Current Gastroenterology Reports (2019) 21: 24
https://doi.org/10.1007/s11894-019-0691-8

PEDIATRIC GASTROENTEROLOGY (S ORENSTEIN AND S KEEMA, SECTION EDITORS)

Bariatric Surgery in Children: Indications, Types, and Outcomes

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Published online: 25 April 2019

Abstract

Purpose of Review The purpose of this review is to discuss the current state of surgical intervention for obesity in children and adolescents. Specifically, this review will discuss the different types of metabolic and bariatric surgery (MBS) procedures, guidelines for patient selection, and recent findings regarding surgical outcomes and complications.

Recent Findings MBS is safe in adolescents and has also demonstrated sustainable long term weight loss and improvement in obesity-associated comorbidities. A recent prospective multi-institutional trial demonstrated BMI reductions of 3.8 kg/m^2 (8%) to 15.1 kg/m^2 (28%) after 3 years among adolescents undergoing the three most common MBS procedures. Moreover, MBS is associated with remission of type 2 diabetes, prediabetes, hypertension, dyslipidemia, and abnormal kidney function in 65–95% of patients in the study.

Summary Childhood and adolescent obesity is a continuing problem that has not been adequately addressed by the medical community. MBS is currently the most successful strategy for significant and sustained weight loss and improvement of associated comorbidities. This review focuses on the different types of MBS, the selection and preparation of patients for surgery, and the expected outcomes and common complications.

Keywords Adolescent obesity · Severe obesity · Metabolic and bariatric surgery · Vertical sleeve gastrectomy · Bariatric surgery center · Adolescent bariatric surgery outcomes

Introduction

Obesity is a widespread and significant health problem facing children and adolescents both today and for the foreseeable future [1]. Approximately 18.5% of youth in the USA meet the criteria for obesity, which is defined as a body mass index (BMI) ≥ 95th percentile for age and sex. Moreover, 8.5% of those aged 12 to 19 are categorized as severely obese (BMI ≥ 120% of the 95th percentile) [2, 3]. Severe obesity, in fact, is the fastest growing subcategory of obesity in adolescents [4].

Obesity is associated with a wide range of adverse effects, both immediate and long-term, including type 2 diabetes (T2D), obstructive sleep apnea, hypertension, nonalcoholic fatty liver disease, and dyslipidemia [5–7]. Furthermore, the risk of obesity-related morbidity and mortality increases over time, suggesting that children who develop obesity are at higher risk of experiencing complications from their obesity than individuals who develop obesity later in life [8]. Moreover, adolescent obesity predicts adult obesity and its many associated metabolic complications [9].

Obesity, officially recognized as a disease state by the American Medical Association in 2013, is a multifactorial condition resulting from a combination of genetics, environment, and metabolic programming [10]. Therefore, the treatment of obesity also requires a multidisciplinary approach [11••]. First line therapy has primarily consisted of structured diet and exercise programs [1]. Long-term outcomes for this approach in adolescents, however, have generally been poor. Behavioral therapy has also been recommended, but is seldom effective, especially for older adolescents and those with severe obesity. In fact, a study of behavioral treatment demonstrated that only 2% of adolescents achieved any meaningful weight reduction after 3 years of therapy [12]. Pharmacologic options and meal replacements are also being investigated. There are limited data; however, demonstrating the safety and effectiveness of many of these pharmacologic agents in adolescents as the commonly used weight loss medications do

This article is part of the Topical Collection on *Pediatric Gastroenterology*

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not have FDA approval in patients under the age of 18. In fact, many bariatric centers are forced to use these agents off-label and, thus, are unable to publish their results, further limiting their acceptance and widespread use. Meanwhile, protein-sparing modified fasts have been demonstrated as safe and effective methods of weight loss, but only when performed in a supervised inpatient setting and thus, long-term recidivism remains an issue [4, 13].

Metabolic and bariatric surgery (MBS), on the other hand, has been shown to be effective in both achieving sustained weight loss and resolution of comorbid conditions, such as cardiovascular risk factors and diabetes [1]. Recently reported 3-year outcomes data from the Teen-Longitudinal Assessment of Bariatric Surgery (Teen-LABS) study, a prospective, multi-institutional observation study of 242 adolescents undergoing MBS demonstrated that MBS is a safe and effective treatment for children [14••]. The American Society for Metabolic and Bariatric Surgery (ASMBS) Pediatric Committee, therefore, considers MBS standard of care and a primary part of the multidisciplinary paradigm of obesity management [11]. In the following sections, we address the different types of MBS, outline selection criteria that may be used, and describe expected outcomes for the main procedures used in adolescents.

Types of Metabolic and Bariatric Surgery Procedures

The first MBS procedure, the precursor to the current Roux-en-Y gastric bypass (RYGB), was performed by Mason and Ito in 1967 [15]. Since then, MBS has demonstrated significant and sustained reductions in BMI and associated comorbidities in adults, while also lessening mortality [16, 17]. Meanwhile, MBS has been performed in small cohorts of adolescents since the 1970s, and the volume of MBS cases being performed in adolescents has gained significant momentum since the early 2000s [18]. Data from the US National Inpatient Sample indicate that 2744 adolescent bariatric surgeries were performed between 1996 and 2003 [19]. Recent estimates are approximately 1600 adolescent bariatric cases per year as of 2009 [20]. There appears to be a plateau, however, in the number of adolescents undergoing surgery despite the increasing number of patients who actually meet criteria for surgery [21]. In fact, less than 1% of all MBS is performed in adolescents [22].

