REVIEW ARTICLE

Adolescent Bariatric Surgery

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Pediatric obesity has increased from a relatively uncommon problem to one of the most important public health problems facing children today. Typical "adult" diseases, such as type 2 diabetes mellitus, hypertension, and dyslipidemia, have become increasingly prevalent in the pediatric population. The earlier presentation of these comorbidities will have a significant impact for the future because this population of children will require more medical resources at an earlier age and will have a significantly decreased life expectancy. The significant morbidity of obesity in the pediatric population has led to consideration of more aggressive treatment protocols for obesity in children, including the introduction of surgical management at an earlier age. Surgery for obesity in adolescents has particular risks and benefits that must be accounted for when considering this approach. The unique psychological and emotional needs of adolescent patients make the patient selection process and perioperative management substantially different from those of adult patients. Initial outcomes of bariatric surgery in adolescents are comparable to those seen in adults in the short term. However, the long-term effects of these procedures on the adolescent population are not known. This review discusses the epidemiology of pediatric obesity, the indications for operative therapy in adolescent patients, the common surgical procedures used for weight loss, the reported outcomes of these procedures, and the importance of multidisciplinary management for this unique patient population.

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The definition of pediatric obesity is not straightforward. Because directly measuring body fat is difficult and time intensive, the surrogate measurement of body mass index (BMI), which takes into account both weight and height (calculated as weight in kilograms divided by height in meters squared), is most commonly used.[1] However, BMI does not always accurately reflect body composition. For example, professional athletes with high muscle mass and an extremely low percentage of body fat may have BMIs in the "obese" range. The use of BMI as a predictor of body fat mass in pediatrics has been found to be variably accurate, with correlation ranging between 0.5 and 0.94, depending on sex and age group.[2,3] Despite these limitations, BMI has been shown to be predictive of the presence of cardiovascular risk factors in pediatric patients and is considered the most relevant clinical measure of obesity in children.[4,5]

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In adults, a BMI of 25 or greater is defined as overweight, and a BMI of 30 or greater is defined as obese.[6] Adults with a BMI of greater than 40 are considered morbidly obese, and those with a BMI of greater than 50 are considered "super" obese. The use of BMI as a marker of obesity in children is more complicated than it is in adults because age, sex, and growth patterns change the proportion of height to weight.[7] The BMI growth curves avail-

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able from the Centers for Disease Control and Prevention take these variables into account and are considered the standard for assessing obesity in children. The BMI growth curves define a child in the 85th to 94th percentile range as overweight, whereas a child in the greater than 95th percentile is defined as obese.[8] More specific guidelines have recently been suggested for adolescents because their BMI measurements may begin to reflect adult physiology, particularly in severely obese patients. An American Academy of Pediatrics expert committee proposed the recognition of a BMI of 30 to 32 for youths 10 to 12 years old and of 34 for youths 14 to 16 years old as the 99th percentile, with any value over the 99th percentile termed "extreme obesity."[1] This correlates with the adult model of reporting a BMI of greater than 40 as "morbidly obese." Most experts feel that adult measurements and categories should be used for adolescents with a BMI of greater than 40 because their physiology and comorbidities often resemble those of morbidly obese adults.

THE EPIDEMIOLOGY OF PEDIATRIC OBESITY

From 1959 to 2002, a slow increase in average BMI was seen in all ages from 12 to 26 years. Since 2002, there has been an even more dramatic increase in average BMI in children.[9] The most recent National Health and Nutrition Examination Survey data from 2009 to 2010 report that 31.8% of children aged 2 to 19 years were overweight or obese (≥85th percentile of BMI for age), 16.9% were obese (≥95th percentile), and 12.3% had a BMI in the 97th percentile or greater.[10]

The implications for future public health are significant because obese children usually become obese adults.[11,12] In the Bogalusa Heart Study,[4] 84% of children with a BMI in the 95th to 98th percentile had a BMI of greater than 30 as adults. Data from the National Longitudinal Study of Adolescent Health[11] showed that 37.1% of obese male adolescents and 51.3% of obese female adolescents became severely obese by their early 30s. This can lead to life-threatening comorbidities in many if not all of these young adults. Current estimates predict a decrease in life expectancy in obese adolescents of 5 to 20 years depending on race and sex.[13] The direct costs of this epidemic are significant; treatment of obesity-related conditions currently accounts for 5% to 10% of health care spending in the United States.[14]

