment of eligible adolescents. (J Am Coll Surg 2008;206:1–12. © 2008 by the American College of Surgeons)

National rates of overweight among children and adolescents (body mass index [BMI; calculated as kg/m^2] $\geq 95^{th}$ percentile for age and gender) have increased steadily during the past 3 decades.[1] The serious health consequences of overweight for children and obesity for adults are well documented.[2-10] Among adults, bariatric surgery has been shown to be more effective than nonsurgical treatment of severe obesity (BMI ≥ 40), both in terms of durable weight loss and control of comorbid conditions.[11,12]

Consequently, there has been growing interest in developing bariatric surgery programs for adolescents with severe overweight (also referred to as obesity).[13,14] Recent estimates suggest that, across the US, the number of bariatric operations performed on adolescents and young

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Abbreviations and Acronyms
BMI = body mass index
KID = Kids' Inpatient Database
NIS = Nationwide Inpatient Sample

adults (younger than age 20 years) more than tripled between 2000 and 2003.[15] Early clinical results have been promising: Tsai and colleagues'[15] recent study found nationally representative estimates of in-hospital complications similar between patients younger than 20 years of age and adults of all ages. Recent systematic review of the adolescent bariatric surgery literature suggested that adolescents lose substantial weight and achieve improved control of obesity-related comorbid conditions.[16] Nevertheless, the vast majority of studies about adolescents are single-center case series, with sample sizes no more than 50 patients during multiple years.[14,17-25]

Given the absence of strong, longterm, clinical evidence, a consensus report on adolescent bariatric surgery was published in 2004 by a panel of surgeons and pediatricians expert in the treatment of childhood overweight and obesity.[26] The report established guidelines for patient evaluation, patient selection, surgical treatment, and longterm followup, with stricter, more conservative selection criteria than those for adults to avoid inappropriate use or overuse of weight-loss operations for adolescents. The report also stressed the importance of the unique metabolic, developmental, and psychologic needs of severely obese adolescents relative to their adult counterparts. To meet these unique needs, the expert panel called for the development of regional centers of excellence where adolescents' unique needs could be managed by multidisciplinary teams with specialty expertise in adolescent obesity. Centers of excellence would not only help ensure that patients received appropriate specialty care with requisite lifelong followup but also facilitate essential collection of high-quality, longterm outcomes data necessary to guide optimization of treatment.

In the context of these recommendations, we conducted this study to characterize recent national trends in the use of bariatric surgical procedures for obese adolescents. We limited our study to patients younger than 18 years of age, to specifically focus on adolescent minors, distinct from young adults, because minors do not give informed consent. We report trends in patient characteristics, hospital characteristics, and in-hospital complications using available national data specific to children for the years 1997, 2000, and 2003. Our primary objective was to examine whether the recommendations put forth by the consensus report appear to have been realized during this early time period. Most important, and unique to our study, we investigate whether adolescent bariatric specialty centers appear to have emerged by 2003. Alternatively, in the absence of specialty centers, we investigate whether adolescents were treated at experienced adult bariatric centers. The ultimate goal of our study is to help frame important quality-related issues in adolescent bariatric surgery by characterizing the institutions already engaged in the surgical treatment of adolescent obesity.

METHODS

Data source

The Kids' Inpatient Database (KID) was used to identify bariatric surgery procedures in children younger than 18 years of age in 1997, 2000, and 2003.[27-29] The KID was developed by the Health Cost and Utilization Project to analyze inpatient hospital use by children across the US. It is the only national, all-payor database of hospitalizations for children. The KID is compiled every 3 years. It contains 2 to 3 million hospital discharge records per year by sampling from 22 states in 1997, 27 states in 2000, and 36 states in 2003. Each hospitalization includes information on patient demographics, diagnosis/procedure codes, and hospital characteristics. Hospital characteristics include total bed size, teaching status, children's hospital status, and regional location.[30,31]