The three most commonly performed adolescent bariatric procedures are RYGB, vertical sleeve gastrectomy (VSG), and adjustable gastric band (AGB). All of the procedures can be performed via laparoscopy and produce weight loss by one of three mechanisms, malabsorption, restriction (AGB or VSG), and combined (RYGB). The AGB, however, employs a device that is restricted by the FDA for use only in patients after they have reached the age of 18.

The AGB involves placement of an adjustable silicone band around the stomach, 1 to 2 cm below the gastroesophageal junction, which is attached to a small reservoir that is implanted subcutaneously [23]. The band can be adjusted by altering the amount of fluid in the reservoir. The tighter the band, the slower the gastric pouch empties [24]. The AGB had been a popular choice in adults due to its relatively reduced level of surgical complexity, reversibility, and lower risks of morbidity and mortality [25]. Recent adult literature, however, demonstrates decreased use of the AGB because of a high rate of conversions to RYGB or VSG, poorer weight loss, and a higher rate of weight regain [24]. In fact, only about 5% of adults undergoing MBS currently undergo ABG, and its lack of FDA approval in adolescents makes it even less used in this group [26].

While AGB is the least complex surgical procedure, RYGB is the opposite end of the spectrum, representing the most complex of the three major operations. In RYGB, a small (approximately 30 mL) gastric pouch is created from the upper stomach. The small intestine is then divided 30 to 50 cm distal to the duodenojejunal junction creating a biliopancreatic limb (transports secretions from gastric body, liver, and pancreas) and a Roux limb (alimentary limb). The Roux limb is then anastomosed to the gastric pouch while the biliopancreatic limb is connected back to the alimentary limb 75 to 150 cm from the gastrojejunal anastomosis. This procedure is therefore restrictive and malabsorptive. RYGB has been demonstrated to be the most effective procedure in terms of weight loss and improvement in associated comorbidities and is currently the gold standard MBS in adults in the USA [23, 27]. However, it is now the second most common surgical procedure performed for weight loss in adults, mostly due to its surgical risk [26].

VSG has now become the most popular procedure for weight loss in both adults and adolescents [26]. VSG involves the removal of most (80–90%) of the greater curvature of the stomach. This leaves a tubular remnant stomach about 10 to 15% of its original size. The procedure was originally performed as the initial stage of a two-stage weight-loss procedure (the duodenal switch) for adults who were extremely obese and believed to be poor surgical candidates for RYGB. Observation of these patients, however, demonstrated significant short-term weight loss and improvement in comorbidities achievable with VSG alone, leading to its current role as a stand-alone operation [24]. VSG has become increasingly popular due to its technical simplicity and decreased rate and severity of complications when compared with RYGB. Moreover, when compared with another purely restrictive procedure like AGB, VSG significantly reduces plasma ghrelin levels and subsequently suppresses appetite [28].

While there are no other surgical interventions available for adolescents currently, there are several new modalities on the horizon. Recently, the FDA approved an intragastric balloon device for treatment of adult patients with a BMI of 30 to 40 kg/m^2 who have failed to lose weight through diet and exercise. This is a restrictive procedure in which the balloon is inserted into the stomach via upper endoscopy under mild sedation. Once in place, the balloon is filled with saline from 400 to 700 mL and left in place for 6 months. No external tubing is left in place to access the balloon. The procedure was originally used as an adjuvant before bariatric surgery in morbidly obese adults to reduce life-threatening comorbidities and perioperative risk. Initial studies demonstrate that the technique is safe and effective for short-term weight loss in adults. No data exist for adolescents, and the procedure is not currently approved for patients less than 18 years of age [29]. Similarly, endoscopic assisted placement of a percutaneous gastrostomy device termed AspireAssist that facilitates drainage of about 30% of the calories consumed in a meal has been evaluated in adults. Preliminary data demonstrates a mean excess weight loss of 31.5% at 1 year in those using the device in conjunction with diet and exercise modification [30]. Meanwhile, another modality involves laparoscopic placement of electric leads on the anterior and posterior vagal trunks near the gastroesophageal junction, connected to a subcutaneous regulator device that delivers intermittent vagal stimulation resulting in reduced food intake and weight loss through vagal blockade. Preliminary data demonstrate a mean excess weight loss of 21% at 2 years, with improvement in several metabolic profile categories [31]. Both of these devices are currently only FDA approved in adults. Until these alternative procedures become options for adolescents, RYGB and VSG will continue to be the most commonly performed MBS in adolescents, although VSG is rapidly becoming the procedure of choice in both adults and adolescents due to its relative technical simplicity, low complication profile, and good weight loss and comorbidity improvement outcomes [11••].

