

ADOLESCENT BARIATRIC SURGERY

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ABSTRACT

The prevalence of adolescent obesity has rapidly increased over the past several decades. With this increase, there has also been a rise in the prevalence of complications of obesity leading to premature mortality. While lifestyle and medical management remain a part of the initial treatment of obesity, these therapies have been shown to be inferior when compared to metabolic and bariatric surgery (MBS) for adolescents with severe obesity. A multidisciplinary approach is recommended to evaluate medically eligible candidates for MBS, prepare patients for surgery, and guide postoperative management. Laparoscopic sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) are the most common MBS procedures performed in both adolescent and adult patients. Postoperative hospital stays are generally short and long-term routine follow-up with the MBS team is recommended to monitor weight loss, resolution of complications of obesity, and to monitor for postoperative complications. Most adolescent MBS studies demonstrate an average percent body mass index loss between 25-29% after surgery. This is also associated with resolution or improvement of most complications of obesity at rates that are similar or superior to adult studies. Resolution and prevention of type 2 diabetes mellitus (T2DM) after MBS is a particularly compelling reason to pursue surgical

treatment due to the complications from T2DM that occur over a patient's lifetime as well as the overall burden of health-related costs. These adverse consequences of T2DM can be mitigated by early use of MBS. MBS is generally well tolerated. Complication rates are similar to adult patients therefore it is recommended to refer patients for MBS whenever they are medically qualified. Most common short-term (<30 days) complications include leak, bleeding, and surgical site infections. Most common long-term (>30 days) complications are nutritional deficiencies.

INTRODUCTION

The prevalence of worldwide overweight and obesity in adolescents has more than quadrupled since 1975. Currently, it is estimated that over 14 million children and adolescents age 2-19 years suffer from obesity in the United States alone (1, 2). Adolescents with obesity are at risk for developing significant comorbidities including insulin resistance, type 2 diabetes mellitus (T2DM), hypertension, dyslipidemia, obstructive sleep apnea, nonalcoholic fatty liver disease, depression, polycystic ovarian syndrome, impaired quality of life, cardiovascular disease, and longer term, certain malignancies (3-9). Similar to obesity, the prevalence of T2DM has been increasing dramatically (3). Obesity is a major risk factor the

development of T2DM with overweight adolescents having close to a three times greater risk of developing T2DM when compared to adolescents with normal weight (10-12). Additionally, obesity in adolescence is associated with persistent obesity into adulthood, increased risk for obesity related comorbidities, and premature mortality in adulthood (13-15). Lifestyle and medical management remain the first-line treatment for adolescent obesity. However, current evidence suggests that pharmacotherapy, dietary, and behavioral modifications rarely lead to long-term weight loss in adolescents with severe obesity (16-18). The use of metabolic and bariatric surgery (MBS) in adolescents with severe obesity and complications of obesity has been shown to have superior results in both efficacy and durability (19). Despite growing evidence of the efficacy and durability of MBS for the treatment of severe obesity in adolescent patients, utilization of MBS in adolescent patients is low and there have been documented racial and socioeconomic disparities (20-22).

PREOPERATIVE EVALUATION

Multidisciplinary Program

A multidisciplinary approach is recommended when considering MBS for an adolescent (23, 24). At a minimum, this includes a bariatric surgeon with adolescent experience, pediatrician, dietitian, nurse, and pediatric psychologist. It is also important that the core providers have access to additional pediatric specialists including anesthesiologists, radiologists,

and appropriate specialists to aid the management of complications of obesity (e.g., pulmonology, endocrinology, gastroenterology/hepatology). Adolescents undergoing preoperative work-up should be evaluated for the presence and severity of complications of obesity. Additionally, it is important for the multidisciplinary team to determine a potential patient and caregivers' ability to assess the risks and benefits of surgery as well as to adhere to postoperative requirements including daily vitamin regimens and attending postoperative visits.

Patient Selection

BODY MASS INDEX (BMI)

The following criteria have been recommended by multiple panels of experts for consideration of weight loss surgery in adolescents under 18 years old: (4, 19, 25)

- **BMI \geq 120 percent of the 95th percentile for BMI for age or BMI \geq 35kg/m²**, whichever is lower, **with complications of obesity** that have a significant effect on health (Table 1).
 - OR -
 - **BMI \geq 140 percent of the 95th percentile of BMI for age or BMI \geq 40 kg/m²**, whichever is lower
- Of note, the BMI threshold for adult patients for the recommendation has been reduced in the 2022 guidelines, therefore changes to adolescent recommendations may follow suit in future updates (26).

