

Bariatric Surgery in Adolescents: An Update

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The prevalence and severity of obesity have increased rapidly and dramatically in the last 3 decades in the United States in adults and children. Not only has the prevalence of obesity among American adults (defined as a body mass index [BMI] ≥ 30 kg/m²) doubled from 14.5% to 30.9%, but also the prevalence of extreme obesity (defined as BMI ≥ 40 kg/m²) has quadrupled to affect 6.4% of women and 3.3% of men [1,1a]. Children and adolescents have not been immune from this obesity epidemic. During the same time period, the prevalence of overweight (defined as BMI $> 95\%$ for age and gender) doubled for children age 6–11 years and tripled for adolescents age 12–19 [2,3]. It has been estimated that more than 1 million adolescents between the ages of 13 and 21 years have a BMI greater than 35 kg/m² [4].

The dramatic increase in obesity in children and adolescents portends a further increase in the prevalence and severity of the obesity epidemic in the next generation of adults because obese teenagers are far more likely to carry obesity into adulthood than to outgrow obesity [5]. Obesity is a risk factor for numerous diseases, in particular for type 2 diabetes mellitus, the prevalence of which has risen in parallel with obesity [6]. Obese

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adolescents increasingly are being diagnosed with medical complications formerly associated with obese adults, including obstructive sleep apnea, type 2 diabetes, metabolic syndrome, hypertension, dyslipidemia, insulin resistance, polycystic ovary syndrome, and degenerative joint disease (Fig. 1) [7–11]. Severe obesity is associated with a reduced quality of life in adolescents [12].

The pathogenesis of obesity is multifactorial and involves a complex interplay of genetic (metabolic and hormonal) and environmental (lifestyle, behavior, and socioeconomic) factors. Perhaps because of this multiplicity of potential causes, successful treatment and prevention of obesity are equally complex, and no single method, whether medical or surgical, is likely to prove equally efficacious for all cases. The first line of treatment is typically behavioral modification aimed at decreasing caloric intake and increasing physical activity to promote negative energy balance and gradual weight loss. In some adolescents and adults, pharmacotherapy also is used to decrease appetite or promote malabsorption of fat. Long-term studies have failed to show significant sustained weight loss using these noninvasive interventions for most obese adults [13–16]. Weight regain after discontinuing therapy is often significant [16,17].

As a consequence, an increasing array of surgical treatments for obesity has been developed over the last 4 decades, primarily intended for adult patients with extreme obesity. At present, bariatric surgery is the most effective long-term treatment for morbid obesity, yielding significant sustained weight loss (loss of 20–30 kg maintained 10 years) and significant resolution of obesity-related comorbidities, such as type 2 diabetes mellitus, hypertension, hyperlipidemia, and obstructive sleep apnea [13,18,19]. With the

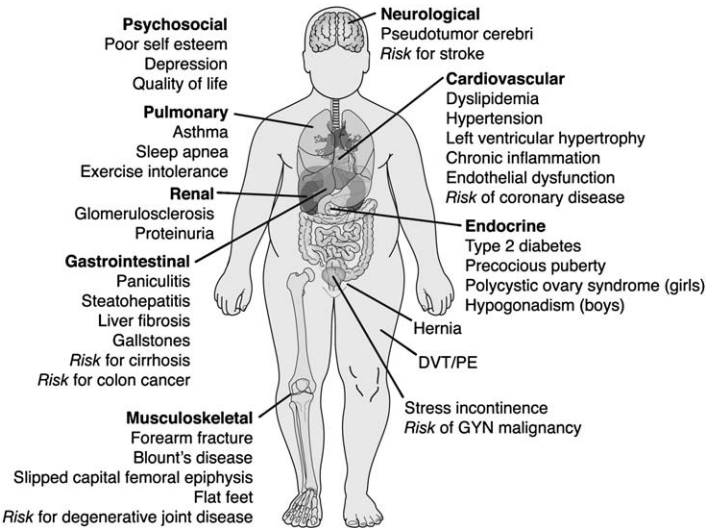


Fig. 1. Associated complications of obesity in childhood and adolescence.

epidemic of obesity, these surgeries have become increasingly prevalent in the United States, increasing from less than 20,000 procedures in 1992 to an estimated 140,000 procedures in 2004 [18]. The introduction of minimal access laparoscopic techniques contributed to this dramatic increase and may have led to improved perioperative outcomes [20,21].

In contrast to numerous published reports investigating the outcome of bariatric surgery in adults, there is a relative paucity of published data on the application of bariatric surgery in adolescents. Bariatric surgery increasingly is being considered as an adjunct treatment tool for selected extremely obese adolescents with severe comorbidities, such as diabetes mellitus, obstructive sleep apnea, and bone disease [22–24]. It has been estimated from nationally representative data that more than 1000 adolescent bariatric procedures were performed in the United States in 2003, almost doubling the number in 2002 (R. Burd, MD, PhD, personal communication, 2006). Although this represents a small proportion of bariatric procedures performed annually, the frequency of adolescent bariatric surgery is likely to increase, as the number of adolescent bariatric surgical treatment programs increases [25]. It is important for all clinicians who care for obese adolescents, in particular adolescents with extreme obesity ($\text{BMI} \geq 40$), to be aware of the current status of bariatric surgery in this age group. This article summarizes the current guidelines for selection of adolescent candidates for bariatric surgery, the types of surgeries available, potential complications, and long-term outcomes of bariatric surgery in this special population. Bariatric surgery, although not a cure for obesity, can be a helpful tool for selected extremely obese adolescents, to achieve significant weight loss and improvement of comorbidities, in conjunction with preoperative and postoperative behavioral and dietary intervention.