Eligibility Criteria

Expert opinion has served as the basis for surgical practice guidelines outlining criteria for selection of adolescent patients for MBS. Based on the initial NIH guidelines for adults [32], adolescents with a BMI greater than or equal to 35 kg/m^2 with severe comorbidity, such as T2D, moderate to severe obstructive sleep apnea, benign intracranial hypertension (pseudotumor cerebri), or nonalcoholic steatohepatitis, were considered candidates. Those with a BMI greater than or equal to 40 kg/m^2 and less severe comorbidities have also been considered candidates for MBS. In general, previous guidelines have also suggested that patients should attain Tanner stage IV or 95% of linear growth (based on bone age) prior to undergoing MBS. These physiologic maturity criteria may be modified, however, in special cases of rapid weight gain due to defined medically recalcitrant causes (i.e., hypothalamic obesity) or if the mortality risk of comorbidities outweighs the theoretic risk of growth impairment after surgery [11, 33, 34]. The most recent ASMBS Pediatric Committee guidelines [11••], however, have suggested adjusting criteria for MBS. First, they define adolescence by the World Health Organization definition as any person who falls between 10 and 19 years of age. Second, review of the literature demonstrates no data to suggest that a youth's puberty status, as measured by Tanner staging or linear growth, as measured by height, is adversely affected by MBS. In fact, one study by Alqahtani et al. demonstrated improved linear growth in children after VSG compared with matched controls [35]. Therefore, the ASMBS Pediatric Committee recommends that Tanner staging and linear growth not be used to determine readiness for adolescent MBS. Furthermore, the ASMBS suggests adjusting criteria from predominantly weight based, as is common in adult patients, towards a more comorbidity-based approach. This adjustment is due to several recent reports that have demonstrated significant improvements in nearly all measures of cardiovascular risk factors by 2 years after MBS [36, 37••]. Moreover, younger age at the time of surgery predicted an increased likelihood of normalization of certain measured risk factors [11••]. Therefore, the most recent ASMBS guidelines suggest that CVD risk factors should be considered a strong indicator for MBS. Similarly, certain comorbidities, specifically the psychosocial burden of obesity, the orthopedic diseases specific to children, idiopathic intracranial hypertension (pseudotumor cerebri), gastroesophageal reflux disease (GERD), and T2D, for which there are poorer outcomes in children on medical therapy, should be considered an indication for MBS in younger adolescents or those with lower BMI percentiles. In addition, the committee felt that requiring adolescents with a BMI greater than 40 to have comorbidity (as in previous guidelines for adolescents), puts children at a significant disadvantage to attaining a healthy weight. Earlier surgical intervention (at a BMI of less than 45 kg/m^2) can allow adolescents to reach a normal weight and avoid lifelong medication therapy and end-organ damage from comorbidities [38]. Therefore, the current recommendations are that MBS should be considered for all adolescents with a BMI ≥ 35 or ≥ 120% of the 95th percentile with comorbidities or BMI ≥ 40 or ≥ 140% of the 95th percentile with or without comorbidities similar to the criteria in adults. Interestingly, adult criteria have never been updated since the original NIH consensus conference in 1991, at which time the most common surgical option was open gastric bypass. Thus, it is possible that these cutoffs should be lowered in both adults and adolescents alike. All adolescents with obesity syndromes or medically recalcitrant obesity should continue to be referred for MBS. In addition, adolescents who are recognized to suffer from severe obesity should be referred to

MBS earlier, regardless of physiologic maturity by Tanner stage or linear growth [11••].

Traditionally, contraindications to MBS included medically correctable causes of obesity, active substance abuse problems, and psychosocial, medical, unstable psychiatric, or cognitive conditions that impair decision making or prevent adherence to recommendations. In addition, current or planned pregnancy (within 18 months of surgery) and inability to understand the risks and benefits of surgery were also contraindications [33, 34, 39]. The most recent ASMBS guidelines acknowledge many of these contraindications but are careful to point out that these issues are not absolute contraindications. Developmental delay and autism spectrum disorders should be evaluated by a multidisciplinary team along with the caregiver in order to agree on the specific needs and abilities of a given patient, and care environment and MBS should be considered on a case-by-case basis. Similarly, unstable family environments, eating disorders, mental illness, or prior trauma should not be absolute contraindications but should be optimized and treated where possible before and surrounding any potential surgical intervention [11••]. In fact, recently published data demonstrated that psychiatric diagnoses had no impact on outcomes in a cohort of adolescents after VSG [40].

Pre-operative Evaluation

A multidisciplinary, team-based approach for the evaluation and preparation of all adolescents with obesity for bariatric surgery is recommended. This multidisciplinary team should include an experienced pediatric bariatric surgeon (which may be a pediatric surgeon with bariatric experience or a bariatric surgeon with pediatric experience), pediatric obesity specialists, nurses, dieticians, exercise specialists, a psychologist or psychiatrist with pediatric expertise, and a patient coordinator. In addition, access to pediatric subspecialists for management of complex comorbid conditions is absolutely necessary [1, 34, 39, 41].

Although there are no trials of multidisciplinary care versus care provided by a single practitioner, nearly every published position paper has advocated the importance of this team approach [42–44]. The purpose of this multidisciplinary team is not only to determine candidates for MBS but also to ensure appropriate preoperative medical evaluation. This evaluation aims to identify, characterize, and ultimately optimize the severity of comorbidities and the presence of any nutritional deficiencies preoperatively [39]. Every patient should have a complete history and physical examination, with an emphasis on identifying obesity-related comorbidities, possible contributors to obesity, and conditions that may increase surgical risk. There should also be documentation of the history of weight-loss attempts and an assessment of readiness to change. Standard laboratory and nutrition evaluation, including fasting blood glucose, lipid panel, liver function tests, coagulation studies, and vitamin profile, are also recommended [39].

Obesity is a known risk factor for vitamin and micronutrient deficiencies, such as low ferritin, vitamin A, and vitamin D. Deficiencies in other micronutrients such as vitamin B12, B1, and folic acid have also been reported. Therefore, preoperative treatment with a multivitamin (one standard multivitamin with iron and 1000 IU vitamin D) may be recommended [39]. Adolescent candidates for MBS are also recommended to undergo a cardiac evaluation and sleep apnea screening if indicated after history and physical, prior to surgery [45]. Helicobacter pylori screening should also be pursued in high prevalence areas, although screening is less important for those undergoing VSG [46].

All patients should also undergo psychosocial/behavioral evaluation with a goal of identifying strengths that would lead to positive surgical outcomes in addition to potential barriers to success [47]. The practical goal of this assessment is that it is required by all insurers prior to authorization for payment for surgery. The importance of this evaluation is highlighted by the high prevalence of mental health needs in this population, with studies demonstrating that up to 30% of adolescents seeking weight-loss surgery self-reported symptoms consistent with clinical depression and had significantly lower health-related quality of life scores as compared to norms [48]. Additionally, up to 45% of adolescents seeking weight loss treatment reported binge eating behaviors at some point in their life [49]. Ongoing psychosocial evaluation and support with an emphasis on optimizing mental health, social support structure, and adequately assessing whether an adolescent and their guardian fully understand the risk and benefits of MBS, and the potential postoperative course are very important to ensure successful outcomes.

