ARTICLE

Bariatric Surgery in Adolescents

Recent National Trends in Use and In-Hospital Outcome

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Objectives: To analyze recent nationwide trends in the use of adolescent bariatric surgery and to compare early postoperative outcomes of adolescents and adults undergoing these procedures.

Design: Analysis of national administrative data by using survey analysis techniques.

Setting: Data obtained from the Nationwide Inpatient Sample from 1996 to 2003.

Participants: Adolescents (aged <20 years) and adults undergoing bariatric surgery.

Intervention: Bariatric surgery.

Main Outcome Measures: Population-based case rates, major postoperative complications, length of hospital stay, hospital charges, and mortality.

Results: The population-based annual adolescent bariatric case volume varied little between 1996 and 2000 but more than tripled from 2000 to 2003. Despite this trend, only 771 bariatric procedures were performed in adolescents in 2003, representing fewer than 0.7% of bariatric procedures performed nationwide. Univariate comparison with data from 2003 showed a similar in-hospital complication rate in adolescents and adults but a significantly shorter length of stay among adolescents. Although in-hospital mortality was observed in 0.2% of adults, no in-hospital deaths were observed in any adolescents.

Conclusions: Although procedure rates have increased recently, bariatric surgery in adolescents remains an uncommonly performed procedure. These data support efforts to align bariatric surgery programs for adolescents initially with higher volume programs for adults and to develop multicenter collaborative studies directed at defining the short- and long-term effect of bariatric surgery in morbidly obese adolescents.

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ALTHOUGH DIETARY AND BEhavioral approaches represent the mainstays of treatment of childhood obesity, bariatric (weight-loss) surgery increasingly is considered an option for treatment of adolescents with significant obesity-related comorbidities.[1-4] This paradigm shift has occurred in part because of the realization that nonsurgical approaches are of limited effectiveness for severe obesity (body mass index, calculated as weight in kilograms divided by height in meters squared, ≥40) in children[5] and in part because of the documented health benefits of bariatric surgery in adults.[6,7] On the basis of these factors, a number of pediatric groups have suggested that bariatric surgery is an appropriate treatment for carefully selected morbidly obese adolescents with severe comorbidities.[8-11] To date, a range of different types of bariatric procedures has been performed in this age group, including gastric bypass, vertical banded gastroplasty, and adjustable gastric banding.[1,2,12] Gastric bypass restricts intake and diverts nutrients from the proximal stomach to the mid jejunum. This procedure poses a risk of vitamin and mineral deficiency due to bypass of the stomach and duodenum. In contrast, adjustable gastric banding and vertical banded gastroplasty are nondiversion operations, achieving weight loss by restriction of nutrient intake alone. While these restrictive operations pose little risk of nutritional deficiency, predictably lower weight loss is achieved with these procedures compared with gastric bypass.

A recent surge in interest in bariatric surgery in adolescents parallels the rapid increase in these procedures among obese adults. Results of several observational studies suggested that short-term results achieved after bariatric surgery in adolescents may be similar to those observed in adults.[1,13-15] Because bariatric surgery is not commonly performed in adolescents, most

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reports of this procedure in this age group have been small case series, usually from single institutions.[1,13-15] National studies of bariatric surgery have focused on trends in bariatric surgery volume for adults and not on recent experience with this procedure among younger patients.[16-18] The aim of the present study was to use data from a large national administrative database to assess the use and short-term outcome of bariatric surgery in adolescents. Although the use of administrative data has limitations,[19] these pooled data permit accrual of more cases from a shorter study period than is possible in single-center series. The use of administrative data also avoids potential bias that may occur when only hospitals with a specialty interest in bariatric surgery report their results and is useful for obtaining population-based estimates.