The KID comes with sample weights designated by the survey design for nationally representative estimates. The KID samples pediatric discharges from all community, nonrehabilitation hospitals in participating states. From these hospitals, pediatric discharges are stratified across three domains: uncomplicated in-hospital birth, complicated hospital birth, and pediatric nonbirth discharges. Systematic random samples of discharges are drawn from each of these strata. The data set provides discharge weights created by poststratification of the hospitals in the sampling frame on six characteristics: geographic region, urban/rural location, teaching status, bed size, control, and hospital type. To produce national estimates, these discharge weights can be used to extrapolate from sampled discharges to all discharges from US, community, nonrehabilitation hospitals. Point values reported in this study are survey-weighted estimates (unless otherwise specified) that reflect national numbers, and the associated standard errors reflect the inherent variability in these estimates. The KID is publicly available and is widely considered the premier database to study hospitalizations for relatively rare pediatric conditions and procedures.[30,31]

Patient identification

Our study design echoed those published by Santry and colleagues[32] and Davis and colleagues,[33] both of which ex-

amined national trends in bariatric surgery among adults. We characterized bariatric procedures with appropriate combinations of ICD-9-CM[34] procedure codes for foregut surgery. Bariatric surgery patients were identified by foregut surgery procedure code(s) (43.0 to 44.99, 45.50 to 45.91) and were additionally required to have both a diagnosis-related group code for obesity surgery (288) and a confirmatory diagnosis code for obesity (278.00 to 278.8) (Appendix). We excluded procedures that did not appear to be intended for weight loss, based on diagnosis codes for gastrointestinal tract neoplasm (150.0 to 159.9), inflammatory bowel disease (555.0 to 556.9), and noninfectious colitis (557.0 to 558.9). We ensured that cases were elective in nature by excluding emergency admissions and hospital transfers.

Cases meeting these criteria were divided into five procedure categories: gastric bypass, gastroplasty (vertical banded gastroplasty and adjustable gastric banding), malabsorptive (duodenal switch, biliopancreatic diversion, and isolated intestinal bypass), gastrectomy (all types of partial gastrectomies), and other (nonspecified gastric procedures and gastric bubble insertion) (see Appendix). We were not able to distinguish open from laparoscopic procedures because there is no ICD-9-CM code for laparoscopic bariatric surgery. Adjustable gastric banding could not be tracked independent of vertical banded gastroplasty because there were not individual codes available to separate the procedures.

Patient characteristics

The KID reports patient demographic data including age, gender, race, and type of insurance.[30,31] For each patient, we calculated the Charlson Comorbidity Index with Deyo adaptation[35] using the 15 diagnosis codes included in the KID. We were not able to report detailed estimates of patient race because of both relatively small sample sizes and large amounts of missing data (race variable missing for 27% of our cohort). Dichotomizing the race variable (as Caucasian versus non-Caucasian) did enable us to report sufficiently robust estimates of the proportions of Caucasian versus non-Caucasian patients among those without missing data.

Hospital characteristics

The KID also provides detailed information on hospital characteristics, including teaching status, bed size (small, medium, or large), and region (Northeast, South, Midwest, and West). The KID characterizes hospitals according to the National Association of Children's Hospitals and Related Institutions designation. National Association of Children's Hospitals and Related Institutions classifies hospitals as a children's general hospital, children's specialty hospital, children's ward in a general hospital, or nonchildren's hospital.[30,31] We combined the categories for two variables (region and National Association of Children's Hospitals and Related Institutions designation of hospital) because of low cell counts within individual categories.

In-hospital complications

After the approach used by Santry and colleagues[32] and others,[36-42] we identified in-hospital complications to encompass both technical and systemic complications. Technical complications included unexpected reoperation for surgical complications, splenic injury, hemorrhage, anastomotic leaks, and wound complications. Systemic complications included respiratory tract, cardiac, neurologic, thromboembolic, genitourinary tract, and multisystem (shock) complications (Appendix).[32] Technical and systemic complications were summed for each patient to create cumulative complication counts. We made special note of five specific complications, including unexpected reoperation, postoperative bleeding, anastomotic leak/abscess, pulmonary embolism/deep venous thrombosis, and other pulmonary complications. In-hospital mortality was also available in the data set.

Hospitals' bariatric surgery patient volume

A number of studies have demonstrated volume–outcomes relationships for bariatric surgery among adults.[37,42-46] With these relationships in mind, we made estimates of hospitals' annual bariatric surgery volume, first for adolescent patients, and then for patients of all ages (adolescent and adult patients). Adolescent case volume estimates were made using the 2003 KID. Every discharge record in the KID includes a unique hospital identifier, which enabled us to sum the weighted number of adolescent bariatric surgery discharges generated by the KID hospitals during 2003.