McNiece et al[15] reported the prevalence of prehypertension or hypertension to be 18.9% after screening 6790 adolescents. Population studies of adolescents conducted from 1988 to 2002 found an increase in the prevalence of prehypertension from 7.7% to 10.0% and an increase in the prevalence of hypertension from 2.7% to 3.7% over that time span.[16] Multiple studies[17-19] have found that overweight or obese adolescents predictably become hypertensive adults. As of 1994, the prevalence of metabolic syndrome was 35.5% in overweight and obese adolescents.[20] Between 1982 and 1994, the prevalence of type 2 diabetes mellitus in children quadrupled from 4% to 16%.[21] Studying the National Health and Nutrition Examination Survey data from 1999 to 2002, Duncan[22] found that 29% of children with diabetes had type 2 diabetes, a dramatic increase from previous decades. Nonalcoholic fatty liver disease, which can lead to liver failure, is estimated to affect 2.6% to 9.8% of obese adolescents.[23] The National Health and Nutrition Examination Survey data from 1999 to 2006 showed that 22.3% of overweight adolescents and 42.9% of obese adolescents 12 to 19 years old had at least 1 abnormal lipid level.[24] The increased cost of obesity measured financially or in years is directly related to the increase in comorbid disease seen in obese adolescents.

RATIONALE FOR SURGICAL TREATMENT OF OBESITY IN ADOLESCENTS

It is clear that aggressive treatment of pediatric obesity is necessary, but finding a method for successful, sustained treatment remains problematic. Dietary restriction is considered the cornerstone of any treatment program for obesity but is only rarely successful for morbidly obese patients.[25-32] Although individuals who are on the K diet (ie, a high-protein, low-carbohydrate, low-fat ketogenic diet), a low-fructose diet, or a low-glycemic index diet all show small, transient improvement in weight loss and in BMI, the clinical significance of this weight loss is not clear, and long-term maintenance of the weight loss is rare.[26,28-31,33-35] Some studies[25,32] have demonstrated no effect of change in diet on the treatment of pediatric obesity, suggesting that dietary restriction alone is ineffective. Although adults experience the same difficulty losing weight with modification of diet and exercise, children have the additional factors of reliance on their parents and the psychosocial impact of family dynamics. For example, children whose parents are leaner and married tend to lose more weight than those whose parents are heavier and divorced.[36]

Although some evidence supports the use of pharmacotherapy in the treatment of pediatric obesity, none of the available medications have demonstrated efficacy as independent therapy to reduce both BMI and comorbid disease. A few studies have evaluated metformin's effects on reducing BMI in adolescent patients.[37] Although a small decrease in BMI was noted with the use of metformin compared with placebo, the effect only lasted for 12 to 24 weeks after a year of treatment, and no changes were noted in other important health parameters, including insulin levels and hypertension.[37] Orlistat, an intestinal lipase inhibitor, was approved for the treatment of obesity in adolescents in 2003 for severely obese patients aged 12 to 16 years. Multiple studies have shown a decrease in BMI with minimal adverse effects, especially when prescribed with a lifestyle modification program.[37] However, the use of orlistat alone leads to small changes in BMI (range, −0.5 to −4.2), which limits its use among morbidly obese adolescents.[37] In addition, to our knowledge, no study has shown this weight loss to be sustained after stopping the medication.[38,39] Combined behavior, diet, and pharmacotherapy programs in adolescents have demonstrated minimal longitudinal efficacy as well; in 3 recent trials,[40-42] BMI decreased by an average of 1.82, and only 71% of patients completed therapy after 1 year.

Adult studies have also shown that, compared with medical treatment, surgical treatment is cost-effective when evaluating quality-of-life years gained.[43] However, studies comparing medical and surgical therapies for obesity in the pediatric population are rare. In one of the first studies of its kind, O'Brien et al[44] compared laparoscopic adjustable gastric banding (LAGB) with a combined medical program of lifestyle change, low-calorie diet, and pharmacotherapy in adolescents and showed statistically significant improvement in weight loss, the presence of metabolic syndrome, and quality of life.

Given the dramatic increase in obesity and related diseases in adults, it is not surprising that there has been a dramatic increase in bariatric surgical procedures, paralleling the increase in the prevalence of morbid obesity. In the United States, procedures for adults have increased from 12 775 to 124 838 per year during the 10-year period from 1998 to 2008.[45] Because of the lack of data, procedures for adolescents have been much less commonly performed than procedures for adults. From 1997 to 2003, the number of adolescent bariatric surgical procedures performed in the United States was estimated to have increased 5-fold, from 51 to 282.[46] Because of the paucity of long-term outcome data, the role of bariatric surgery in the pediatric patient remains controversial, which may account for the hesitancy on the part of pediatricians and pediatric specialists to consider surgery, even for adolescents with life-threatening comorbidities. Woolford et al[47] polled more than 500 pediatric doctors; half of the respondents would not refer their patients for bariatric surgery prior to 18 years of age. In another study,[48] only half of the respondents indicated that they would be willing to refer an adolescent patient for bariatric surgery.