Table 1. Qualifying Comorbidities for Consideration of MBS in Adolescents (4).

Obstructive sleep apnea (apnea-hypoxia index > 5)
Type 2 diabetes mellitus
Idiopathic intracranial hypertension
Nonalcoholic steatohepatitis
Blount's disease
Slipped capital femoral epiphysis
Gastroesophageal Reflux Disease
Hypertension

CONTRAINDICATIONS

Contraindications to adolescent MBS are listed in Table 2.

Table 2. Contraindications to Adolescent MBS

Medically correctable cause of obesity
Ongoing substance abuse problem (within the preceding year)
Medical, psychiatric, psychosocial, or cognitive condition that prevents adherence to postoperative dietary and medication regimens or impairs decisional capacity
Current or planned pregnancy within 18 months of the procedure
Inability for patient or caregivers to comprehend risks and benefits of surgical weight loss procedure

AGE

A recent cohort analysis of more than 600,000 adolescents aged 13-17 found that 1 in 23 adolescents met criteria for MBS (27). A retrospective review of the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) data registry from 2015 to 2018 demonstrated that adolescents and young adults only represented 3.7% of total MBS cases performed, suggesting significant underutilization within this population (28). Multiple studies have evaluated the safety and efficacy of MBS in younger adolescents. Current evidence suggests there are no significant clinical differences in outcomes between MBS in younger (e.g., <13 years) versus older adolescents (e.g., ≥13 years) (29-35). It is therefore not recommended to limit access to MBS based on patient's age, physical maturity (e.g., bone age), or

pubertal status. These findings have prompted increased advocacy for the use of MBS in the adolescent population by the American Academy of Pediatrics (19, 36).

TYPES OF SURGERY

Sleeve Gastrectomy

A laparoscopic sleeve gastrectomy (SG) results in the removal of the greater curvature of the stomach resulting in a smaller, tubular stomach that has a reduced capacity (Figure 1). Given the procedure is less complex than the Roux-en-Y gastric bypass (RYGB) and has less risk for micronutrient deficiencies, it is an appealing option for adolescents. Sleeve gastrectomies currently account for approximately 80% of bariatric procedures in

adolescents (28, 37-39). A SG may also be converted to RYGB in the event additional MBS is indicated or in

the setting of postoperative medically refractory gastroesophageal reflux disease (GERD).

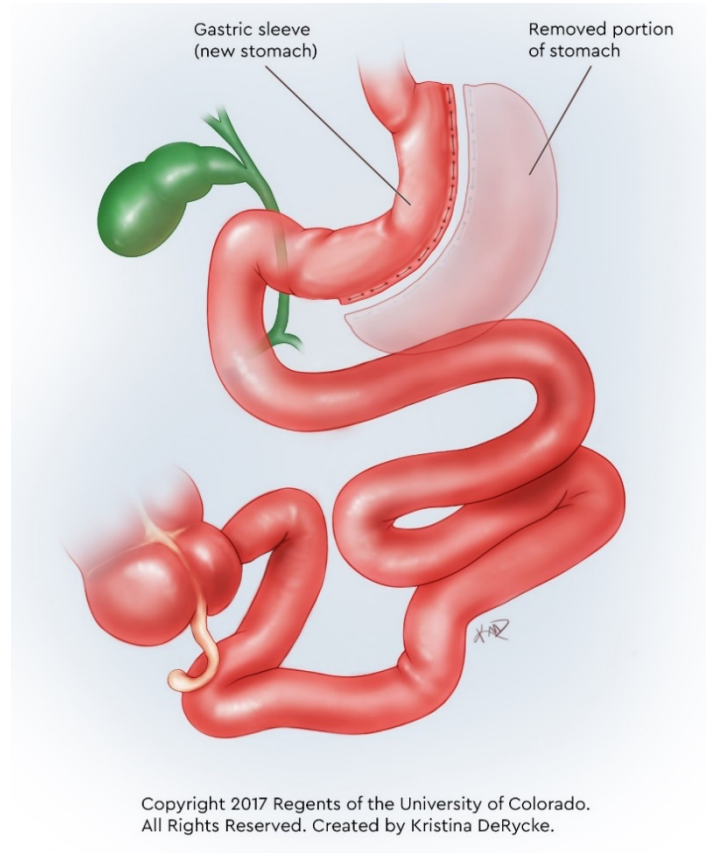
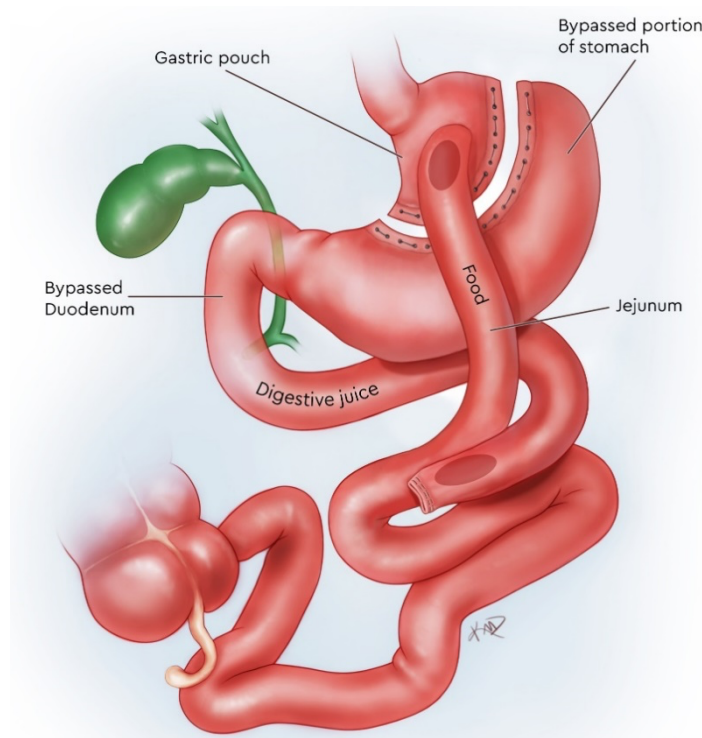