For adolescent patient volume estimates, it is important to note one of the data set's key limitations: the KID does not include hospital-level weights, only weights at the discharge level. Without hospital-level weights it is not possible to generate nationally representative estimates of the number of hospitals performing a procedure. The discharge-level weights did enable us to estimate the adolescent case volume of those hospital actually sampled by the KID in 2003. In that year, the KID's sample included all community, nonrehabilitation hospitals from 36 US states (3,438 hospitals) or 71% of the total universe of US hospitals (4,836 hospitals as defined by the American Hospital Association). Empiric comparisons of the KID hospitals and the American Hospital Association universe of hospitals have shown that the KID sampling frame is highly reflective of the larger universe of US hospitals.[30,31] In other words, adolescent bariatric case volume estimates are highly likely to reflect the experience of the remaining 29% of US hospitals not sampled by the KID in 2003.

Table 1. Types of Adolescent Bariatric Surgical Procedures Performed from 1997, 2000, and 2003, Based on Data from the Kids' Inpatient Database

Procedure type*	1997	2000	2003	p Value for trend
Gastric bypass, n (%)	37 (74)	93 (96)	256 (91)	$< 0.01^{\dagger}$
Gastroplasty, n (%)	13 (26)	4 (4)	19 (7)	
Malabsorptive, n (%)	0	0	2 (1)	
Gastrectomy, n (%)	0	0	1 (< 1)	
Other, n (%)	0	0	4 (1)	
Total no. of procedures ± SE	51 ± 3.3	98 ± 6.9	282 ± 17.9	$< 0.01^{\ddagger}$

Adolescent is defined as age younger than 18 years. Numbers in columns do not necessarily sum, nor do percentages sum to 100% because these values are survey weighted estimates and are subject to variability.
*Definitions of procedures are provided in the Methods section.
†p Value indicates a significant increase in the proportion of gastric bypass procedures relative to other bariatric procedures.
‡p Value indicates a statistically significant increase in the overall population-based rate of bariatric procedures for individuals younger than age 18 years.

We augmented our analysis of case volume by using a second data set, the 2003 Nationwide Inpatient Sample (NIS). The NIS enabled us to estimate hospitals' overall bariatric volume (adolescent and adult patients).[47] Like the KID, the NIS was developed by the Health Cost and Utilization Project to analyze inpatient hospital utilization. The NIS is designed to include a representative 20% sample of US community hospitals each year on the basis of 5 characteristics: geographic region, urban/rural location, teaching status, bed size, and hospital control (public/private). The NIS comes with sample weights based on the survey design, to generate nationally representative estimates. The NIS does not limit its sampling by age and includes a nationally representative sample of hospital discharges for patients of all ages (adolescents and adults).[48,49]

The NIS employs a sampling design different from the KID, which prohibits the data sets from being merged.[48,49] To calculate hospital volume without age restriction, we applied the same inclusion and exclusion criteria (except age) to the NIS, creating a separate cohort of bariatric surgery patients for the year 2003. Using this NIS cohort, we calculated each hospital's overall annual bariatric surgery volume, but only if that hospital had performed at least one adolescent bariatric procedure during the calendar year. We divided total annual bariatric surgery volume into 4 strata: very low (< 50 bariatric procedures total), low (50 to 100 procedures), moderate (101 to 200 procedures), and high (> 200 procedures). We defined the volume strata based on cut-offs used in earlier studies, and the cut-offs used in designating "Centers of Excellence" by some organizations.[37,42-46,50-52]

Statistical analysis

Our primary outcomes of interests included time trends in bariatric procedures, patient characteristics, hospital characteristics, length of stay, and in-hospital complication rates. We used the appropriate sample weights for each year to calculate nationally representative point estimates and trends in both means and frequencies. US census population estimates were used to calculate rates of bariatric operations for individuals younger than 18 years of age for each year.[53] All statistics, including point estimates, variances, and p values, accounted for the sampling designs and sampling weights of the KID or NIS data sets. Trends in continuous variables were evaluated using ANOVA. Trends in categorical variables were evaluated by Rao-Scott chi-square, a chi-square test that corrects for the design effects of sample data. All analyses were performed using SAS software and the software's statistical procedures specifically reserved for complex survey data (SAS software version 9.1; SAS Institute).[30,48]

RESULTS

From 1997 to 2003, the estimated number of adolescent bariatric operations performed nationally increased 5-fold, from 51 to 282. This represented a statistically significant increase in the overall population-based rate of bariatric procedures for individuals younger than age 18 years ($p < 0.01$) (Table 1; Fig. 1). Gastric bypass comprised a growing majority of procedures, increasing from 74% in 1997 to 91% in 2003 ($p < 0.01$) (Table 1). During that same time period, the proportion of gastroplasty procedures decreased from 26% in 1997 to 7% in 2003, although absolute numbers increased.