PREOPERATIVE CONSIDERATIONS IN ADOLESCENT BARIATRIC SURGERY

The criteria for undergoing bariatric surgery in adults are well established and include a BMI of greater than 40 or a BMI of greater than 35 with comorbid disease or functional limitation, acceptable operative risk, a low probability of success with nonoperative measures, and a motivation to continue medical treatment after surgery.[49] Given the unknown long-term risks of the surgery in the still-developing adolescent, more stringent criteria have been proposed for adolescent patients.[50] In 2009, the International Pediatric Endosurgery Group published updated guidelines that indicated similar BMI cutoffs for surgery in adolescents as in adults but included important stipulations concerning growth, the commitment to lose weight, assent for surgery, and long-term follow-up[51] (**Table 1**). Additional criteria for surgery in adolescents include a Tanner stage of 4 or greater, 95% skeletal maturity, a demonstrated commitment to lifestyle change, and a stable psychosocial environment (**Table 2**).[51] The importance of adhering to these criteria cannot be understated. In adolescents with comorbidities, the unknown long-term risks of surgery are counterbalanced by the potential benefits of improved quality and length of life. Until the long-term outcomes of bariatric surgery in adolescents are known, surgery should ethically be limited to patients with comorbidities.

Contraindications to adolescent bariatric surgery include a medically correctable cause of obesity, a documented substance abuse problem, a disability that would impair adherence to postoperative treatment, current or planned pregnancy or breastfeeding, and an unwillingness to comprehend and acknowledge the consequences of the procedure, particularly the nutritional concerns.[52] Elucidating the presence of these issues prior to offering a patient surgical therapy is a multidisciplinary effort and is often the most important predictor of outcome.

Table 1. Criteria for Adolescent Bariatric Surgery

Criteria
BMI > 35 with severe comorbidities:
Type 2 diabetes mellitus
Moderate to severe sleep apnea
Pseudotumor cerebri
BMI > 40 with mild comorbidities
Hypertension
Dyslipidemia
Mild obstructive sleep apnea
Venous stasis disease
Panniculitis
Urinary incontinence
Impairment in activities of daily living
Steatohepatitis
Gastroesophageal reflux disease
Severe psychosocial distress
Weight-related arthropathies

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

Table 2. Requirements for Adolescent Bariatric Surgery

Requirements
Have attained 95% of adult stature
Have failed to attain a healthy weight with prior organized attempts at weight loss
Demonstrate commitment to psychologic evaluation in the perioperative period
Avoid pregnancy for 1 y after surgery
Will adhere to postoperative nutritional guidelines
Have decisional capacity and will provide informed assent

BARIATRIC PROCEDURES

Bariatric procedures work by either restricting the amount of oral intake and/or creating a malabsorptive environment. Currently, there are 4 procedures that are used, the majority of which are performed laparoscopically. Laparoscopic adjustable gastric banding and laparoscopic sleeve gastrectomy (LSG) are purely restrictive procedures, the biliopancreatic diversion is a mostly malabsorptive procedure, and the Roux-en-Y gastric bypass (RYGB) is a combination restrictive and malabsorptive surgical procedure (**Figure**). The selection of the correct procedure is based on an evaluation of the patient's medical, psychological, and social issues, as well as a thorough discussion of the risks and benefits of surgery with the patient and his or her family.

Preoperative evaluation for all patients involves understanding the burden of comorbid disease by the use