Initiating weight loss prior to bariatric surgery in patients with severe obesity has also been recommended and is associated with improved operative safety, particularly reduced operative times, intraoperative blood loss, and other complications [50–54]. Preoperative weight loss with medical nutrition therapy has also been demonstrated to improve glycemic control and should be utilized in all obese patients with diabetes. Furthermore, preoperative weight loss has been linked to decreased liver size and reduced length of hospital stay and may lead to more rapid weight loss after surgery [55]. Most multidisciplinary bariatric surgery programs now recommend a preoperative protein-rich liquid diet immediately prior to surgery to aid weight loss and some have even advocated inpatient weight-loss programs in the adolescent with extreme obesity (BMI > 60 kg/m^2) [45, 56]. Weight loss, however, should not be absolutely required prior to surgery as many patients cannot achieve that goal even while working with a multidisciplinary team.

Outcomes

MBS has been demonstrated to be safe in both adults and adolescents. A 2014 cohort study of 345 adolescents after bariatric surgery demonstrated a low rate of short term complications and weight loss similar to adults [57]. Similarly, data from Teen-LABS demonstrated a favorable short-term complication profile with no perioperative deaths, a major complication rate of 8% and a minor complication rate of 15% [37••]. MBS has also been demonstrated to result in clinically significant weight loss. A systematic review and meta-analysis of adolescent MBS demonstrated an average weighted BMI difference from baseline to 1 year of − 13.5 kg/m^2 when including all procedures. When analyzed by procedure type, weight loss was greatest for RYGB and least for AGB [58]. Inge and colleagues found a 37% reduction in BMI at 1 year for patients undergoing RYGB, regardless of starting BMI [38]. More recently, data from Teen-LABS including 242 adolescents who underwent MBS at one of five adolescent bariatric centers demonstrated BMI reductions of 15.1 kg/m^2 (28%), 13.1 kg/m^2 (28%), and 3.8 kg/m^2 (8%) among adolescents undergoing RYGB, VSG, and AGB procedures, respectively after 3 years (Table 1) [14••]. Similarly, a study of adolescents in Saudi Arabia who underwent VSG demonstrated a BMI decrease of 20 kg/m^2 over 3 years [59].

Furthermore, excess body weight loss at 1 year was similar between adolescents and adults, 32.9% versus 32.5%, respectively [60]. When looking specifically at VSG, now the most commonly performed procedure in adolescents, similar weight loss has also been observed at 12 and 24 months for adolescents (65.8% and 64.9%, respectively) compared with adults (68.9% and 69.7%, respectively) [61]. Adult studies, however, have commonly demonstrated a modest degree of weight gain from 3 to 10 years following essentially all MBS. Therefore, longer-term follow-up is necessary to assess the long-term durability of weight loss outcomes in adolescents [62].

MBS also results in significant improvement in comorbidities. Adult studies have demonstrated that MBS results in complete resolution of T2D in 78% of patients and improvement in 86% of patients [63]. Interestingly, the degree of weight loss has not been found to be a predictor of diabetes remission, suggesting that surgery may improve glycemic control by some other mechanism or a threshold phenomenon [64]. Similarly, Teen-LABS demonstrated that by 3 years after MBS, remission of type 2 diabetes occurred in 95% of patients. Moreover, remission of abnormal kidney function, prediabetes, hypertension, and dyslipidemia occurred in 86%, in 76%, 74%, and 66% of patients respectively [14]. These findings are consistent with other retrospective studies and systematic reviews including adolescent cohorts [65].

Teen-LABS also demonstrated a significant improvement in weight-related quality of life as well as overall improved functional status, resting heart rate, and reduction of walking-related musculoskeletal pain up to 2 years after surgery [14••, 66]. Other studies have also demonstrated improvement in depression, anxiety, and self-image following adolescent MBS, with the most substantial improvements observed within the first year after surgery. The greatest gains appear to be in physical comfort and body esteem domains of quality of life [67–69], and these improvements are markedly better than what is observed in adult MBS patients [69, 70]. Perhaps most importantly, a recent pilot study has shown improvements in cognitive and executive function after weight loss in adolescents after VSG, suggesting that the developing adolescent brain itself suffers adverse effects of obesity [71, 72]. Larger and more extensive studies are required, however, to determine the direct mechanism by which obesity affects brain function, and how it is reversed with weight loss.

Complications

Unfortunately, data regarding complications after adolescent MBS are inconsistently reported in the literature (Table 1).

Table 1 Perioperative complications of the three main bariatric surgical procedures along with BMI reduction by procedure as reported by the Teen-LABS study group [14]

	Adjustable gastric band (ABG)	Vertical sleeve gastrectomy (VSG)	Roux-en-Y gastric bypass (RYGB)
Perioperative complications	•Band migration •Band erosion	•GERD •Staple line leak •Postoperative hemorrhage •DVT •Dehydration •Nutritional deficiencies	•Anastomotic leak •Stricture •Bowel obstruction •Wound infection •Postoperative hemorrhage •DVT •Dumping syndrome •Nutritional deficiencies
BMI (kg/m2) reduction at 3 years	3.8	13.1	15.1

Postoperative complications after RYGB include, but are not limited to, anastomotic leak, strictures, postoperative bleeding, bowel obstructions, wound infections, deep venous thrombosis, and hospital readmissions [37••]. Nutritional complications are also common and include deficiency of folate, vitamin B12, iron, and calcium. Dumping syndrome also occurs in the majority of patients but can be ameliorated by dietary behavior modification [27]. Therefore, RYGB for adolescents is not the preferred primary procedure in many centers. Common postoperative risks after VSG include, but are not limited to, worsened gastroesophageal reflux, staple line leak, deep venous thrombosis, hemorrhage, dehydration, and malnutrition. However, the overall complication rate is significantly less than that of RYGB [73].