Trends in patient characteristics are displayed in Table 2. Across all years, patients were predominantly Caucasian (68% to 85%) and female (69% to 73%), with mean age of 16 years (minimum age 12 years). The most common primary payor was private insurance (78% to 82%), although Medicaid was the payor for an increasing number of patients during the time period, growing from 0% in 1997 to 10% in 2003 (not shown in Table 2). An increasing majority of patients registered a score of 0 on the Charlson Comorbidity Index (ie, low comorbid burden) from 60% in 1997 to 73% in 2003 ($p < 0.03$).

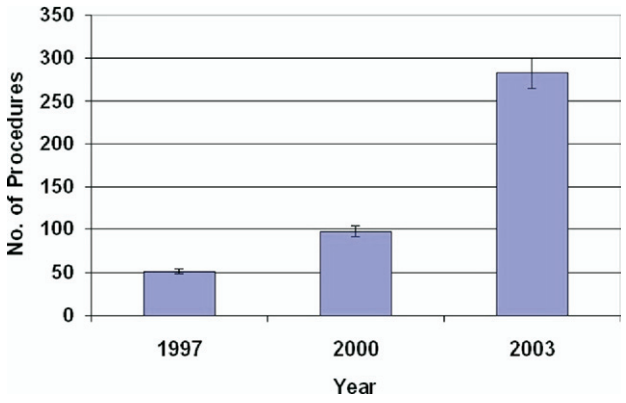

Figure 1. National trends in annual numbers of pediatric bariatric procedures: 1997, 2000, and 2003. Counts based on Kids' Inpatient Database (error bars represent standard error).

Trends in hospital characteristics are displayed in Table 3. Across all years, operations were primarily performed in nonchildren's hospitals (80% to 86%). Operations were roughly split across teaching and nonteaching institutions, with a time trend toward a greater share of operations being done at nonteaching centers, although the trend did not reach statistical significance. There was a strong trend related to hospital size: the share of procedures done in large hospitals increased from 8% in 1997 to 59% in 2003 ($p < 0.01$). Although hospitals in the West performed the largest share of procedures in 1997 (61%), by 2003, hospitals in the Midwest and South performed more than twice as many as hospitals in the West ($p < 0.01$). Absolute numbers of procedures increased for all regions across time.

Trends for in-hospital complications are presented in Table 4. There were no in-hospital deaths observed in 1997, 2000, or 2003. During this time period, average length of stay decreased from 4.5 days to 2.8 days ($p < 0.01$). In-hospital complications occurred in 11% of patients in 1997, 7% in 2000, and 6% in 2003, although the trend did not reach statistical significance. The most frequent technical complication during the study years was hemorrhage (2% to 6%). Unexpected reoperation occurred in $\leq$ 2% of admissions. The most common systemic complications were pulmonary (0% to 4%). Other complication rates were low.

Table 5 displays the adolescent bariatric surgery volume of KID hospitals that performed at least 1 adolescent bariatric procedure in 2003. Within the KIDs' sample, there were 112 hospitals that performed bariatric operations on adolescents in 2003, most of which (87%) performed 4 or fewer adolescent bariatric procedures annually. No hospital was estimated to have performed $>$ 12 adolescent bariatric procedures.

Using data from the NIS, we also characterized the overall bariatric surgery volume (adolescent and adult procedures) for

Table 2. Characteristics of Adolescent Patients Undergoing Elective Bariatric Surgical Procedures from 1997, 2000, and 2003