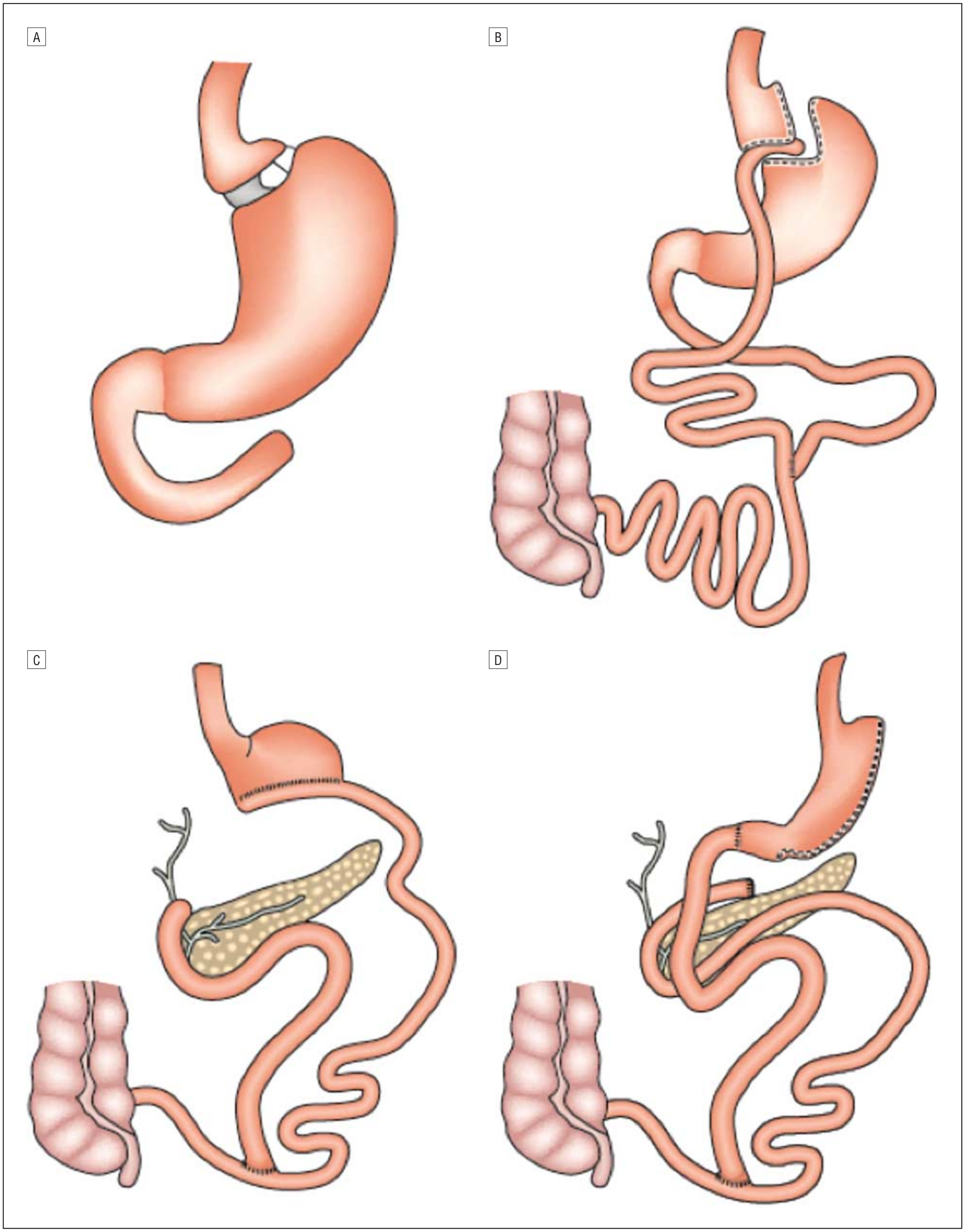

Figure. Bariatric surgical procedures: laparoscopic adjustable gastric banding (A); Roux-en-Y gastric bypass (B); and horizontal (C) or vertical (D) resection of the stomach (sleeve gastrectomy) as part of a biliopancreatic diversion. Reprinted with permission from Nature Publishing Group.[53]

of appropriate screening tests, including a complete blood count, liver function tests, a lipid profile, thyroid function tests, fasting glucose and insulin measurements, hemoglobin A_{1c} level, urinalysis, vitamin D level, parathyroid hormone level, and *Helicobacter pylori* testing. Polysomnography is indicated if there is any symptom suggestive of sleep apnea. Abdominal ultrasonography is required if biliary colic symptoms are present and may be helpful to screen for asymptomatic gallstones in all patients. A dual-energy x-ray absorptiometric scan for bone mineral density may be necessary for the appropriate patients.[54] Deep venous thrombosis and pulmonary embolism are known complications of bariatric surgery. The incidence of deep venous thrombosis and/or pulmonary embolism after bariatric surgery is 2% in adults, and cases of both deep venous thrombosis and pulmonary embolism have been documented in adolescents.[55-57] All patients undergoing bariatric procedures, including adolescents, should receive prophylaxis for deep venous thrombosis with both pharmacologic therapy and mechanical compression stockings.[56-58] A coagulation profile such as a thromboelastogram may help in more accurately guiding prophylaxis.[59]

COMMON OPERATIONS

Laparoscopic Adjustable Gastric Banding

Laparoscopic adjustable gastric banding is a purely restrictive procedure in which a synthetic band with an adjustable diameter is placed laparoscopically around the proximal stomach, usually 1 to 2 cm below the gastroesophageal junction. The band is positioned diagonally across the stomach and is then secured in place with 2 sutures to prevent migration. Tubing connecting the band to a subcutaneous injection port is brought through one of the trocar sites above the fascia.[58] Saline is injected or removed from the port to adjust the diameter of the band as needed; this usually requires multiple postoperative visits in the first year after surgery to find the optimal diameter for the band. Benefits of this procedure include a lack of staple lines, potential reversibility, and fewer nutritional deficits than the malabsorptive procedures. However, patients are required to follow up at regular intervals for band adjustment. In addition, the device has not been approved for therapy for adolescents in the United States, raising both ethical and financial issues.[60] In theory, the synthetic device will have to be replaced after a certain period of time, which would require another operation.[61]

Laparoscopic adjustable gastric banding does result in significant benefits for adolescent patients. In a recent meta-analysis of adolescent bariatric surgery outcomes, Treadwell et al[62] found an aggregate decrease in BMI that ranged from 10.6 to 13.7. They[62] also found reports of significant resolution of hypertension and type 2 diabetes in multiple series; data concerning other comorbidities are equivocal. A more recent prospective trial[63] examining outcomes in LAGB found a mean decrease in BMI of 9.4, sustained resolution of hypertension, 82% resolution of dyslipidemia and metabolic syndrome, and statistically improved quality-of-life scores. Nadler et al[64] reported a 70% total reduction in comorbid conditions after LAGB, and the mean compliance rate with treatment was listed at 89.5%.