METHODS

This study was approved by the institutional review board at University of Medicine & Dentistry of New Jersey, Robert Wood Johnson Medical School. Data were obtained from the Healthcare Cost and Utilization Project Nationwide Inpatient Sample (NIS) from 1996 to 2003. The NIS is designed to contain a representative 20% sample of US community (nonfederal) hospitals from each year on the basis of 5 hospital characteristics: ownership (public vs private), number of beds, teaching status, location (urban vs rural), and US census region.[20] Because the database contains a sample of discharges in each year, each record has a sampling weight that allows calculation of nationwide estimates. The NIS includes information available in a typical discharge record, including diagnoses and procedures classified by using *International Classification of Diseases, Ninth Revision* codes. Similar data have been used to address factors related to postoperative results in previous studies of adults undergoing bariatric surgery.[16-18,21]

Adolescents were defined as individuals aged 10 to 19 years, consistent with the definition used by the World Health Organization.[22] Adolescents and adults (aged 20-64 years) undergoing bariatric surgery were identified by using *International Classification of Diseases, Ninth Revision* diagnosis and procedure codes and exclusion criteria as previously described.[16] Patients who were included for study had a diagnosis code for obesity (278.0, 278.00, 278.01, 278.1, and 278.8) and a procedure code for gastric bypass (44.31 and 44.39) or gastroplasty (44.69). To exclude patients undergoing gastric bypass for malignancy, we excluded from analysis patients with a diagnosis code for abdominal tumors (150.0-159.9). Patients with procedure codes for both gastric bypass and gastroplasty were assumed to have undergone gastric bypass. No records with procedure codes for placement or revision of an adjustable gastric band (44.95-44.98) were identified in either adolescents or adults in the NIS database because this code has only recently been introduced.

Age, sex, length of hospital stay, hospital mortality, and hospital charges were variables available in the database. Although race is available in the NIS database, this variable was missing in 22% of adolescent patients and, therefore, was not included in the analysis. Major complications were identified by using *International Classification of Diseases, Ninth Revision* codes for respiratory complications (aspiration [507, 507.0, and 997.3], postoperative pulmonary edema [518.4], pulmonary insufficiency after surgery [518.5], acute respiratory failure [518.81, 518.82, and 518.84], pneumonia [480-487], prolonged ventilation [96.72], or tracheostomy [519.0, 519.00, 519.01, 519.02, 519.09, 31.1, 31.2, 31.21, 31.29, 96.55, and 97.23]), pulmonary embolism (415.1), cardiac complications (myocardial infarction [410], cardiac arrest [427.5], or other postoperative cardiac complications [997.2]), infectious complications (septicemia [038], postoperative infection [998.5]), acute renal failure (584), and surgical complications (reoperation for hemorrhage, anastomotic leakage, abscess, or dehiscence [54.11, 54.12, 54.19, and 54.61] or other major surgical complications [998.1, 998.2, and 998.3]). The Charlson Comorbidity Index was used to evaluate the severity of comorbid illnesses.[23]

Nationwide procedure counts were estimated by using sample weights available in each record. The US census population estimates in each year were used to calculate population rates of bariatric surgery.[24] Secular trends were evaluated by using logistic regression for dichotomous variables and linear regression for continuous variables modeling time as a continuous variable. Univariate comparisons were performed by using a 2-sided Wald test[25] or a 2-sided Fisher exact test for small group size. Analyses were performed accounting for the variance arising from the hospital sampling method used in the NIS (Stata 8.0; Stata Corp, College Station, Tex).[26] Statistical significance was defined as $P<.05$.

RESULTS

In the NIS from 1996 to 2003, 566 bariatric procedures performed on adolescent patients were recorded. Based on sample weights, these records corresponded to a national estimate of 2744 bariatric procedures performed on adolescents during this period. An overall increase in the population-based rate of procedures was observed between 1996 and 2003 (**Table 1**). Although no significant change in the procedure rate was observed between 1996 and 2000, the procedure rate was more than 3-fold higher in 2003 than in 2000 (rate ratio, 3.3; 95% confidence interval, 1.4-5.2; $P=.001$). This increase in the population rate was associated with a substantial increase in in-hospital charges, with charges for bariatric surgery in adolescents reaching more than $23 million in 2003 ($30 804 per hospitalization). Most adolescents were female (78.6%), had no comorbid conditions (89.4%), and underwent a gastric bypass procedure (90.0%). The youngest patients were aged 12 years, with most 15 to 19 years (96.4%) (**Figure**). Overall, most procedures were performed in teaching (53.5%) and urban (95.9%) hospitals. Major complications, most of which (78.3% [119/152]) were respiratory, occurred in 5.5% of patients. Length of stay significantly decreased during the study period (Table 1).