Retrospective analyses of administrative databases suggest that the frequency of complications is comparable and perhaps lower in adolescents as compared with adults undergoing MBS [74]. These results, however, have been validated in only a few prospective clinical studies. Our center published a review of 30-day outcomes in children and adolescents after VSG and demonstrated a major and minor complication rate of 3.8% [75]. Meanwhile, multicenter prospective complication data were reported in the Teen-LABS studies, which included a majority of patients undergoing RYGB. An additional intraabdominal procedure was required in 13% of all study participants. Twenty-four percent of these procedures occurred in the first year after surgery, while 55% and 21% occurred in the second and third year, respectively. The most common operation performed was a cholecystectomy, which was performed in 8% of all participants after MBS. Upper endoscopic procedures were also common. The most serious complications were observed in patients undergoing RYGB, while only four VSG patients required reoperation, including two with serious complications; a staple line leak requiring a stent and one conversion to bypass due to severe reflux [14••].

The most significant long-term complications of adolescent MBS are nutritional deficiencies, which may be associated with all three procedures, but occur most frequently after RYGB. Preoperative deficiencies obviously place patients at increased risk for postoperative deficiencies. The most common vitamin deficiencies include vitamin B12, thiamine, vitamin D, vitamin A, folic acid, iron, copper, and zinc [1]. Teen-LABS demonstrated that 37% of patients were vitamin D deficient at baseline, and 43% of RYGB and VSG patients were deficient at 3 years post-surgery. Vitamin B12 deficiency had a statistically significant increase from 1 to 8% from baseline to 3 years. Similarly, low ferritin levels increased from 5 to 57% of patients from baseline to 3 years, and vitamin A deficiency increased from 6 to 13% [14••]. Lifelong nutritional monitoring and vitamin supplementation are therefore recommended for all MBS patients and continued supplementation recommended based on periodic monitoring [39].

Access to MBS

Despite current literature supporting the potential benefits of MBS in achieving sustainable weight loss and improving comorbid conditions, access to MBS continues to be a problem for many patients. Attitudes among primary care providers, the first line in the identification of potential surgical candidates, remain mixed, and delayed referral may be due to inadequate knowledge or unsupported fears about MBS. There is also a paucity of MBSAQIP- accredited adolescent bariatric surgery centers, often making travel time and geographic access more difficult. Furthermore, there is a discrepancy between insurance approvals for adults and adolescents desiring MBS. A multi-institutional retrospective review demonstrated that less than half of adolescents meeting criteria for weight loss surgery were approved on initial request, as compared to more than 80% of adults [76]. Fortunately, 80% of those adolescents were eventually able to obtain insurance approval following multiple appeals [76]. These barriers and delay to care, however, can have significant consequences. Delay in referral and operation can result in more weight gain and advanced comorbid conditions prior to surgery. MBS is highly successful but, in general, results in a fixed percent of excess weight loss so that those starting at a higher weight and BMI will likely remain over the threshold for obesity (BMI > 30) even after their MBS. Patients at a lower preoperative BMI, conversely, have an improved chance of attaining normal or near-normal BMI after MBS as compared with patients who have to wait for surgery at a higher BMI. Remission of comorbid conditions is also more likely less advanced than the conditions. For example, analysis of adults with long duration (> 10 years) T2D demonstrated smaller improvements in HbA1c and pancreatic β cell function as compared with those with shorter duration (< 5 years), independent of weight loss after surgery [77]. As more and more data become available concerning the long-term outcomes of MBS, it is likely that earlier surgical intervention will be preferred. Moreover, earlier intervention at both younger ages and lower BMI will likely make the most significant difference for the adolescent patient [78].

Conclusions

The rise of childhood obesity and its associated comorbidities has been rapid, and proposed treatment options have not kept pace. Early referral to a multidisciplinary adolescent bariatric surgery program is essential to help treat patients suffering from this debilitating disease. Once in a multidisciplinary clinic, all modalities including diet and exercise, behavioral therapy, pharmacological, and surgical intervention play a role in providing optimal care for these patients. And as newer interventions become approved for use in adults, they too should be trialed in adolescents. In the current state of field, however, MBS is indeed the most successful strategy for significant and sustained weight loss and remission of comorbidities for adolescents suffering from severe obesity. Thus, any adolescent eligible for MBS should be suitably informed regarding potential surgical interventions if best practice is to be achieved.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
•• Of major importance