	1997 (n = 51 ± 3.3*)	2000 (n = 98 ± 6.9)	2003 (n = 282 ± 17.9)	p Value for trend
Age (y)				
Mean ± SE	16 ± 0.1	16 ± 0.1	16 ± 0.1	< 0.37
Minimum	14	13	12	
Maximum	17	17	17	
Gender, n (%)				
Girls	35 (69)	71 (73)	201 (72)	< 0.91
Missing	0	0	1	
Type of insurance, n (%)				
Private	40 (82)	78 (81)	219 (78)	< 0.77
Other	9 (18)	18 (19)	62 (22)	
Missing	1	1	1	
Charlson Index, n (%)				
None	31 (60)	82 (84)	206 (73)	< 0.03
1	20 (40)	16 (16)	77 (27)	
> 1	0	0	0	
Race, n (%)†				
Caucasian	31 (70)	70 (85)	128 (68)	< 0.06
Non-Caucasian	14 (30)	12 (15)	61 (32)	
Missing	3	10	59	

Adolescent is defined as age younger than 18 years. Numbers in columns do not necessarily sum, nor do percentages sum to 100% because these values are survey weighted estimates and are subject to variability.
*Standard error estimate for the estimated sample size.
†For our sample, 27% of race data was missing.

Table 3. Characteristics of Hospitals Performing Elective Adolescent Bariatric Surgical Procedures from 1997, 2000, and 2003

	1997 (n = 51 ± 3.3*)	2000 (n = 98 ± 6.9)	2003 (n = 282 ± 17.9)	p Value for trend
Teaching status, n (%)				
Teaching	29 (58)	44 (45)	118 (43)	< 0.44
Nonteaching	21 (42)	52 (55)	157 (57)	
Missing	0	1	4	
Children's versus adults', n (%)				
Children's hospital	10 (20)	14 (14)	38 (15)	< 0.51
Non-children's	41 (80)	82 (86)	218 (85)	
Missing	0	1	14	
Bed size, n (%)				
Small	20 (40)	16 (16)	33 (12)	< 0.01
Medium	26 (52)	17 (18)	78 (29)	
Large	4 (8)	63 (66)	163 (59)	
Missing	0	1	4	
Region, n (%)				
Northeast	4 (9)	15 (16)	55 (19)	< 0.01
Midwest/South	16 (31)	38 (39)	165 (58)	
West	31 (61)	44 (46)	62 (22)	
Missing	0	0	0	

Adolescent is defined as age younger than 18 years. Numbers in columns do not necessarily sum, nor do percentages sum to 100% because these values are survey weighted estimates and are subject to variability.
*Standard error estimate for the estimated sample size.

hospitals that had performed at least 1 adolescent bariatric procedure during 2003 (because of the different methods of sampling, the NIS estimates 195 adolescent bariatric surgical procedures for 2003, versus 282 in the KID for the same year). As shown in Table 6, 61% of adolescent bariatric surgical procedures were performed in high-volume hospitals (defined as > 200 bariatric operations annually for any age). Conversely, more than one-third of adolescent bariatric procedures (39%) were performed outside of high-volume institutions.

DISCUSSION

Although bariatric surgery remains a relatively new approach to obesity among adolescents, the absolute number performed for adolescents increased markedly from 1997 through 2003, an increase that paralleled overall growth in bariatric surgery during this time period.[32,33] We found this increase almost exclusively attributable to growth in gastric bypass, the procedure that most agree is the best surgical option for adolescents.[26]

Table 4. In-Hospital Complications after Elective Adolescent Bariatric Surgical Procedures for 1997, 2000, and 2003

Type of complication	1997 (n = 51 ± 3.3*)	2000 (n = 98 ± 6.9)	2003 (n = 282 ± 17.9)	p Value for trend
Mortality (%)	0	0	0	
Length of stay (d), mean ± SE	4.5 ± .03	3.4 ± .3	2.8 ± 0.1	< 0.01
Common complications, n (%)				
PE/DVT	0	0	0	
Pulmonary	0	4 (4)	5 (2)	
Leak	0	0	0	
Hemorrhage	3 (6)	2 (2)	7 (2)	
Take back to OR	0	1 (2)	2 (1)	
Complications, n (%)				
No	45 (89)	90 (93)	264 (94)	< 0.63
Yes	6 (11)	7 (7)	18 (6)	

Adolescent is defined as age younger than 18 years. Numbers in columns do not necessarily sum, nor do percentages sum to 100% because these values are survey weighted estimates and are subject to variability.
*Standard error estimate for estimated sample size.
DVT, deep vein thrombosis; OR, operating room; PE, pulmonary embolism.