Guidelines for bariatric surgery in adolescence

According to the 1991 National Institutes of Health Consensus Panel guidelines for adults, bariatric surgery is an appropriate treatment modality for adults who have failed conventional weight management efforts when the BMI reaches 40 kg/m^2 or if BMI is 35 kg/m^2 or greater in the presence of significant associated comorbidities [26]. These guidelines intentionally did not include recommendations for obese adolescents, however, owing to the relative lack of data on outcomes in this age group. Because of the unique physical, behavioral, psychosocial, and emotional needs of adolescents and their families, it is appropriate to consider more conservative patient selection criteria in adolescents. Other specific reasons to view this population differently include the following: (1) Associated comorbidities in extremely obese adolescents are typically less advanced than in adults; (2) the long-term impact of significant weight loss and ongoing malabsorption on final physical maturation are not yet fully understood; (3) surgical techniques for obesity treatment are rapidly evolving, with less risky and less invasive surgical

interventions expected in the near future; (4) adolescents may have different susceptibility to nutritional effects of gastric bypass surgery [27] and may be less apt to comply with important lifelong postoperative nutritional guidelines and medical visits after surgery [28] and (5) there are few data in adults and no data in adolescents suggesting that surgical weight loss improves the early mortality experienced by individuals with severe obesity. As better outcomes data become available for adolescent bariatric surgery, the utility and safety of applying bariatric surgery more liberally (eg, to prevent development of comorbidities) are likely to become clearer.

In 2004, pediatric surgeons and pediatricians specializing in the treatment of obese children created specific recommendations for contemplation of bariatric surgery in adolescents—distinct from the adult criteria [29]. These guidelines, intended to provide a safe and more standard approach for the evaluation and management of adolescent bariatric patients, were endorsed by the American Pediatric Surgical Association [30] and, with some amendments, by the American Society for Bariatric Surgery [31]. In particular, although there was controversy regarding a more conservative threshold for operation in teenagers, there was strong consensus that ongoing clinical data collection and long-term follow-up were essential to address the long-term efficacy and safety of bariatric surgery in adolescents.

When contemplating bariatric surgery in adolescents, it is important to consider unique aspects of patient evaluation, choice of surgical procedure, and postoperative management strategies including long-term follow-up and monitoring [29]. The accepted consensus is that the adolescent candidate should be evaluated in the context of a multidisciplinary program, including a pediatric obesity specialist, bariatric surgeon, psychiatrist, psychologist, bariatric nurse, dietitian, and exercise therapist. In addition to these core members of the team, experts in adolescent medicine, endocrinology, pulmonology, gastroenterology, cardiology, orthopedics, ethics, and radiology should be available at the center. Because of the extreme weight of these adolescents, specific awareness of the radiologic limitations and alternatives available for imaging these patients is necessary [32].

Recommended criteria for bariatric surgery in adolescents

Specific criteria for bariatric surgery as recommended by the published guidelines [29] are summarized in **Box 1**. The classification of severe and less severe obesity-related comorbidities is not uniformly accepted among all experts [30]. The initial guidelines for adolescent bariatric surgery define severe comorbidities as type 2 diabetes, obstructive sleep apnea, and pseudotumor cerebri [29]. Less severe associated sequelae were considered to include hypertension, dyslipidemia, hyperinsulinemia, gastroesophageal reflux disease, nonalcoholic fatty liver disease, venous stasis disease, panniculitis, stress urinary incontinence, arthropathies in weight-bearing joints, impairment in activities of daily living, and significant psychosocial distress secondary to obesity.

Box 1. Recommended criteria for bariatric surgery

Surgery should be considered appropriate if the following conditions are met:

- Failure of at least 6 months of organized attempts at weight management, as determined by the primary care physician or multidisciplinary team
- Attainment or near-attainment of physiologic maturity (Tanner stage IV)—in some cases, a bone age is required to determine skeletal maturity
- Severe obesity: defined as BMI ≥ 40 kg/m² with serious obesity-related comorbidity or BMI ≥ 50 kg/m² with less severe comorbidities
- Commitment to comprehensive medical and surgical evaluations before and after surgery
- Avoidance of pregnancy for at least 1 year postoperatively
- Capable and willing to adhere to nutritional guidelines postoperatively
- Must be able to show decisional capacity and maturity in psychological evaluation and provide informed assent
- Supportive and committed family environment

Surgery should *not* be considered appropriate if there is:

- A medically correctable cause of obesity
- A substance abuse problem within previous year
- A medical, psychiatric, or cognitive disability that impairs ability for adherence
- Current pregnancy or breastfeeding, including planned pregnancy within the first year after surgery
- Inability or unwillingness of the patient or parents to understand the procedure or its medical consequences, including the need to maintain lifelong dietary guidelines and supplementation

(Modified from Inge TH, Krebs NF, Garcia VF, et al. Bariatric surgery for severely overweight adolescents: concerns and recommendations. *Pediatrics* 2004;114:217–23; with permission.)