1. Desai NK, Wulkan ML, Inge TH. Update on adolescent bariatric surgery. Endocrinol Metab Clin N Am. 2016;45(3):667–76.
2. Skinner AC, Ravanbakht SN, Skelton JA, Perrin EM, Armstrong SC. Prevalence of obesity and severe obesity in US children, 1999–2016. Pediatrics. 2018;141(3).
3. Ogden CL, Carroll MD, Fryar CD, Flegal KM. Prevalence of obesity among adults and youth: United States. NCHS Data Brief. 2011-2014;2015(219):1–8.
4. Kelly AS, Barlow SE, Rao G, Inge TH, Hayman LL, Steinberger J, et al. Severe obesity in children and adolescents: identification, associated health risks, and treatment approaches: a scientific statement from the American Heart Association. Circulation. 2013;128(15):1689–712.
5. Kohler MJ, Thormaehlen S, Kennedy JD, Pamula Y, van den Heuvel CJ, Lushington K, et al. Differences in the association between obesity and obstructive sleep apnea among children and adolescents. J Clin Sleep Med. 2009;5(6):506–11.
6. May AL, Kuklina EV, Yoon PW. Prevalence of cardiovascular disease risk factors among US adolescents, 1999-2008. Pediatrics. 2012;129(6):1035–41.
7. Holterman A, Gurria J, Tanpure S, DiSomma N. Nonalcoholic fatty liver disease and bariatric surgery in adolescents. Semin Pediatr Surg. 2014;23(1):49–57.
8. Abdullah A, Wolfe R, Stoelwinder JU, de Courten M, Stevenson C, Walls HL, et al. The number of years lived with obesity and the risk of all-cause and cause-specific mortality. Int J Epidemiol. 2011;40(4):985–96.
9. Juonala M, Magnussen CG, Berenson GS, Venn A, Burns TL, Sabin MA, et al. Childhood adiposity, adult adiposity, and cardiovascular risk factors. N Engl J Med. 2011;365(20):1876–85.
10. Upadhyay J, Farr O, Perakakis N, Ghaly W, Mantzoros C. Obesity as a disease. Med Clin North Am. 2018;102(1):13–33.
11.•• Pratt JSA, Browne A, Browne NT, Bruzoni M, Cohen M, Desai A, et al. ASMBS pediatric metabolic and bariatric surgery guidelines, 2018. Surg Obes Relat Dis. 2018;14(7):882–901 **This is the most currently updated evidence-based guideline for the selection of adolescent patients for metabolic and bariatric surgery.**
12. Danielsson P, Kowalski J, Ekblom Ö, Marcus C. Response of severely obese children and adolescents to behavioral treatment. Arch Pediatr Adolesc Med. 2012;166(12):1103–8.
13. Watowicz R, Tindall A, Eneli U. Implementation of an inpatient protein-sparing modified fast for severely obese adolescents. J Acad Nutr Diet 2014. p. A35.
14.•• Inge TH, Courcoulas AP, Xanthakos SA. Weight loss and health status after bariatric surgery in adolescents. N Engl J Med. 2016;374(20):1989–90 **This multicenter, prospective study of bariatric surgery in adolescents demonstrates outcomes in weight loss and associated comorbidities at 3 years after surgery**.
15. Mason EE, Ito C. Gastric bypass in obesity. Surg Clin North Am. 1967;47(6):1345–51.
16. Sjöström L, Narbro K, Sjöström CD, Karason K, Larsson B, Wedel H, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. N Engl J Med. 2007;357(8):741–52.
17. Adams TD, Gress RE, Smith SC, Halverson RC, Simper SC, Rosamond WD, et al. Long-term mortality after gastric bypass surgery. N Engl J Med. 2007;357(8):753–61.
18. Greenstein RJ, Rabner JG. Is adolescent gastric-restrictive antiobesity surgery warranted? Obes Surg. 1995;5(2):138–44.
19. Tsai WS, Inge TH, Burd RS. Bariatric surgery in adolescents: recent national trends in use and in-hospital outcome. Arch Pediatr Adolesc Med. 2007;161(3):217–21.
20. Zwintscher NP, Azarow KS, Horton JD, Newton CR, Martin MJ. The increasing incidence of adolescent bariatric surgery. J Pediatr Surg. 2013;48(12):2401–7.
21. Kelleher DC, Merrill CT, Cottrell LT, Nadler EP, Burd RS. Recent national trends in the use of adolescent inpatient bariatric surgery: 2000 through 2009. JAMA Pediatr. 2013;167(2):126–32.
22. Dimick JB, Finks JF. The beginning of the end for laparoscopic banding. JAMA Surg. 2014;149(12):1287–8.
23. Elder KA, Wolfe BM. Bariatric surgery: a review of procedures and outcomes. Gastroenterology. 2007;132(6):2253–71.
24. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2011. Obes Surg. 2013;23(4):427–36.
25. Nadler EP, Youn HA, Ren CJ, Fielding GA. An update on 73 US obese pediatric patients treated with laparoscopic adjustable gastric banding: comorbidity resolution and compliance data. J Pediatr Surg. 2008;43(1):141–6.
26. Koh CY, Inaba CS, Sujatha-Bhaskar S, Hohmann S, Ponce J, Nguyen NT. Laparoscopic adjustable gastric band explantation and implantation at academic centers. J Am Coll Surg. 2017;225(4):532–7.
27. Treadwell JR, Sun F, Schoelles K. Systematic review and meta-analysis of bariatric surgery for pediatric obesity. Ann Surg. 2008;248(5):763–76.
28. Langer FB, Reza Hoda MA, Bohdjalian A, Felberbauer FX, Zacherl J, Wenzl E, et al. Sleeve gastrectomy and gastric banding: effects on plasma ghrelin levels. Obes Surg. 2005;15(7):1024–9.
29. Mion F, Napoléon B, Roman S, Malvoisin E, Trepo F, Pujol B, et al. Effects of intragastric balloon on gastric emptying and plasma ghrelin levels in non-morbid obese patients. Obes Surg. 2005;15(4):510–6.
30. Thompson CC, Abu Dayyeh BK, Kushner R, Sullivan S, Schorr AB, Amaro A, et al. Percutaneous gastrostomy device for the treatment of class II and class III obesity: results of a randomized controlled trial. Am J Gastroenterol. 2017;112(3):447–57.
31. Apovian CM, Shah SN, Wolfe BM, Ikramuddin S, Miller CJ, Tweden KS, et al. Two-year outcomes of vagal nerve blocking (vBloc) for the treatment of obesity in the ReCharge trial. Obes Surg. 2017;27(1):169–76.
32. NIH conference. Gastrointestinal surgery for severe obesity. Consensus development conference panel. Ann Intern Med 1991;115(12):956–61.