Table 5. One-Year (2003) Volume Characteristics of Hospitals Performing Elective Adolescent Bariatric Surgical Procedures

	Hospitals (n = 112)†	
Estimated adolescent bariatric volume*	**n**	**%**
< 3	68	61
3−4	29	26
5−6	9	8
7−8	3	3
9−10	1	< 1
11−12	2	2
> 12	0	

Adolescent is defined as age younger than 18 years.
*The Kids' Inpatient Database (KID) does not include hospital-level weights. Hospital sample size (n = 112) is not a nationally representative estimate of the number of hospitals performing adolescent bariatric surgery but is instead the actual number of hospitals performing this surgery within the sampling frame of the KID.[30,31] See Methods section for additional details.
†All hospitals performing an adolescent bariatric surgery were identified. Adolescent bariatric volume (age younger than 18 years) of each of these hospitals was estimated for 2003 based on data from the 2003 Kids' Inpatient Database.

Table 6. Elective Adolescent Bariatric Surgical Procedures Characterized by the Performing Hospitals' Overall (Adolescent and Adult) Bariatric Surgery Volume for 2003

	Adolescent procedures† (n = 195 ± 16.3‡)	
Total bariatric volume*	**n**	**%**
Very low (< 50)	21	11
Low (50−100)	8	4
Moderate (101−200)	47	24
High (> 200)	118	61

Adolescent is defined as age younger than 18 years.
*All hospitals performing an adolescent bariatric surgery were identified. Total bariatric volume of each of these hospitals (including adolescent and adult procedures) was totaled for the year 2003 and stratified into the volume ranges designated previously. All estimates are based on data from the 2003 Nationwide Inpatient Sample.
†Weighted estimates of the number and percent of elective adolescent bariatric procedures performed in the year 2003 based on data from the 2003 Nationwide Inpatient Sample. Numbers in columns do not necessarily sum, nor do percentages sum to 100% because these values are survey weighted estimates and are subject to variability.
‡Standard error estimate for the estimated sample size.

The popularity of gastric bypass appears to have overshadowed the adjustable gastric band, despite the device's lower perioperative mortality in adults.[54] The proportion of gastroplasty procedures remained unchanged between 2000 and 2003, even as absolute numbers of gastroplasty procedures increased. The adjustable gastric band still awaits approval by the US Food and Drug Administration for use in patients younger than 18 years, and, as a result, many insurers do not cover the device.[26] The appeal of the adjustable gastric band is also diminished by studies that suggest it is less effective than gastric bypass in imparting durable weight loss.[55-59]

Characteristics of adolescents undergoing bariatric operation

In terms of demographic characteristics, the distribution of patient age was reassuring: patients averaged 16 years of age and no patient was younger than 12 years old. It is clinically plausible that, at these ages, patients had achieved much of their skeletal maturity and decisional capacity. Although age alone does not determine a patient's decisional capacity, none of the patients' ages was clearly prohibitive of informed decision making.

Like the adult literature, adolescent patients undergoing weight-loss operations were overwhelmingly female.[32] This finding could be justified if girls do, in fact, constitute the greater proportion of severely obese adolescents. Direct estimates of this proportion are not available for adolescents from published national data. Hedley and colleagues[1] found the prevalence of severe obesity (BMI ≥ 40) among young adults (ages 20 to 39 years) to be one-third higher in women than in men (5.6% versus 3.7%, respectively). In contrast, the same study did not find a statistically significant difference in the prevalence of overweight for adolescent boys (ages 12 to 19 years) versus girls (16.7% versus 15.4%, respectively). The disproportionate share of girls undergoing bariatric operation might also be related to the greater social acceptability of obesity for boys relative to girls.

Socioeconomic disparities may also be present in bariatric surgery patterns to date. In adults, the morbidly obese population is comprised of a disproportionate share of disadvantaged socioeconomic groups (eg, African American, poor, less educated).[60,61] The same pattern may hold for adolescents. Nevertheless, Livingston and Ko[61] found that the socioeconomic characteristics of morbidly obese adults did not match those of adult bariatric surgery patients. They found that those who actually had weight-loss procedures performed were disproportionately Caucasian, privately insured, and with higher incomes. We found that adolescents undergoing weight-loss operations were predominantly Caucasian (~70%) and most often covered by private insurance (~80%); however, without the appropriate reference group for comparison (ie, the proportions of severely obese adolescents who are Caucasian or covered by private insurance), assessing potential disparities in adolescent bariatric surgery is difficult. This further was complicated by missing race data in the KID, which could lead to biased estimates of racial proportions of note an increasing share of operations was covered by Medicaid with time, increasing from none in 1997 to 10% by 2003. As bariatric surgery becomes more widely adopted for use among severely obese adolescents, potential disparities in socioeconomic status certainly deserve attention in future studies.