Complications of LAGB include tube leaks, band migration, and erosion of the band into the stomach. Treadwell et al[62] found an aggregate reoperation rate of 8% for any reason in adolescents, with the most common complication being band migration (3%). In a recent trial,[63] 5 of 26 patients (19.2%) had complications relating to either the tubing/port system or an actual band malfunction, which is a higher reported complication rate than the recent Treadwell et al meta-analysis.[62] Another study[64] reported an operative complication rate of 15% and found 35 nonoperative complications in 27 patients, including iron and vitamin D deficiency. To date, no studies have indicated long-term data on whether or not these nutritional deficiencies impact growth or development. One small study by Widhalm et al[65] of pediatric patients found a 50% reoperation rate (4 of 8 patients) after LAGB due to failure to lose weight.

Despite the success of the LAGB for weight loss, recent adult studies raise serious concerns about the long-term safety and efficacy of the LAGB. A study of adults by Campos et al[66] found that RYGB had a higher rate of early complications (11% vs 2%) but that LAGB had a significantly increased rate of late complications with reoperation occurring much more frequently (13% vs 2%). More concerning are 2 prospective studies[67,68] from Europe of long-term outcomes after placement of the LAGB. The study by Naef et al[67] followed up with 167 adults for a median time of 79 months. They reported a 40% total complication rate, a 20% reoperation rate, and a failure rate (defined as a percentage of excess weight loss of <30% or removal of band due to complication) between 25% and 30%.[67] The study by Boza et al[68] followed up with 62 adult patients for 5 years and reported that 45% of patients underwent a failed surgical procedure (<50% excess weight loss) and that 20% of patients required a reoperation.

Laparoscopic Sleeve Gastrectomy

Laparoscopic sleeve gastrectomy is primarily a restrictive procedure, but it is also thought to work by decreasing appetite by removing the portion of the stomach that produces ghrelin.[69] This surgical procedure was originally performed as the first step in a staged weight loss procedure for severely obese adults.[70] Many of these patients lost enough weight that the second stage of the procedure was not necessary, which led to the adoption of the sleeve gastrectomy as an accepted bariatric procedure. The procedure entails dividing the short gastric vessels and then removing the greater curvature of the stomach from approximately 6 cm proximal to the pylorus to the angle of His.[58] The benefits of this procedure include the lack of a foreign body, no need for the frequent adjustments necessary with the LAGB, fewer nutritional deficiencies than seen in malabsorptive procedures, and a decreased risk of dumping syndrome because the vagus nerve is preserved. Drawbacks to the procedure include irreversibility and the current lack of longitudinal data on outcomes.[71]

The majority of studies on outcomes after the sleeve gastrectomy involve adult patients. A small study[72] (n = 7) of pediatric patients (mean age, 16.2 years) demonstrated weight loss in 85.7% of patients, improvement in comorbid conditions, and no operative complications. Another small study[73] (n = 4) demonstrated similar findings with all patients achieving weight loss, no patients having operative complications, and no patients having postoperative malnutrition or vitamin deficiency. Adult data from a recent large, multicenter trial by Hutter et al[74] comparing LSG with LAGB and RYGB showed a decrease in BMI of 11.87 with LSG that was sustained over 12 months compared with a decrease in BMI of 7.05 with LAGB and 15.34 with RYGB. Hutter et al[74] also noted that LSG had higher morbidity and reoperation rates than LAGB but better rates than RYGB. Complications occur in 5% to 14% of patients undergoing an LSG. One study[75] found a 5% complication rate in 121 adult patients, including wound infection, stricture, and intraoperative leak. Bobowicz et al[76] reported a major complication rate of 7.1% (spleen infarction, incisional hernia, or depression) and a minor complication rate of 8.3% (wound infection, anemia, or hair loss) in 84 adult patients. The study by Stroh et al[77] of 3122 patients undergoing LSG reported an overall complication rate of 14.1% and a surgical complication rate of 9.4%; the most common single postoperative complication was a leak from the suture line (7%), followed by stenosis. Long-term complications of the LSG, including nutritional deficiencies and failure to sustain weight loss, are not well described because this is a relatively new procedure.