Screening and selection of candidates

Despite the existence of published guidelines for adolescent bariatric surgery, the decision to proceed with bariatric surgery can be complicated and fraught with uncertainty for the multidisciplinary team, the candidate, and family. Defining a reasonable attempt to lose weight by nonsurgical

means can be challenging. Although it has been shown that 30% of pediatric participants in a 6- to 8-month family-centered, multidisciplinary, behavior-based weight management program can achieve normal weight at 10-year follow-up [14], such organized weight management programs for children are not widely available. When they are, they are not always covered by insurance, making it impossible for some bariatric candidates to participate because of socioeconomic limitations [33]. Similar family-based interventions for more extremely obese adolescents may be less effective [34].

In addition, numerous less tangible and readily measurable psychosocial concepts and capabilities must be evaluated, such as the candidate's motivation, his or her understanding of the risks and limitations of the surgery and the physiologic and lifestyle changes that follow, and the extent of family support and stressors, all of which can have an impact on success after surgery. In particular, the family environment has been shown to be an extremely influential factor in childhood obesity [35]. Childhood obesity is affected by parental obesity [5,36], lower family socioeconomic status [37], parental neglect, and poor living conditions [38,39]. In contrast to most obese adults considering surgery, an adolescent is still a relatively subordinate member of a family and has less control over the food bought and prepared at home and, to some extent, the activities in which he or she can participate. It is crucial to conduct a careful psychosocial assessment not only of the adolescent, but also of the family. In extremely obese adults, 20% to 60% may have a form of psychopathology, most commonly major depression disorder, dysthymia, and anxiety disorder [17]. In obese children, a high prevalence of maternal distress has been found in participants in a weight management program [40]. The impact of the preoperative mental health of the patient and the family on postoperative outcome is not fully known and is under further investigation [17].

To assess nutritional status and evaluate the extent of associated comorbidities before surgery, a panel of preoperative diagnostic testing is recommended. Because micronutrient deficiencies are common in morbidly obese patients preoperatively [41], nutritional screening should be obtained before surgery, and deficiencies should be corrected before surgery with preoperative multivitamin and mineral supplementation as needed. **Box 2** summarizes recommended preoperative screening tests.

Before making specific recommendations about bariatric surgery to an adolescent candidate, the core members of the multidisciplinary team review and discuss each case, a process similar to that used in pediatric oncology and transplantation programs [29]. Based on the medical, behavioral, and psychosocial assessments, a decision can be made regarding appropriateness of surgical treatment, the timing of the procedure, and whether any other preoperative evaluations or interventions are necessary before surgery.

If a candidate is accepted for bariatric surgery, thorough preoperative education should be provided. Goals include achieving an understanding

Box 2. Preoperative laboratory and diagnostic tests

- Complete blood cell count with differential
- Liver panel
- Prothrombin time
- Lipid profile
- Thyroid-stimulating hormone
- Fasting glucose
- Fasting insulin
- Hemoglobin A_{1c}
- 2-hour oral glucose tolerance test (unless prior diagnosis of diabetes has been made)
- Clean-catch urinalysis
- *Helicobacter pylori* testing (serology, followed by urea breath test if positive)
- Polysomnography (as indicated)
- Ultrasound of gallbladder (as indicated)
- Radiographic bone age (if skeletal maturity in doubt)*

* This is particularly important given the long-term concerns about vitamin D and calcium deficiency after bariatric surgery.

by the patient and family regarding (1) specific features of the surgical intervention; (2) expected outcomes; (3) necessary lifestyle modifications, including nutritional guidelines and exercise [29]; (4) specific risks, including death and that long-term success in terms of achieving acceptable weight loss is not guaranteed, in particular if dietary and exercise compliance is poor after surgery [29]. It may be helpful to begin some of the dietary and exercise recommendations before surgery to assess a candidate and family's ability to understand and apply them at home. Some degree of weight loss is recommended before surgery primarily to reduce liver size and enable a less risky laparoscopic procedure. Setting a goal of preoperative weight loss also provides a useful means of assessing the candidate's ability to understand and comply with dietary and exercise recommendations, in particular, tracking and self-monitoring of dietary intake and exercise.

Finally, the complexities and vagaries of modern health care insurance and individual financial limitations may have an impact on a candidate's ability to comply with recommended preoperative and postoperative care and monitoring. Financial counseling should be offered when needed so that the family can prepare adequately and is not caught off guard by unanticipated expenses and third-party coverage limitations.

Types of bariatric surgery

In adults, the most commonly performed surgeries worldwide are the vertical banded gastroplasty (VBG) (5.4%), the adjustable gastric band (AGB) (24%), the Roux-en-Y gastric bypass (RYGB) (65.1%), and the biliopancreatic diversion with or without duodenal switch (BPD) (4.9%) [42]. These procedures can be divided into two general categories: purely restrictive (VBG, AGB) and combined restrictive-malabsorptive procedures (RYGB, BPD). In adolescents, the RYGB [4,24,28,43–45] and the AGB [46,47] are being used successfully. In the United States, the most commonly performed procedure in adolescents is the RYGB because the AGB currently is approved by the Food and Drug Administration (FDA) only for patients age 18 or older. Earlier reports of obesity surgery in children also included the BPD, but this is now rarely performed in this age group because of an increased risk of malabsorptive complications (Fig. 2) [43].