Adolescents and adults undergoing bariatric surgery were compared by using data from 2003, the most recent year with available data (**Table 2**). Adolescents represented 0.73% (771/105 473) of patients undergoing bariatric surgery. No significant difference was observed in the percentage of adolescent and adults undergoing the gastric bypass procedure. Although 69.9% (539/771) of adolescents were female, adolescent patients had a significantly lower proportion of female patients than the adult surgical group. In addition, significantly fewer comorbid conditions were documented in adolescents than in adults. Differences in payer source and percentage of those treated at teaching and urban hospitals were not statistically significant ($P>.05$). Between 1 and 10 bariatric procedures (mean ± SD of 2.3 ± 1.7 procedures per hospital) were performed in adolescents in the 75 hospitals treating patients in this age group, with 29.3% (22/75) treating only 1 patient and 70.7% (53/75) treating 2 or fewer patients. In contrast, between 1 and 733 bar-

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Table 1. Summary of Bariatric Surgery in Adolescents in the NIS, 1996 to 2003

Characteristic	1996	1997	1998	1999	2000	2001	2002	2003	*P* Value for Trend
No. of NIS entries	32	33	34	49	47	83	118	170	. . .
Procedures' characteristics									
Projected No. of procedures (95% CI)	188 (64-312)	185 (2-369)	161 (77-245)	240 (116-364)	222 (116-328)	408 (238-578)	568 (345-792)	771 (588-954)	. . .
Projected rate per 100 000 population (95% CI)	0.6 (0.2-1.0)	0.6 (0.1-1.2)	0.5 (0.2-0.8)	0.8 (0.4-1.2)	0.7 (0.4-1.0)	1.3 (0.7-1.8)	1.8 (1.0-2.4)	2.3 (1.8-2.9)	.01
Length of stay (days, mean ± SE)	4.1 ± 0.2	4.0 ± 0.3	3.7 ± 0.2	4.8 ± 0.9	3.7 ± 0.6	3.2 ± 0.2	3.3 ± 0.2	3.1 ± 0.2	<.001
Hospital charges, $*	3 717 316	3 511 227	3 435 243	6 691 383	4 945 939	9 667 810	15 440 603	23 607 959	.03

Abbreviations: CI, confidence interval; NIS, Nationwide Inpatient Sample.
*Amounts in 2003 dollars.

iatric procedures (mean ± SD of 96 ± 127 procedures per hospital) were performed in adults in 235 hospitals, with only 12.8% (30/235) treating 2 or fewer patients and 69.8% (164/235) treating 15 or more patients.

Univariate comparison of several in-hospital outcomes also was performed. Respiratory complications were most common among adolescents (84.4% [27/32]) and adults (67.5% [4644/6880]) undergoing bariatric surgery. The percentage of major complications did not significantly differ between age groups, whereas length of hospital stay was significantly shorter in adolescents than adults (Table 2). Total hospital charges in 2003 for adolescents were $23.6 million and for adults, $3.8 billion. The average hospital charges were 15% lower for adolescent than adult hospitalizations in 2003 (Table 2). In-hospital deaths were observed in 0.20% (212/104 702) of adults, but no adolescent deaths before discharge were recorded in 2003 or any other years included in this study. When age 19 years instead of 20 years was used as a cut-point definition for adolescents, the findings in this study were not affected.

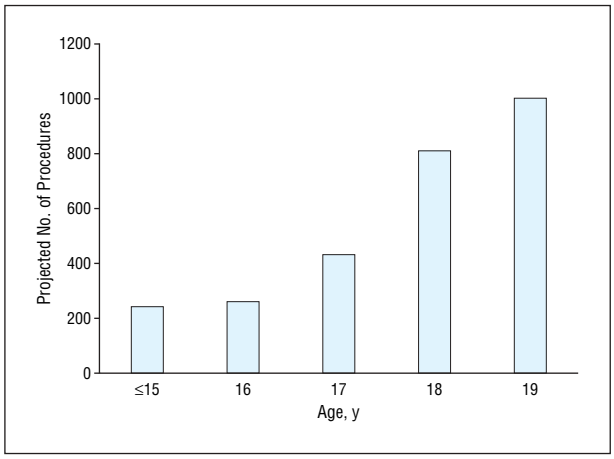

Figure. Distribution of adolescents undergoing bariatric surgery from 1996 through 2003 on the basis of data obtained from the Nationwide Inpatient Sample.