33. Pratt JS, Lenders CM, Dionne EA, Hoppin AG, Hsu GL, Inge TH, et al. Best practice updates for pediatric/adolescent weight loss surgery. Obesity (Silver Spring). 2009;17(5):901–10.
34. Michalsky M, Reichard K, Inge T, Pratt J, Lenders C. Surgery ASfMaB. ASMBS pediatric committee best practice guidelines. Surg Obes Relat Dis. 2012;8(1):1–7.
35. Alqahtani A, Elahmedi M, Qahtani AR. Laparoscopic sleeve gastrectomy in children younger than 14 years: refuting the concerns. Ann Surg. 2016;263(2):312–9.
36. Teeple EA, Teich S, Schuster DP, Michalsky MP. Early metabolic improvement following bariatric surgery in morbidly obese adolescents. Pediatr Blood Cancer. 2012;58(1):112–6.
37.•• Inge TH, Zeller MH, Jenkins TM, Helmrath M, Brandt ML, Michalsky MP, et al. Perioperative outcomes of adolescents undergoing bariatric surgery: the Teen-Longitudinal Assessment of Bariatric Surgery (Teen-LABS) study. JAMA Pediatr. 2014;168(1):47–53 **This multicenter, prospective study of adolescents undergoing bariatric surgery demonstrates the safety and short term effectiveness of surgery**.
38. Inge TH, Jenkins TM, Zeller M, Dolan L, Daniels SR, Garcia VF, et al. Baseline BMI is a strong predictor of nadir BMI after adolescent gastric bypass. J Pediatr. 2010;156(1):103–8.e1.
39. Mechanick JI, Youdim A, Jones DB, Garvey WT, Hurley DL, McMahon MM, et al. Clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient–2013 update: cosponsored by American Association of Clinical Endocrinologists, the Obesity Society, and American Society for Metabolic & Bariatric Surgery. Endocr Pract. 2013;19(2):337–72.
40. Mackey ER, Wang J, Harrington C, Nadler EP. Psychiatric diagnoses and weight loss among adolescents receiving sleeve gastrectomy. Pediatrics. 2018;142(1).
41. Wulkan ML, Walsh SM. The multi-disciplinary approach to adolescent bariatric surgery. Semin Pediatr Surg. 2014;23(1):2–4.
42. Inge TH, Krebs NF, Garcia VF, Skelton JA, Guice KS, Strauss RS, et al. Bariatric surgery for severely overweight adolescents: concerns and recommendations. Pediatrics. 2004;114(1):217–23.
43. Inge TH, Garcia V, Daniels S, Langford L, Kirk S, Roehrig H, et al. A multidisciplinary approach to the adolescent bariatric surgical patient. J Pediatr Surg. 2004;39(3):442–7 **discussion 6-7**.
44. Hsia DS, Fallon SC, Brandt ML. Adolescent bariatric surgery. Arch Pediatr Adolesc Med. 2012;166(8):757–66.
45. Koeck ES, Barefoot LC, Hamrick M, Owens JA, Qureshi FG, Nadler EP. Predicting sleep apnea in morbidly obese adolescents undergoing bariatric surgery. Surg Endosc. 2014;28(4):1146–52.
46. Franklin AL, Koeck ES, Hamrick MC, Qureshi FG, Nadler EP. Prevalence of chronic gastritis or helicobacter pylori infection in adolescent sleeve gastrectomy patients does not correlate with symptoms or surgical outcomes. Surg Infect. 2015;16(4):401–4.
47. Austin H, Smith K, Ward WL. Psychological assessment of the adolescent bariatric surgery candidate. Surg Obes Relat Dis. 2013;9(3):474–80.
48. Zeller MH, Roehrig HR, Modi AC, Daniels SR, Inge TH. Health-related quality of life and depressive symptoms in adolescents with extreme obesity presenting for bariatric surgery. Pediatrics. 2006;117(4):1155–61.
49. Glasofer DR, Tanofsky-Kraff M, Eddy KT, Yanovski SZ, Theim KR, Mirch MC, et al. Binge eating in overweight treatment-seeking adolescents. J Pediatr Psychol. 2007;32(1):95–105.
50. Ochner CN, Dambkowski CL, Yeomans BL, Teixeira J, Xavier Pi-Sunyer F. Pre-bariatric surgery weight loss requirements and the effect of preoperative weight loss on postoperative outcome. Int J Obes. 2012;36(11):1380–7.
51. Aberle J, Freier A, Busch P, Mommsen N, Beil FU, Dannheim V, et al. Treatment with sibutramine prior to Roux-en-Y gastric bypass leads to an improvement of metabolic parameters and to a reduction of liver size and operative time. Obes Surg. 2009;19(11):1504–7.
52. Liu RC, Sabnis AA, Forsyth C, Chand B. The effects of acute preoperative weight loss on laparoscopic Roux-en-Y gastric bypass. Obes Surg. 2005;15(10):1396–402.
53. Fris RJ. Preoperative low energy diet diminishes liver size. Obes Surg. 2004;14(9):1165–70.
54. Benotti PN, Still CD, Wood GC, Akmal Y, King H, El Arousy H, et al. Preoperative weight loss before bariatric surgery. Arch Surg. 2009;144(12):1150–5.
55. Still CD, Benotti P, Wood GC, Gerhard GS, Petrick A, Reed M, et al. Outcomes of preoperative weight loss in high-risk patients undergoing gastric bypass surgery. Arch Surg. 2007;142(10):994–8 **discussion 9**.
56. Kruger AJ, Hrovat KB, Xanthakos SA, Inge TH. Preparation of a severely obese adolescent for significant and long-term weight loss: an illustrative case. Pediatr Surg Int. 2013;29(8):835–9.
57. Lennerz BS, Wabitsch M, Lippert H, Wolff S, Knoll C, Weiner R, et al. Bariatric surgery in adolescents and young adults–safety and effectiveness in a cohort of 345 patients. Int J Obes. 2014;38(3):334–40.
58. Black JA, White B, Viner RM, Simmons RK. Bariatric surgery for obese children and adolescents: a systematic review and meta-analysis. Obes Rev. 2013;14(8):634–44.
59. Alqahtani AR, Antonisamy B, Alamri H, Elahmedi M, Zimmerman VA. Laparoscopic sleeve gastrectomy in 108 obese children and adolescents aged 5 to 21 years. Ann Surg. 2012;256(2):266–73.
60. Zitsman JL, Digiorgi MF, Marr JR, Witt MA, Bessler M. Comparative outcomes of laparoscopic adjustable gastric banding in adolescents and adults. Surg Obes Relat Dis. 2011;7(6):720–6.
61. Alqahtani A, Alamri H, Elahmedi M, Mohammed R. Laparoscopic sleeve gastrectomy in adult and pediatric obese patients: a comparative study. Surg Endosc. 2012;26(11):3094–100.
62. Odom J, Zalesin KC, Washington TL, Miller WW, Hakmeh B, Zaremba DL, et al. Behavioral predictors of weight regain after bariatric surgery. Obes Surg. 2010;20(3):349–56.
63. Buchwald H, Estok R, Fahrbach K, Banel D, Jensen MD, Pories WJ, et al. Weight and type 2 diabetes after bariatric surgery: systematic review and meta-analysis. Am J Med. 2009;122(3):248–56.e5.
64. McGinty S, Richmond TK, Desai NK. Managing adolescent obesity and the role of bariatric surgery. Curr Opin Pediatr. 2015;27(4):434–41.
65. Paulus GF, de Vaan LE, Verdam FJ, Bouvy ND, Ambergen TA, van Heurn LW. Bariatric surgery in morbidly obese adolescents: a systematic review and meta-analysis. Obes Surg. 2015;25(5):860–78.
66. Ryder JR, Edwards NM, Gupta R, Khoury J, Jenkins TM, Bout-Tabaku S, et al. Changes in functional mobility and musculoskeletal pain after bariatric surgery in teens with severe obesity: Teen-Longitudinal Assessment of Bariatric Surgery (LABS) study. JAMA Pediatr. 2016;170(9):871–7.
67. Järvholm K, Olbers T, Marcus C, Mårild S, Gronowitz E, Friberg P, et al. Short-term psychological outcomes in severely obese adolescents after bariatric surgery. Obesity (Silver Spring). 2012;20(2):318–23.
68. Karlsson J, Taft C, Rydén A, Sjöström L, Sullivan M. Ten-year trends in health-related quality of life after surgical and conventional treatment for severe obesity: the SOS intervention study. Int J Obes. 2007;31(8):1248–61.
69. Zeller MH, Reiter-Purtill J, Ratcliff MB, Inge TH, Noll JG. Two-year trends in psychosocial functioning after adolescent Roux-en-Y gastric bypass. Surg Obes Relat Dis. 2011;7(6):727–32.
70. Zeller MH, Modi AC, Noll JG, Long JD, Inge TH. Psychosocial functioning improves following adolescent bariatric surgery. Obesity (Silver Spring). 2009;17(5):985–90.