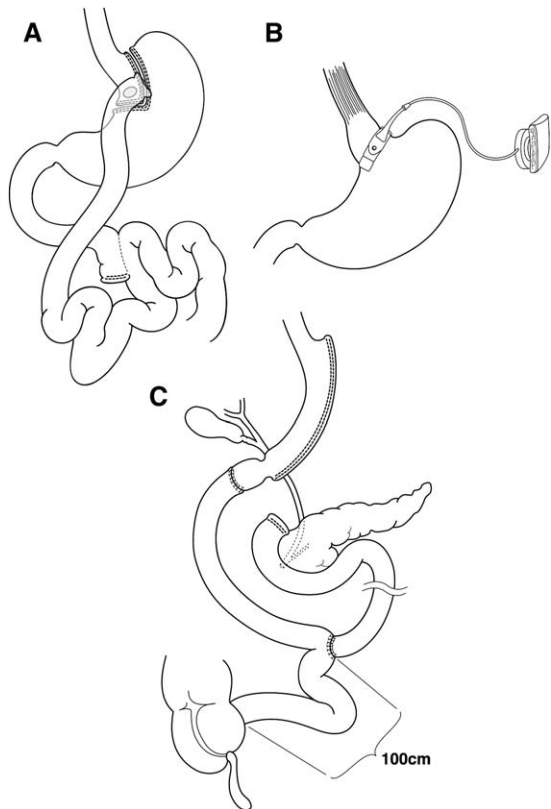


Fig. 2. Bariatric procedures successfully used in adolescent subjects. (A) Roux-en-Y gastric bypass, most commonly performed procedure in adolescents. (B) Adjustable gastric band. (C) Biliopancreatic diversion, less commonly performed.

The AGB is a purely restrictive procedure in which an adjustable band is laparoscopically placed around the cardia of the stomach, just below the gastroesophageal junction, to create a functional pouch. After surgery, the band can be adjusted to modulate the degree of restriction, by injecting saline into a port placed under the skin on the abdominal wall during surgery. The AGB does not alter the absorption of micronutrients in the small intestine, but rather limits the amount that can be eaten at a given meal by creating a sensation of early satiety and reducing the quantity ingested at each meal. The restriction of intake may lead to malnutrition secondary to a reduction in the quantity and quality of nutrient intake. In addition, associated complications of nausea and vomiting can reduce intake of essential nutrients further. Although successfully performed in adolescents, mainly in Europe, the AGB can be hampered by device-related complications, unknown long-term efficacy, and eventual need for replacement [47]. The advantage is that it does not alter the gastrointestinal physiology and is more readily reversible.

The RYGB is the malabsorptive-restrictive procedure most commonly performed in adolescents. As a result of the added malabsorptive component, the RYGB generally produces a greater degree of weight loss (on average about 10 kg more) than the purely restrictive procedures [18]. The RYGB creates a small gastric pouch (15–30 mL in volume) restricting the amount that can be eaten at one time, owing to sensation of satiety. The gastric pouch is anastomosed to a Roux limb of proximal jejunum, bypassing the distal stomach and duodenum. The bypassed segment of bowel is anastomosed to a more distal segment of the Roux limb of jejunum, at which point biliary and exocrine pancreatic secretions contact luminal nutrients to aid in absorption. By varying the length of the bypassed limb of small intestine, the degree of malabsorption can be adjusted. A longer length of bypassed small intestine results in greater weight loss, but increases the risk of developing metabolic and nutritional abnormalities, such as anemia [48,49].

Complications and outcomes

Complications

Despite its overall success, bariatric surgery remains controversial with regard to cost-effectiveness and overall short term and long-term safety. More recent reports have called attention to an increase in hospitalization after RYGB surgery in California [50] and higher mortality rates than previously suggested after surgery in Medicare recipients of gastric bypass [51].

The overall morbidity and mortality of bariatric surgery are better defined in adults because of the greater numbers of procedures, which permit more accurate estimation of risk. A large-scale systematic review of the literature reported an overall early mortality rate (defined as ≤ 30 days from procedure) for RYGB of 0.3% to 1% and a rate of 0.02% to 0.4% for AGB

[18,51a]. Late mortality rates remained low at 0.6% to 1.1% for RYGB and 0.1% for AGB. The true incidence of morbidity is more difficult to calculate, but may occur in 10% to 20% of patients [18,51a].

Reported complications after bariatric surgery are numerous, but vary considerably in severity. Intraoperative complications include accidental bowel perforation, hemorrhage, and complications related to anesthesia. Short-term complications within the first 30 days after surgery include pneumonia, deep vein thrombosis, pulmonary embolus, wound infection, gastrointestinal hemorrhage, gastrojejunal anastomotic obstruction leading to dilation and rupture of the gastric pouch, obstruction of the jejunojejunal anastomosis, leakage of intestinal contents from staple lines or from anastomoses, incisional hernia, and wound infections. Long-term complications after the first 30 days include stomal stenosis (may require endoscopic balloon dilation), nutritional deficiencies and dehydration, marginal ulceration gastric staple line breakdown and gastrogastic fistula formation, symptomatic cholelithiasis, and internal herniation. Prompt evaluation of abdominal pain, nausea, and vomiting is mandated and may involve radiographic evaluations, including upper gastrointestinal series, ultrasonography, CT, and in some cases upper endoscopy [51b].

Less severe complications include diffuse alopecia, which is common during the period of rapid weight loss after gastric bypass surgery [52]. The exact cause of alopecia is unknown and could be related to stress (telogen effluvium), protein-calorie malnutrition, or various nutritional deficiencies, such as zinc [53]. Excess skin folds resulting from dramatic weight loss also can lead to recurrent and severe intertriginous dermatitis and ulcerations and are a significant cosmetic concern for many adult and adolescent patients [54].