Characteristics of hospitals performing adolescent bariatric operations

Our analysis of hospital characteristics suggests that few adolescent bariatric surgery "centers" appear to have existed in 2003. We base this conclusion on 2 findings: first, the relatively large number of US hospitals performing bariatric surgery on adolescents in 2003 (> 100 hospitals). Second, that most of these hospitals performed relatively few adolescent procedures (nearly 90% performed 4 or fewer adolescent cases in 2003). Putting both of these findings together, it appears that, in the absence of select centers performing the majority of adolescent procedures, patients instead sought care from a variety of adult centers. This conclusion is further supported by the share of hospital care being delivered outside of children's hospitals.

These findings raise an important question concerning quality of care for adolescents eligible for bariatric procedures: should there be bariatric surgery centers specializing in the care of adolescents? Many have indeed advocated for such centers, reasoning that adolescent-specific "centers of excellence" would ensure that patients were managed by the appropriate specialists and also facilitate collection of longterm outcomes data.[26] On the contrary, there may never be enough eligible adolescents to support adolescent-specific "centers of excellence." Nor is it clear how many pediatric centers have surgeons trained to perform bariatric procedures. In fact, in terms of the operative procedure specifically, experience with bariatric procedures might be the most important technical qualification for the surgeon, especially if the operation is contraindicated in patients who have not achieved at least a minimum level of adult development (ie, age 12 years or older). It is plausible that a sophisticated center, primarily experienced in adult bariatric surgery with a surgeon, could provide high-quality care to the few adolescents who undergo operations by ensuring the involvement of other important specialists in the care of the patient (eg, social workers, psychiatrists, pediatricians, adolescent obesity specialists, and so forth). We propose yet a "third way," when an adolescent bariatric center would include experienced adult bariatric surgeons, pediatric surgeons, and the other important adolescent-specific specialty care. This model currently exists at Lucile Packard Children's Hospital at Stanford University.

Indeed, we did find that most of these adolescent patients were treated at experienced adult centers (high-volume adult centers with > 200 bariatric patients annually). The data sets did not enable us to specifically discern the operating surgeon's experience with bariatric procedures nor the involvement of other adolescent obesity specialists. This finding does raise a second important question concerning quality of care: should adolescent procedures be performed at high-volume bariatric centers? Currently, there is no evidence that high-volume centers provide the highest quality care for the adolescent population. The sample size of our study was too small to permit us to stratify our analysis of complications by institutional volume. On the other hand, volume−outcomes relationships have been clearly demonstrated in the adult literature.[37,42-46] Weller and Hannan's[42] study, for example, would suggest that the risk of complications in patients at non-high-volume sites could be twice as high as for those who had their care at high-volume hospitals (> 200 procedures annually). If this relationship holds for adolescent patients, the one-third of adolescent procedures that were performed at lower-volume centers in 2003 were at twice the risk of complications compared with those performed at high-volume adult centers (> 200 bariatric procedures annually).

Despite a substantial portion of care being delivered at lower-volume hospitals, our estimates of in-hospital morbidity and mortality were on par with what has been seen in adults, if not lower. No deaths were observed. The most frequent in-hospital complications included hemorrhage (2% to 6%), pulmonary complications (< 4%), and unexpected reoperation (< 2%). Santry and associates[32] found similar in-hospital complication rates in adults using precisely the same study design: hemorrhage (1% to 2%), pulmonary complications (2% to 7%), and unexpected reoperation (6% to 9%).

Our estimates of complication rates must be interpreted with some caution. In-hospital complications are relatively infrequent events, and although these estimates might be the best currently available for adolescents, the estimates do lack precision because of small sample size. Our study lacked adequate power for risk adjustment of complication rates, although the majority of adolescents in this study did not have a single comorbidity according to the Charlson Index. A final important caveat is that these complication rates include only in-hospital events. Complications that typically occur after hospital discharge could not be accounted for, especially considering that the mean length of hospital stay in our study decreased from roughly 5 days in 1997 to 3 days by 2003. Nonetheless, these low complication rates suggest that bariatric surgical procedures are relatively safe procedures for well-selected patients, particularly in light of the procedures' anticipated benefits. Longterm outcomes could not be assessed with these data and require additional study.