COMMENT

Adults with severe obesity achieve a significant and sustained health benefit from surgical weight reduction. In 1991, this conclusion was expressed by a Consensus Development Conference panel convened by the National Institutes of Health to consider gastrointestinal surgery for severe obesity.[27] At that time, insufficient data existed to draw conclusions about the use of bariatric surgery in adolescents. The Centers for Medicaid and Medicare Services of the US Department of Health and Human Services in 2005 determined that costs for surgical weight-loss procedures should be a covered benefit for Medicare subscribers because of the strong evidence of the benefit attained from these procedures.[28] Because the number of bariatric procedures performed in adolescents remains small, there is little available data that can be used to judge the risks and benefits of surgical weight loss for teenagers. Although health benefits of bariatric surgery in adolescents increasingly are being documented in single-center and multicenter studies,[15,29] accurate information about lower frequency outcomes such as complications and mortality is not yet available.

The NIS data offer a preliminary evaluation of the early outcome after bariatric surgery in adolescents. These data demonstrate a recent dramatic increase in the number of adolescents undergoing bariatric surgery. This finding contrasts with the sustained and dramatic increase in the use of bariatric surgery in adults that has occurred annually since the 1990s.[21] This trend suggests that the health benefits of bariatric surgery increasingly are being recognized by patients and physicians treating adult and pediatric patients. During the study period, there has been a substantial increase in the use of laparoscopic bariatric surgery that may also have had an important effect on the acceptance of bariatric surgery among patients and their families.[21]

Important similarities and differences were observed between the characteristics and outcome of adolescent and adult patients undergoing bariatric procedures. Similar to adults, most adolescents underwent gastric bypass, had private insurance, and underwent surgery at similar hospital types. In contrast to adults, adolescents were less likely to be female and had fewer major comorbid conditions. Using

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Table 2. Univariate Comparison of Adolescent and Adult Patients Undergoing Bariatric Surgery: Data From the Nationwide Inpatient Sample 2003

Variable	Age, y		*P* Value for Comparison
	<20	20-64	
Projected No. of procedures (95% CI)	771 (588-954)	104 702 (88 014-121 390)	
Projected rate per 100 000 population (95% CI)	2.3 (1.8-2.9)	62.9 (52.9-73.0)	<.001
Gastric bypass, %	87.1	92.1	.06
Patient characteristics			
Age range, y	12-19	20-64	
Female sex, %	69.9	82.6	<.001
≥1 Comorbid conditions, %*	11.6	32.0	<.001
Payer source, %			
Private	81.4	83.0	
Medicaid/Medicare	8.9	10.9	.67
Other	9.7	6.1	
Hospital characteristics, %			
Teaching hospital	45.6	52.3	.10
Urban hospital	95.1	93.6	.39
Outcome			
Any complication, %	4.2	6.6	.11
Length of stay, days, mean ± SE	3.2 ± 0.2	3.5 ± 0.1	<.001
Hospital charges per patient, $, mean ± SE†	30 804 ± 2941	36 056 ± 2575	.008

Abbreviation: CI, confidence interval.
*Charlson Comorbidity Index ≥1.
†Amounts in 2003 dollars.

the current data, we could not determine whether the lower frequency of comorbid illnesses in adolescents was due to acquisition of more obesity-related complications in adults because of longer obesity duration, age-related acquisition of comorbidities independent of obesity, or age-related differences in patient selection. Although we observed no difference in overall complications between adolescents and adults, adolescents had a shorter length of stay and lower immediate postoperative mortality.