Data on complications in adolescent bariatric recipients is less extensive, but reports to date are generally favorable with low rates of surgical or medical complications, in particular with the introduction of laparoscopic techniques [45]. In an early series that also included adolescents who had undergone biliopancreatic diversion, serious nutritional deficiencies were found only in the patients who had undergone the BPD and included three protein deficiencies, vitamin A, D, and folic acid deficiency [42]. One incisional hernia was reported. Two late deaths also occurred, however, one at 15 months (in a patient who had biliopancreatic diversion and a brain tumor) and the second at 3.5 years after surgery (RYGB), for an undetermined cause.

Complications in series of adolescents undergoing RYGB are similar to the complications reported in adults. Early complications include pulmonary embolus, wound infections, stomal stenoses, dehydration, and marginal ulcers, whereas later surgical complications include small bowel obstruction, cholelithiasis, and incisional hernias [24,44]. Severe nutritional complications also have been reported, including more severe beriberi owing to thiamine deficiencies [27] and a case of protein-calorie malnutrition and micronutrient deficiency at 1 year postsurgery, requiring institution of total parenteral nutrition [24]. Finally, an 18-year-old woman had a generalized

seizure and acute ischemic stroke 4 months after laparoscopic RYGB, possibly secondary to a venous infarction [55]. Her postoperative course had been complicated by nausea secondary to chronic cholecystitis, resulting in malnutrition and dehydration.

The authors' most recent study of RYGB in adolescents reported complications in 15 (39%) of 36 adolescent patients [4]. Of these 15 adolescents, 9 had minor complications, 4 had moderate complications, and only 2 had severe complications. Minor complications were defined as a readmission of less than 7 days and no long-term sequelae. These included endoscopy (for melena, suspected obstruction or stricture), food obstruction, wound infection, anastomotic stricture/gastrojejunostomy stricture, nausea and dumping syndrome secondary to overeating, diarrhea, dehydration, mild beriberi, hypokalemia, and deep vein thrombosis. Moderate complications were defined as readmission or sequelae for more than 7 days but less than 30 days. These included persistent iron deficiency anemia, peripheral neuropathy secondary to vitamin deficiency, reoperation, shock, and internal hernia. Severe complications were defined as sequelae lasting more than 30 days. These included persistent neurologic symptoms from beriberi and one late death of an 18-year-old patient who developed *Clostridium difficile* colitis and consequent severe dehydration several months after his procedure. Including this report, only four late deaths have been reported in adolescents occurring 15 months to 6 years postsurgery [43,44]. To date, no perioperative deaths have been reported in adolescent bariatric patients.

AGB complications also have been reported in adolescents, but do not seem to differ significantly from those reported in adults. Postoperative complications occurred in 10% (6 of 58) of adolescents undergoing laparoscopic AGB placement, including gastric erosion, psychological intolerance, and conversion to gastric bypass at 2 years after band placement [47]. Dolan and Fielding [46] also reported no significant difference in complication rate between adolescents and adults undergoing laparoscopic AGB and zero mortality rate.

Ensuring technical expertise of the bariatric surgeon also has come under increased focus, as data in adults indicate that mortality and morbidity decline as surgeon experience increases [18]. The American Society for Bariatric Surgery has recommended that an experienced bariatric surgeon should have performed at least 100 bariatric procedures or have completed a year-long bariatric surgery fellowship [31]. It is likely that different training standards will need to be set at pediatric institutions, however, given the smaller volume of candidates at adolescent programs (eg, through surgical mentoring or collaboration with adult centers).

Nutritional deficiencies

Nutritional deficiencies are among the most significant long-term complications of bariatric surgery and have been reported in adult and adolescent

patients. Adolescents who undergo bariatric surgery are expected to have a longer life span with altered gastrointestinal physiology, increasing the importance of lifelong dietary supplementation to avoid long-term problems with osteoporosis, anemia, and neurologic sequelae. Ensuring adherence among adolescents with chronic disease can be a challenge; teenage kidney transplant patients have the worst graft survival compared with any other age group, a difference that has been linked to lower compliance with immunosuppression medication regimens [56,57]. Similarly, in adolescents who had undergone RYGB, only 14% took recommended supplements [44]. Close supervision and continued monitoring of supplement intake is crucial.

Malnutrition after bariatric surgery occurs through two primary mechanisms: (1) bypass of crucial absorptive and secretory areas of the stomach and small intestine and (2) restricted intake of dietary macronutrients and micronutrients after surgery. Serious macronutrient deficiencies are rare, particularly after the restrictive procedures. Insufficient intake of protein after bariatric surgery can occur, however, after more malabsorptive bariatric surgeries, owing to decreased absorption and increased intolerance of meats [24,48,58,59]. Symptoms of protein-calorie malnutrition include loss of muscle mass, anemia, alopecia, hypoalbuminemia, and edema.

A wide variety of micronutrient deficiencies have been reported after bariatric surgery, most commonly iron [24,60,61], calcium and vitamin D [62], thiamine [27,63–66], and vitamin B₁₂ [60,61]. Symptoms are related to the specific deficiency, but can include anemia, osteoporosis, and various neurologic symptoms. The early timing of some of these deficiencies after surgery suggests that nutritional adequacy already may be suboptimal preoperatively in morbidly obese patients, despite high caloric intake [62,67,68].