Laparoscopic RYGB

An RYGB is a combination restrictive and malabsorptive procedure. Although LSG and LAGB are gaining in the numbers of procedures performed, RYGB is still one of the most commonly used bariatric procedures for adolescents.[54] For the restrictive portion of the procedure, the proximal stomach is divided, creating a small 15 to 20 cm^3 gastric pouch. The mid-jejunum is transected approximately 40 cm from the ligament of Treitz, and a Roux limb is brought up to the new gastric pouch. The biliopancreatic limb is attached to the distal jejunum 100 to 125 cm from the gastric pouch.[58] Xanthankos[78] has hypothesized that superior outcomes from an RYGB are due to an alteration of the gut-brain axis induced by bypassing the duodenum, which induces an anorexigenic state. The benefits of an RYGB include a proven ability to induce long-term weight loss and to decrease comorbid disease.[50] However, the procedure is irreversible, causes significant change to the normal gut orientation, and carries a risk of malnutrition if proper attention is not paid to diet and supplementation of essential nutrients.

The efficacy of an RYGB for weight loss is well documented in both adults and adolescents. In the meta-analysis of RYGB procedures among adolescents by Treadwell et al,[62] BMI decreased anywhere from 17.8 to 22.3. Resolution of hypertension occurred in more than half of patients, and sleep apnea resolved in all patients.[62] Lawson et al[56] reported a statistically significant decrease in triglycerides and total cholesterol with an RYGB.

Perioperative complications from an RYGB include pneumonia, deep venous thrombosis, pulmonary embolus, gastrointestinal hemorrhage, anastomotic obstruction leading to rupture of the gastric pouch, obstruction of the jejunojejunal anastomosis, leakage from staple lines or anastomoses, incisional hernias, and wound infections. Long-term complications include stomal stenosis, gastric staple line breakdown with gastrogastric fistula formation, symptomatic cholelithiasis, and internal herniation.[54] In a meta-analysis[62] of 131 adolescents who underwent an RYGB, there were 4 reported postoperative deaths, with only 1 of the deaths potentially related to the procedure (*Clostridium difficile* colitis 9 months after surgery). The most commonly encountered complication was protein malnutrition. In 6 studies of adolescents undergoing RYGB, complication rates ranged from 0% (n = 34) to 39% (n = 36).[56,62,79] Despite the potential for significant complications from an RYGB, data so far have indicated that this procedure is effective and has a good risk-benefit ratio in the adolescent population, making it the current preferred surgical therapy for adolescents.

LAPAROSCOPIE DUODENAL SWITCH WITH BILIOPANCREATIC DIVERSION

The duodenal switch with biliopancreatic diversion is a primarily malabsorptive operation that involves a subtotal gastrectomy (sleeve gastrectomy) with preservation of the pylorus and transection of the duodenum 3 to 4 cm from the pylorus with anastomosis to a Roux limb. This leads to a bypass of the distal 250 cm of ileum. Malabsorption is achieved by this bypass, which results in only approximately 100 cm of bowel exposed to both digestive enzymes and food.[58] Although the procedure has been determined to be highly effective for weight loss, this procedure is the least common (5% of bariatric procedures) and has fallen out of favor owing to increased nutritional deficiencies and greater operative complexity.[80,81]

In one series of 10 adolescent patients undergoing biliopancreatic diversion,[82] all patients lost a significant amount of weight, and all patients had resolution of their comorbidities. Two patients had operative complications, including obstruction and gastric ulcer, and the reported nutritional deficiencies were mild. In another series of adolescents,[83] 68 patients were studied retrospectively for long-term outcomes (mean of 11 years). Although immediate postoperative complications were rare, this series[83] of patients had 19 reoperations in 14 patients (including 4 obstructions and 5 incisional hernias), 3 deaths (protein malnutrition, pulmonary edema, and pancreatitis), and 9 patients with documented protein malnutrition.

OUTCOME AFTER ADOLESCENT BARIATRIC SURGERY

The lack of effective medical therapy for morbid obesity has led to increased research in the outcomes of surgical therapy for weight loss. Numerous studies[43,44,84] in adults have shown that bariatric surgery is the only intervention to reliably decrease weight in a sustainable fashion and reverse many of the comorbidities associated with obesity. In adults, gastric bypass results in an estimated 40% decrease in adjusted long-term mortality from any cause.[85,86] Weight loss in adolescents after bariatric surgery is similar to weight loss in adults after bariatric surgery, with an average of 50% to 60% of excess weight lost in the first

Table 3. Data From Adolescent Bariatric Surgery Studies[a]