71. Mackey ER, Jacobs M, Nadler EP, Olson A, Pearce A, Cherry JBC, et al. Cognitive performance as predictor and outcome of adolescent bariatric surgery: a nonrandomized pilot study. J Pediatr Psychol. 2018;43(8):916–27.
72. Pearce AL, Mackey E, Cherry JBC, Olson A, You X, Magge SN, et al. Effect of adolescent bariatric surgery on the brain and cognition: a pilot study. Obesity (Silver Spring). 2017;25(11):1852–60.
73. Osland E, Yunus RM, Khan S, Alodat T, Memon B, Memon MA. Postoperative early major and minor complications in laparoscopic vertical sleeve gastrectomy (LVSG) versus laparoscopic Roux-en-Y gastric bypass (LRYGB) procedures: a meta-analysis and systematic review. Obes Surg. 2016;26(10):2273–84.
74. Varela JE, Hinojosa MW, Nguyen NT. Perioperative outcomes of bariatric surgery in adolescents compared with adults at academic medical centers. Surg Obes Relat Dis. 2007;3(5):537–40 **discussion 41-2**.
75. Speer AL, Parekh J, Qureshi FG, Nadler EP. Thirty-day outcomes for children and adolescents undergoing laparoscopic sleeve gastrectomy at a free-standing children's hospital. Clin Obes. 2017;7(2):86–91.
76. Inge TH, Boyce TW, Lee M, Kollar L, Jenkins TM, Brandt ML, et al. Access to care for adolescents seeking weight loss surgery. Obesity (Silver Spring). 2014;22(12):2593–7.
77. Khanna V, Malin SK, Bena J, Abood B, Pothier CE, Bhatt DL, et al. Adults with long-duration type 2 diabetes have blunted glycemic and β-cell function improvements after bariatric surgery. Obesity (Silver Spring). 2015;23(3):523–6.
78. Khattab A, Sperling MA. Obesity in adolescents and youth: the case for and against bariatric surgery. J Pediatr. 2019.