It is important to recognize the limitations of this study. While the diagnosis and procedure codes that we used are similar to those in other reports of bariatric surgery, our coding strategy has important limitations. Analysis of administrative data depends on identification of relevant records using *International Classification of Diseases, Ninth Revision* codes rather than more accurate clinical data. The codes that we used to identify obesity are not based on objective criteria such as body mass index and, therefore, may be inaccurately reported. While we excluded records with diagnoses of malignant conditions, the procedure codes that we used may also have identified gastrointestinal bypass procedures performed for nonmalignant diseases other than obesity. The most recent version of the *International Classification of Diseases* includes codes for specific body mass indexes (V85.x) and specific codes for more recent bariatric procedures such as gastric banding. These new codes should increase the accuracy of identifying the records of patients undergoing bariatric surgery in future studies.

Because NIS data do not permit the identification of any postdischarge complications, readmissions, or out-of-hospital deaths, a full evaluation of the long-term safety and efficacy of bariatric procedures in adolescents cannot be achieved by using these data. Clinical databases and studies will be required for adequate risk adjustment by using factors such as body mass index and presence and severity of comorbid illnesses. In particular, shorter length of stay among adolescents may decrease the likelihood that mortality following operation is captured by inpatient databases like the NIS (negative ascertainment bias). Complete postoperative data would therefore be needed for estimating true mortality risk.

Another critical factor that could not be studied adequately by using administrative data was the details of the surgical procedure used. The use of laparoscopy, the type of bypass procedure performed, or the performance of revisional procedures may have a critical effect on postoperative outcome. Differences in factors such as patient selection, preoperative body mass index, and procedure type also may have contributed to observed differences between outcomes in adolescents and adults. Although differences in outcomes between adolescents and adults should be viewed with caution, these findings are potentially important and warrant additional study. Because of the small number of adolescent patients, we could not make more detailed comparisons between the youngest and oldest adolescents by using these data. Sufficient data likely will be available in subsequent years of the NIS to evaluate differences in in-hospital outcome among adolescent patients of different ages. Finally, although most bariatric procedures are performed on an inpatient basis and outpatient bariatric surgery has only recently been reported,[30] we could not identify procedures that were performed on an outpatient basis because the NIS is an inpatient database.

The low number of adolescents undergoing bariatric surgery suggests that many adolescents may undergo bariatric surgery at centers with limited experience with this

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age group. Many adolescents already may undergo surgery at centers with active bariatric surgery programs for adults and benefit from institutional experience with older patients. Bariatric surgery programs with a primary focus on adults may be well equipped to provide safe and effective perioperative care for adolescents but may be less equipped to handle these patients' unique metabolic and challenging psychological needs. At a minimum, adult centers with a small volume of adolescent patients should provide nutritional and psychological support services tailored to this younger age group. Efforts to concentrate adolescent cases at centers that have bariatric and pediatric expertise should be evaluated as a way of increasing the experience of individual surgeons and centers with the adolescent population. Although close coordination of centers performing these procedures will be critical initially for the successful study of the adolescent bariatric patient, referral of adolescents who are candidates for bariatric surgery to regional specialty centers may greatly facilitate research that can lead to a better understanding of the optimal treatment approaches.

In conclusion, while relatively few bariatric procedures were performed in adolescents in the last decade, this study suggests that there has been a dramatic increase in the number of bariatric procedures in adolescents nationwide in the current decade. Because the long-term metabolic and psychological consequences of bariatric surgery may differ between adolescents and adults, this trend toward greater use of bariatric surgery in teenagers emphasizes the importance of rigorous outcomes research in this area. Effective surgical intervention earlier in the life of a morbidly obese person may be preferable to delayed intervention after decades of exposure to the health effects of morbid obesity. The relatively small number of adolescent bariatric procedures performed suggests that multicenter research and coordination between adult and adolescent bariatric programs will be necessary for better quantification of benefits and risks of early surgical intervention for adolescent morbid obesity.

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Author Contributions: Dr Burd had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Tsai and Burd. *Acquisition of data:* Burd. *Analysis and interpretation of data:* Tsai, Inge, and Burd. *Drafting of the manuscript:* Tsai and Burd. *Critical revision of the manuscript for important intellectual content*: Inge and Burd. *Statistical analysis:* Burd. *Administrative, technical, and material support:* Inge and Burd. *Study supervision:* Inge and Burd.
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