Anemia is particularly common and can result from iron, vitamin B₁₂, or folate deficiencies [69]. More recently, pica as a symptom of iron deficiency has been reported in two young women with iron deficiency after RYGB surgery [70]. Folate deficiency occurs less commonly than vitamin B₁₂ and iron deficiency after RYGB (0–38% prevalence) [24,71–73] and does not seem to be a long-term risk [73]. Standard multivitamin supplementation almost always corrects folate deficiency [61]. If a folate deficiency is found postoperatively, it may indicate lack of compliance with multivitamin supplementation [73]. It is particularly crucial to supplement folate in adolescents and young women of childbearing age to prevent neural tube defects in planned and unplanned pregnancies.

Neurologic sequelae of bariatric surgery are estimated to occur in 5% to 16% of patients after bariatric surgery [64,74]. Most cases are believed to result from vitamin B₁₂, folate, and thiamine deficiencies, although in some cases, no vitamin deficiency has been documented [75,76]. Symptoms may include varying degrees of encephalopathy, behavioral changes, peripheral neuropathy, and ataxia [64,74]. Thiamine deficiency after bariatric surgery occurs mainly in the setting of protracted postoperative emesis, as early as 6 weeks but usually 2 to 4 months after surgery, when liver thiamine stores

can be depleted by chronic malabsorption or poor intake [63–65]. More recent case reports of thiamine deficiency in adolescent gastric bypass patients did not always occur in the setting of protracted nausea and vomiting, perhaps as a result of associated noncompliance with supplementation [27].

Thiamine deficiency after bariatric surgery presents most often with cerebral symptoms of Wernicke's encephalopathy (ophthalmoplegia, nystagmus, ataxia, and encephalopathy) [65,77–80] or as a peripheral neuropathy, marked by burning painful paresthesias, peripheral lower extremity weakness, and distal sensory impairment [27,66]. Neurologic sequelae may take months to resolve, and residual neurologic impairment can result even in cases in which treatment is administered promptly. Delayed treatment can lead to permanent neurologic impairment [64,81].

Vitamin D and calcium deficiencies are common even before bariatric surgery in extremely obese individuals (20% of adults) [62,82,83]. A preoperative disturbance in phosphocalcemic metabolism could be worsened by bariatric procedures that promote malabsorption. In addition, intake of calcium may be lower postoperatively because of avoidance of dairy products secondary to lactose intolerance. Over the long-term, deficiencies of calcium and vitamin D could lead to decreased bone mineral density. This possibility needs to be tracked in prospective long-term studies in adolescents and adults [84]. In addition, prolonged hypovitaminosis D potentially may have important secondary effects on multiple metabolic processes in addition to bone health because deficiency of vitamin D has been linked to cancer, hypertension, rheumatoid arthritis, diabetes, and peripheral vascular disease [85]. Severe, symptomatic hypocalcemia also may emerge years after bariatric surgery, triggered by subsequent total thyroidectomy for other causes [86,87].

A few isolated reports have been published involving other fat-soluble vitamins, mainly vitamin A and vitamin K [88–91]. None of these deficiencies have been reported in adolescents. Other rarely reported mineral deficiencies included zinc and copper [67]. Symptomatic zinc deficiency was reported in two adults patients after distal, long segment RYGB who also developed persistent postprandial emesis [48]. Copper deficiency can cause a demyelinating neuropathy that resembles vitamin B₁₂ deficiency, in addition to anemia [92]. Two cases have been reported after gastric bypass surgery in adults, although none presently have been reported in adolescents [93,94]. Copper deficiency should be investigated in patients with neurologic deficits after bariatric surgery.

Outcomes

Prospectively studied outcomes of bariatric surgery in adolescents are not yet available for comparison with adult data, but active research and ongoing data collection continue in this growing surgical area. There is strong interest among adult and pediatric surgeons who conduct adolescent bariatric

surgery in participating in multicenter studies [25]. In addition to collecting standard short-term and long-term morbidity and mortality statistics, rigorously measured data on growth and development measures, quality of life, and academic and social functioning need to be acquired [30]. Data from preliminary retrospective studies indicate that despite significantly higher mean preoperative BMI compared with adult series, extremely obese adolescents who undergo bariatric surgery generally experience good overall postoperative weight loss and significant reduction in metabolic risk factors and obesity-related complications such as obstructive sleep apnea [8].

The Pediatric Bariatric Study Group reported initial 1-year outcome data on RYGB in 36 adolescent patients performed at three different surgical centers. The BMI of the surgical patients (13–21 years old) decreased 37% compared with a 3% decrease in a control group of nonsurgical patients [4]. The surgical cohort also showed significant improvements in serum triglyceride, total cholesterol, fasting blood glucose, and insulin at 1 year postoperatively. Previous smaller series of RYGB in adolescents also reported maintained mean weight loss of 56% to 62% of excess weight [24,44].

Data on the outcome of ABG in adolescents also seems promising. In a report from Europe, excess weight loss of 40% was maintained at 3 years after surgery in a series of 58 adolescents (mean BMI 46, ≤ 19 years old) who had undergone laparoscopic AGB (88.1% follow-up) [47]. Early reports from the United States also have been promising with a 59% excess weight loss in most (76.5%) of 17 adolescents who received a laparoscopic ABG, at an average of 2 years follow-up [46]. Further experience is being obtained with the laparoscopic ABG in the United States. Individual device exemption has been provided to several programs including the University of Illinois (Chicago) to place 50 AGBs in pediatric patients (A. Holterman, personal communication, 2005). The criteria for inclusion in this trial are equivalent to the guidelines for adults: BMI of 35 kg/m² with comorbidities or 40 kg/m² without comorbidities. The FDA convened a special Pediatric Obesity Panel Meeting in November 2005 to begin to contemplate standards for the design of clinical studies of weight loss devices for children and adolescents [95]. FDA guidance on this topic is expected in the upcoming year.