Figure 1. Sleeve Gastrectomy.

Roux-en-Y Gastric Bypass

Laparoscopic Roux-en-Y gastric bypass (RYGB) involves creating a small, proximal gastric pouch which is separated from the remnant stomach and anastomosed to a Roux-limb of small bowel 70-150

cm distally (Figure 2). The RYGB results in similar weight loss when compared to SG and dramatically improves glycemic control (38, 40). The incidence of postoperative GERD is significantly less following RYGB compared to SG, making the procedure an attractive option for adolescents with GERD at baseline (41).



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Figure 2. Roux-en-Y Gastric Bypass.

Others

Additional procedures including intragastric balloons are not currently approved by the United States Food and Drug Administration (FDA) for use in adolescents. Adjustable gastric bands have been previously used in the adolescent population. However, they have fallen out of favor due to inferior efficacy compared to SG and RYGB (42).

POSTOPERATIVE MANAGEMENT

Inpatient

Average inpatient stay is typically <2 days following both a SG and RYGB (43). Patients are monitored for immediate postoperative complications including a leak, bleeding, and venous thromboembolism (VTE).

Following discharge, patients are seen at regular postoperative visits to monitor body weight, nutritional status, and to manage complications of obesity.

Diet

Following a SG or RYGB, patients gradually progress from a high protein liquid diet to incorporating small volumes of regular food. Patients are encouraged to eat three to four protein-rich meals a day while avoiding carbohydrate rich foods. Supplemental sugar-free fluids between meals are also essential following surgery to avoid dehydration. Patients are typically encouraged to avoid excessive fluids with meals to minimize nausea and maximize nutritional intake with meals due to the restrictive component of both procedures.

Postoperative nausea is not uncommon following surgery but typically self resolves. Meals high in carbohydrates or sugar and fats can result in dumping syndrome or weight regain following surgery. Some providers recommend limiting carbonated or caffeinated beverages following MBS based on theoretical concerns, however there is minimal evidence to support this apprehension.

Similar to non-operative weight loss recommendations, general recommendations including exercising for 30 to 60 minutes daily, drinking sugar-free fluids, and portion-controlled protein rich meals are the same. Overall, it is recommended that patient and caregiver meet with a dietitian prior to discharge to develop a plan tailored to patient’s specific nutritional needs. Regular follow-up visits with

a dietitian are also recommended to assist with postoperative weight management and to monitor for nutritional deficiencies.

Nutritional Supplements and Monitoring

Although SG may be associated with a decreased risk of nutritional deficiencies when compared to RYGB, lifelong supplementation with vitamins and minerals is recommended following both operations (Table 3) (44). Patients are particularly at risk for deficiencies in iron, vitamin B12, and vitamin D. Additionally, lifelong annual monitoring of nutritional and micronutrient status is recommended with annual laboratory testing (Table 3). Adjustments in supplements may need to be made over time as specific deficiencies emerge.