Measure	LAGB				RYGB			
	Nadler et al[90] (n=45)	*P* Value	Holterman et al[63] (n=20)	*P* Value	Inge et al[91] (n=11)	*P* Value	Teeple et al[92] (n=15)	*P* Value
% EWL, mean (SD)	46.0 (21.1)		34 (22)		60 (17)		59.7 (13.6)	
Mean SBP, mm Hg								
Before surgery	Unknown		143	.005	129.6	.20	130	.16
After surgery	Unknown		119		120.1		124	
Mean DBP, mm Hg								
Before surgery	Unknown		Unknown		77.0	.001	73	.93
After surgery	Unknown		Unknown		62.0		72	
Mean HbA_{1c}, %								
Before surgery	5.6	≤.001	Unknown		7.33	.04	5.9	.03
After surgery	5.3		Unknown		5.58		5.5	
Mean HOMA-IR value								
Before surgery	Unknown		9.4	.02	5.20	.002	4.4	≤.001
After surgery	Unknown		4.2		0.96		1.4	
Mean total cholesterol, mg/dL								
Before surgery	Unknown		Unknown		202	.02	181.4	≤.001
After surgery	Unknown		Unknown		143		146.4	
Mean triglycerides, mg/dL								
Before surgery	117	≤.001	184	.06	213	.004	141.5	≤.023
After surgery	89		120		83		84.9	

Abbreviations: DBP, diastolic blood pressure; HbA_{1c}, hemoglobin A_{1c}; HOMA-IR, homeostatic model assessment of insulin resistance; LAGB, laparoscopic adjustable gastric banding; RYGB, Roux-en-Y gastric bypass; SBP, systolic blood pressure; EWL, excess weight loss.

SI conversion factors: To convert HbA_{1c} to proportion of total hemoglobin, multiply by 0.01; to convert total cholesterol to millimoles per liter, multiply by 0.0259; and to convert triglycerides to millimoles per liter, multiply by 0.0113.

[a]The mean postoperative follow-up time was 12 months for all studies, and $P < .05$ is considered statistically significant.

year and up to 75% of excess weight lost by the end of the second year.[87] Weight loss is typically slower after LAGB. The absolute BMI reduction in adolescents after surgery is approximately 35%, regardless of the BMI before surgery. Thus, adolescents with the highest baseline BMI (≥65) remain extremely obese with BMIs of 40 or greater 1 year after an RYGB.[88] In a cohort of 61 adolescents with a mean BMI of 60.2, Inge et al[88] reported that only 17% of patients reached a normal BMI after 1 year. In another series[89] examining 73 patients who underwent LAGB, the initial mean BMI was 47, and mean weight loss at 1 and 2 years was 56.7% and 60.9%, respectively.

Adults undergoing bariatric surgery have shown a decrease in mortality of 56% for coronary artery disease, 92% for diabetes, and 60% for cancer when compared with a control group.[85] These results are due to the resolution of the life-limiting comorbidities of hypertension, diabetes, and dyslipidemia. Similar results have been noted in adolescents undergoing bariatric surgery (**Table 3**). Hypertension in teenagers resolves in 50% to 100% of patients after surgery.[62] A prospective trial[63] demonstrated a 33% decrease in hypertension at 6 months and a 100% decrease in hypertension at 12 and 18 months after LAGB. Earlier intervention may result in a higher rate of resolution of hypertension because 19% of adolescents had persistent hypertension after bariatric surgery compared with 41.3% of adults.[93] Inge et al[91] demonstrated resolution of type 2 diabetes in 91% of patients who underwent an RYGB. One study[63] found an improvement in insulin resistance with 39% resolution at 6 months and 72% resolution at 18 months after LAGB. The mechanism involved in the resolution of type 2 diabetes after bariatric surgery is still unclear. There are significant decreases in levels of fasting blood glucose and fasting insulin in patients who underwent an RYGB.[56] Lawson et al[56] reported significant reductions in triglycerides and total cholesterol, as well as a trend toward reduction in high-density lipoprotein and low-density lipoprotein in adolescents who underwent an RYGB. One study[63] reported resolution of dyslipidemia in 27% of patients at 6 months and 67% of patients at 18 months after LAGB. In a comparative study,[93] adolescents had an 87.5% improvement rate in dyslipidemia compared with an adult improvement rate of 18.4%, which again illustrates that earlier intervention could improve the rate of postoperative resolution of comorbidities. Other direct gains of weight loss include improvement in arthropathies, sleep apnea, and urinary continence.[87]

There may also be important psychological benefits from bariatric surgery. Multiple studies have examined the relationship between obesity and psychological illness. Adolescent patients with obesity experience depression, low self-esteem, and social marginalization and have decreased physical activity and lower academic scores.[94] Adolescent patients undergoing bariatric surgery are in a vulnerable psychological state and are at high risk of having mental health complications postoperatively. However, studies have found that adolescents undergoing bariatric surgery have improved mental health postoperatively.[95] Four months after undergoing an RYGB, most patients had a significantly improved image of themselves and fewer symptoms of depression and anxiety.[95] Zeller et al[96] reported an improvement in health-related quality of life and in self-image, as well as a decrease in depressive symptoms 24 months after undergoing an RYGB; however, these results were not necessarily maintained after 24 months, especially when weight regain occurred. Persistent attention to the psychological state of the adolescent patient after bariatric surgery is necessary for optimal outcomes.