Despite these successes, weight regain can occur. In two small series of adolescents after gastric bypass, with at least 4 to 10 years of follow-up, 10% to 15% of the cohort regained weight [24,44]. Weight regain also has been reported in adolescent subjects within the first year of follow-up [4]. Weight regain has been well described in adult subjects. In a prospective study that followed adult bariatric subjects over 10 years, mean weight loss at 2 years was 23% compared with 16% at 10 years [96]. Nonetheless, 73.5% of the RYGB subjects in this cohort maintained a weight loss of 20% or more over this period compared with 3.8% of a matched control group (no surgical intervention), 35.2% of a VBG group, and 27.6% of an AGB group. Similarly, only 8.8% of the RYGB group lost less than 5% of their initial weight compared with 13.8% of the VBG group and 25% of the AGB

group, suggesting a superiority of RYGB for weight reduction. Comparable long-term prospective data in adolescent subjects are lacking, and further investigation is required to identify the predictors of success after adolescent bariatric surgery, including psychosocial and metabolic factors.

Currently, prospective data are being collected by the Pediatric Bariatric Study Group on more than 200 adolescents who have undergone bariatric surgery. This study will allow better calculation of morbidity, mortality, and long-term outcome rates. Despite excellent overall weight loss after operation, the postoperative BMI values still frequently fall within the overweight to severe obesity range [4]. It is important to keep a realistic expectation in mind when counseling morbidly obese adolescents about the outcome of bariatric surgery. As technical expertise continues to evolve in the field, trials that compare outcomes of currently available and future procedures in adolescents are needed to determine the optimal techniques for adolescents and whether procedures should be varied based on individual circumstances, such as extreme BMI greater than 50 kg/m².

Long-term monitoring after surgery

After surgery, long-term, lifelong monitoring is recommended. At the authors' program, follow-up visits are scheduled every other week during the first 2 months, then monthly until 6 months, at 9 and 12 months, and then annually. During these visits, periodic medical assessments are done to evaluate for any short-term and long-term medical and surgical complications and monitor any preexisting comorbidities. Dietary assessment and instruction occur at each visit, with behavioral therapy to reinforce adherence. Dietary recommendations at the authors' center include (1) eating protein first at each meal, with a goal of 0.5 to 1 g/kg/d; (2) drinking 64 to 96 oz of sugar-free liquids daily; (3) avoiding all snacking between meals; (4) exercising 30 to 60 minutes a day; and (5) taking recommended daily vitamins and minerals. As in adults, the degree of postoperative success depends on adherence to dietary and exercise recommendations. In a study of adolescents after gastric bypass surgery, 15% regained most or all of the weight, mainly by snacking on high-fat foods [44].

Monitoring for micronutrient deficiencies

Few long-term studies of long-term nutritional consequences of bariatric surgery have been published. The number of patients successfully followed long-term declines in almost all studies, leading to significant potential ascertainment bias [97]. Monitoring of nutritional deficiencies and supplementation varies widely among bariatric surgery programs [49,98]. As the frequency of bariatric surgery increases in adults and adolescents, it becomes crucial to collect long term data on the nutritional consequences of bariatric surgery.

Compliance with long-term vitamin supplementation should be monitored and reinforced at every follow-up visit. At the authors' center, nutritional laboratories are obtained at baseline, 3 months and 12 months, then annually (Box 3). Lifelong supplementation with specific vitamins and minerals is recommended, although required doses have not been prospectively determined in most cases, and recommendations may vary considerably among different programs (Box 4).

Pregnancy prevention and counseling

Counseling to prevent adolescent pregnancy and unplanned pregnancy both before and after bariatric surgery is of critical importance in any program that includes adolescent patients. National statistics indicate that approximately 50% of adolescents have had intercourse by age 17 [100]. Though sexual behaviors among obese adolescents are not well studied, weight-related stigma may impact rates of sexual activity prior to bariatric surgery [101]. The chance of pregnancy may increase following successful bariatric surgery, as weight loss improves the ovulatory dysfunction often associated with obesity [99]. Gastric bypass surgery itself may not significantly increase risk of pregnancy [25,102–105], although significant complications have been reported in isolated cases [106,107]. Loss of excess weight may in fact reduce the risk of pregnancy complications such as gestational diabetes, macrosomia, preeclampsia, eclampsia and need for operative delivery [108–110]. However, in adolescent women, pregnancy may carry a higher incidence of complications such as prematurity and low birth weight, increasing the infant's risk for numerous medical and psychosocial problems [111]. Moreover, due to the rapid and dramatic weight loss experienced in the first year after bariatric surgery, pregnancy should be avoided until at least the second year after surgery. The American College of Obstetricians

Box 3. Recommended nutritional evaluations (obtained at 3 months, then annually)

Complete blood cell count with differential
Serum iron and ferritin
Serum vitamin B₁₂
Folate (in women of childbearing age)
Calcium
25-hydroxyvitamin D
Parathyroid hormone
Alkaline phosphatase
Dual-energy x-ray absorptiometry (obtained at 3, 6, 9, and 12 months) to assess lean and fat-free mass

Box 4. Recommended vitamin supplementation for adolescents after gastric bypass*

Standard oral high-potency chewable multivitamin daily (contains folic acid)

Calcium citrate oral 1000 mg/d^a

Vitamin B₁₂ 1000 µg intramuscular injection monthly *or* crystalline 500 µg oral daily^b

Elemental iron 65 mg oral daily (ferrous form) in menstruating adolescent girls^{b,c}

Vitamin B1 50 mg oral daily (stopped after first 6 months)

* Guidelines followed at the Comprehensive Weight Management Center, Cincinnati Children's Hospital Medical Center.