In conclusion, our findings indicate a rapid increase in the frequency of adolescent bariatric procedures, an increase that paralleled overall growth in bariatric surgery. We found a relatively large number of US hospitals performing these operations. Most of the hospitals had limited experi-

ence with adolescent bariatric patients, although some were experienced adult centers with high overall bariatric volume (adolescent and adult patients). This pattern could be a cause for concern if adolescents' unique pre- and postoperative needs go unmet in adult centers.

As a result, the surgical community must more rigorously define the essential components of care and institutional qualifications for the adolescent bariatric surgery patient to ensure their proper management. Finally, as bariatric procedures continue to gain wider use in those with refractory obesity, we must closely examine adolescent-specific volume–outcomes relationships. If there are volume–outcomes relationships akin to those observed in adult patients, centralization of care could also help to ensure safe, high-quality care for adolescent patients.[37,42-46]

Appendix

Procedure codes for bariatric surgical procedure categories[32]	**ICD-9 code**
Procedure category	
Gastric bypass	
High or "Mason" gastric bypass	44.31
Gastroenterostomy not otherwise specified	44.39
Gastroplasty*	44.69
Malabsorptive procedures	
Duodenal switch	
Sleeve gastrectomy	43.89
Small bowel to small bowel anastomosis	45.50
Small bowel segment isolation	45.51
Intestine to intestine anastomosis not otherwise specified	45.90
Intestinal isolation not otherwise specified	45.91
Biliopancreatic diversion	
Partial gastrectomy with jejunal anastomosis	43.7
Small bowel to small bowel anastomosis	45.50
Small bowel segment isolation	45.51
Intestine to intestine anastomosis	45.90
Intestinal isolation not otherwise specified	45.91
Isolated intestinal bypass	
Small bowel to small bowel anastomosis	45.50
Small bowel segment isolation	45.51
Intestine to intestine anastomosis not otherwise specified	45.90
Intestinal isolation not otherwise specified	45.91
Gastrectomy	
Sleeve	43.89
Proximal	43.5
Distal	43.6
Other	
Gastric bubble insertion	44.93
Gastric operation not otherwise specified	44.99

* Includes both vertical banded gastroplasty and adjustable gastric banding.

Diagnosis and procedure codes for complications[32]	
Type of complication	
Technical	
Unexpected reoperation for complications	
Wound dehiscence	54.61
Lysis of adhesions	54.51, 54.59
Removal of foreign body	54.92
Laparotomy	54.12
Splenic	

Diagnosis and procedure codes for complications[32]	
Injury	41.2
Partial or complete splenectomy	41.43, 41.5
Hemorrhagic	
Intraoperative hemorrhage	998.11
Postoperative hematoma	998.12
Blood transfusion	99.04, 99.09
Anastomotic	
Leak	998.6
Percutaneous abdominal drainage	54.91
Wound	
Infection	998.5, 998.51, 998.59
Seroma	998.13
Dehiscence	998.3
Obstruction	
Small bowel obstruction	560.0–560.9
Systemic	
Pulmonary	
Respiratory tract complications	997.3
Acute bacterial pneumonia	431, 482.0–482.9, 485, 486
Acute respiratory failure	518.81
Tracheotomy	31.1, 31.29
Cardiac	
Complications	997.1
Acute myocardial infarction	410.0–410.9
Neurological	
Central nervous system complications	997.01–997.03
Acute cerebrovascular accident	431.00−431.91, 433.00−433.91, 434.00−434.91, 436, 437.1
Genitourinary tract	
Urinary tract complications	997.5
Acute renal failure	584.1–584.9
Acute dialysis	38.95
Insertion of short-term dialysis catheter	39.95
Thromboembolic	
Acute pulmonary embolism	415.1, 415.11, 415.19
Acute deep venous thrombosis	453.8, 453.90
Shock	
Postoperative	998.0

Author Contributions

Study conception and design: Schilling, Davis, Albanese, Dutta, Morton
Acquisition of data: Schilling, Davis
Analysis and interpretation of data: Schilling, Davis
Drafting of manuscript: Schilling
Critical revision: Schilling, Davis, Morton

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