NUTRITIONAL CONCERNS AFTER BARIATRIC SURGERY

Close attention to nutritional parameters are necessary after bariatric surgery in adolescents due to the potential for significant metabolic and growth derangements. Both macronutrient intake and micronutrient intake are affected by a decreased total volume intake and in malabsorptive procedures, a decrease in small intestine absorption.[97] In the immediate postoperative period, diet advancement protocols are used both to address the smaller stomach volume and to ensure adequate micronutrient intake and macronutrient intake.[98]

The most common macronutrient concerns for the adolescent bariatric patient are dehydration and protein deficiency.[98] Although clinically significant dehydration resulting in end-organ damage, such as renal failure, is rare, dehydration from inadequate intake, vomiting, and dumping syndrome is common.[98] Protein malnutrition is usually seen after malabsorptive procedures, particularly the biliopancreatic diversion, and occurs more often in patients who do not follow dietary recommendations.

Water-soluble vitamin deficiencies are usually seen after restrictive procedures owing to decreased liquid intake.[52] Vitamin B_{12} deficiency results from a decrease in intrinsic factor, decreased protein intake, and decreased uptake in an often defunctionalized ileum and can lead to anemia, glossitis, and peripheral neuropathy if unrecognized.[99] Folate deficiency, which has been reported in up to 38% of adult patients, is of particular importance in women of child-bearing age owing to the risk of neural tube defects.[52] Thiamine deficiency, a precursor to Wernicke encephalopathy, has been seen in up to 49% of patients who underwent an RYGB and has been reported in pediatric patients.[52,100] Fat-soluble vitamin deficiencies are more commonly seen in malabsorptive procedures, with up to 60% prevalence.[97] Calcium deficiency is of particular concern in adolescent patients given the potential for additional bone mineralization. Kaulfers et al[101] found significant bone density loss in patients after bariatric surgery. The multitude and complexity of nutritional deficiencies after these procedures underscore the need for consultation with an experienced dietician both before and after surgery.

THE ADOLESCENT BARIATRIC SURGERY TEAM

Morbidly obese adolescents have unique physiologic and psychological issues that mandate special care. The evaluation process for bariatric surgery is more complicated for adolescents than for adults. Adolescents often have trouble accurately reporting dietary attempts at weight loss and food habits. Adolescents are still actively growing, with additional risk for potential nutritional deficiencies postoperatively. In addition, because of the unique psychology of adolescence, many adolescents who meet physical criteria for bariatric surgery do not meet psychological criteria. Owing to these additional challenges, a multidisciplinary team is essential to adequately care for the adolescent bariatric patient. The team should include a surgical director with adequate experience and expertise, a medical director or expert consultant, a psychologist/psychiatrist, a social worker, a dietician, an exercise physiologist or physical therapist with expertise in exercise, and an array of available of consulting services.[102] Several models have been proposed and are effective in caring for adolescent bariatric patients. These models include a pediatric surgeon or pediatrician with expertise in obesity, working with an adult bariatric team, or an adult bariatric surgeon, working with a pediatric team. Given the unique social structure and needs of adolescence, support groups that meet on a regular basis provide additional peer interaction and are an important part of the care of these patients.

Pediatric obesity is an important public health problem. There are currently no medical treatments that provide durable and sustainable weight loss for adolescent patients with morbid obesity or that improve the life-threatening comorbidities associated with morbid obesity. Bariatric surgery in adults has been shown to improve or, in many cases, eliminate obesity-related comorbidities. Initial data are supportive that these beneficial effects are also seen in adolescent patients, leading to the consideration of bariatric surgery as an accepted treatment option for morbidly obese adolescents. Adolescents with morbid obesity are a unique and relatively high-risk patient population that requires care by a multidisciplinary team. There are currently no clear guidelines to choose a specific bariatric procedure for a specific adolescent patient. Although the RYGB remains the gold standard bariatric procedure for both adolescents and adults, LAGB and LSG deserve further study, primarily to document the long-term efficacy and risk-benefit ratio. Strict criteria for surgery and the adolescent's understanding of the process are critical for the short-term surgical success and the long-term improvement in comorbidities. Performing bariatric surgery in centers prepared to meet all the special needs of adolescents is essential to minimizing risk and maximizing successful outcomes. Research examining the long-term effects of bariatric surgery in adolescents is ethically essential to help in future patient selection and to determine late clinical outcomes.

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