^a Consider additional vitamin D supplementation (800–1200 IU/daily) [67].

^b Multivitamin supplementation alone does not prevent vitamin B₁₂ or iron deficiency; additional supplementation of these nutrients is required [119,120].

^c Prenatal vitamin contains 40 to 65 mg of elemental iron [70,120]. Coadministration of 500 mg of vitamin C with iron may promote absorption of iron [70,121].

and Gynecologists (ACOG) advises all patients to delay pregnancy for 12 to 18 months after bariatric surgery [110].

Contraception for obese adolescents, as in most adolescents, can be a challenging issue. The appropriate choice for contraception is further complicated in obese adolescents due to undesirable side effects such as weight gain (depot-medroxyprogesterone acetate), increased risk of venous thromboembolic disease which may compound the increased risk associated with obesity (estrogen-containing hormonal methods), and impaired efficacy, possibly secondary to variable absorption or increased adiposity (oral contraceptives, transdermal patches) [112,113]. Progestin-only oral contraceptive require strict compliance with daily use, and in general, may not be optimally effective in adolescents. Newer progestin-only contraception methods such as the progestin intrauterine system are significantly more reliable and carry less risk of these adverse effects [112]. Consultation with an adolescent medicine or gynecology specialist is advocated prior to surgery to determine the optimal method of contraception for extremely obese adolescent females undergoing bariatric surgery.

Pregnant women who have undergone bariatric surgery are also at risk for specific nutritional deficiencies that could potentially impact both the mother and the infant [114]. In both restrictive and malabsorptive procedures, decreased caloric intake can result in drastic weight reduction and a catabolic state. In addition, hyperemesis may be aggravated by small gastric pouch volumes created in restrictive procedures. The RYGP potentially

has a greater impact on pregnancy due to the added malabsorptive component [114]. Iron deficiency anemia, vitamin B12, folate, calcium and vitamin D deficiencies can particularly impair fetal growth and development. If pregnancy is planned or desired, a careful screening of compliance with multivitamin supplementation, anemia, vitamin deficiency and metabolic derangements should be obtained and any deficiencies corrected, prior to pregnancy. During pregnancy, prenatal vitamins, oral iron, and calcium should be prescribed [115]. Folate and iron supplementation may need to be higher due to malabsorption [25,116].

Following delivery, impaired intake of calories and nutrients can result in suboptimal breastmilk quality, resulting in poor infant weight gain [117]. The post-partum diet should be adjusted to provide adequate caloric intake to support milk production and avoid gaining excessive weight. Furthermore, vitamin supplementation should be continued during lactation, as developmental delays and megaloblastic anemia can result in breast-feeding infants due to maternal vitamin B deficiency [118]. In addition, vitamin A deficiency with visual impairment has been reported in a breast-feeding infant of a mother with hypovitaminosis A due to previous biliopancreatic diversion [91].

Summary

Bariatric surgery is a promising, although still controversial, weight loss tool for selected extremely obese adolescents who have failed conventional medical and behavioral therapy for obesity. Early reports of bariatric surgery in adolescents have shown success with this procedure, despite a much higher mean BMI than adult candidates, but long-term studies are necessary to allow quantitative meta-analysis. Rates of morbidity and mortality after bariatric surgery and resolution of preoperative comorbidities need to be rigorously and prospectively studied. Although it would be important to ensure adequate surgeon and hospital procedural volume for all programs accepting adolescent candidates, it is unlikely that any program specifically geared to meet the complex needs of adolescents would attain the volumes reached by larger adult centers. Optimal criteria for adolescent bariatric centers of excellence need to be defined. Comparison of different surgical techniques, including adjustable gastric banding and gastric bypass, is required. Prospective studies of nutrient deficiencies are crucial to determine the long-term prevalence and clinical significance of these deficiencies in adolescent bariatric recipients and to identify optimal dietary supplementation. In addition, data on psychosocial development and quality of life need to be longitudinally collected, and predictors of long-term success need to be defined.

Surgery alone is not likely to be a panacea for all; efficacy of bariatric surgery is linked to continuing follow-up and adherence to a specialized dietary regimen [113]. Surgical bypass may lead to alterations in neuroenteric

hormonal axes that regulate appetite and physical activity and that may play a role in the long-term success of bariatric surgery and long-term weight maintenance [114,115]. Changes in gastrointestinal hormones, such as ghrelin, glucagon-like peptide-1, and peptide YY, continue to be investigated before and after bariatric surgery [116–118]. Although the specific recommendations for bariatric surgery in adolescents undoubtedly will evolve as more data are collected from multicenter studies, adolescent bariatric surgery should continue to occur within a pediatric-oriented multidisciplinary team, to provide optimal counseling, evaluation, and support geared to adolescents and their families.

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