Table 3. Nutritional Supplementation and Monitoring Recommendations (45)
Nutritional Supplements
Standard multivitamin with folate or iron, or prenatal vitamin if female (once or twice daily)
Vitamin B12, 500mcg sublingually daily, or 1000mcg intramuscularly monthly
Calcium, 1200 to 1500mg daily (measured as elemental calcium) with 800 to 1000 international units of vitamin D.
Annual Nutritional Monitoring
Complete blood cell count with differential
Serum iron and ferritin
Red blood cell folate, serum vitamin B12, and serum homocysteine
Serum thiamin (vitamin B1)
Hepatic panel (including albumin, total protein, serum aminotransferase levels, gamma-glutamyl transpeptidase, and alkaline phosphatase
Calcium, 25-hydroxyvitamin D, and parathyroid hormone
Dual-energy x-ray absorptiometry (DXA) scan to monitor bone density (optimal frequency not yet established)

Pregnancy Prevention

Pregnancy should be avoided for 12 to 18 months following MBS to allow patients to achieve weight maintenance and to avoid potential micronutrient deficiencies which may affect both patient and fetus

(46). Obesity can result in decreased fertility secondary to irregular menstruation and ovulatory dysfunction (47, 48). Weight loss after MBS has been shown to result in more regular ovulation and improved fertility (49, 50). In a retrospective review of 47 adolescents who underwent MBS surgery, seven pregnancies occurred, six of them within 10 to 22

months following surgery (51). While all six deliveries were healthy and at term, the twofold higher than anticipated pregnancy rate highlights the need for contraception counseling following MBS.

Multiple studies have evaluated the efficacy of hormonal contraceptive methods in patients with elevated BMIs and no definitive association was found between higher BMI and effectiveness of hormonal contraceptives (52). Due to concern for malabsorption after intestinal bypass procedures and the subsequent potential for decreased oral contraceptive efficacy, the American College of Obstetrics and Gynecology recommend using non-oral forms of hormonal contraception in patients who have undergone malabsorptive MBS (53). Additionally, oral contraceptives are associated with increased risk of venous thromboembolism (VTE) which may be worrisome for adolescents with elevated BMIs who already have a higher predisposition for VTE (54, 55).

Intrauterine devices (IUDs) are an appealing option following MBS in adolescent patients as they are one of the most effective contraception methods, do not increase risk of VTE, and can be placed at the time of surgery (56). Levonorgestrel-releasing IUDs have the added benefit of promoting amenorrhea which could help reduce the risk of iron deficiency anemia following surgery (57). Regardless of the form of contraception selection, adolescents should be counseled on safe sex practices including the use of barrier protection against sexually transmitted infections.

Adolescent patients who become pregnant following MBS should be counseled on adequate nutritional intake with close monitoring of iron, folate, and vitamin B12 levels. Additionally, one must be cautious when screening for gestational diabetes in pregnant patients who have undergone MBS. In a study of a 119 post-bariatric surgery pregnant patients, oral glucose tolerance test resulted in hypoglycemia in 83% of patients with history of RYGB and 55% of patients with history of SG (58). Alternative methods for screening

such as capillary blood glucose measurements are therefore recommended. These methods recommend obtaining capillary blood glucose values before and after each meal for 3-7 days and using pre-and post-prandial capillary glucose values according to recommended cut-off values for defining diabetes mellitus (59, 60).

Comorbidity Reassessment

Regular reassessment of complications of obesity should occur at routine intervals in the postoperative phase to monitor for resolution or need for continued management. Patients with T2DM should be evaluated by their endocrinologist every three months. Repeat polysomnography is generally obtained between three to six months after surgery for patients previously on continuous positive airway pressure therapy (61, 62). Twenty-four-hour blood pressure monitoring can also be repeated three months after surgery to demonstrate resolution or persistence of hypertension. Medication may be restarted if blood pressure is consistently ≥ 120 mmHg systolic or ≥ 80 mmHg diastolic. Patients with biopsy proven nonalcoholic fatty liver disease may be re-biopsied 12 months after surgery to document regression. Finally, patients' mental health needs should be re-evaluated by a pediatric psychologist at 6 and 12 months after surgery.

In the setting of weight regain, patients should be monitored for complications of obesity. There is emerging evidence however, that some complications of obesity may be weight dependent and others non-weight dependent (63). Some surgeons will routinely obtain an upper gastrointestinal contrast study at 12 months after surgery or as needed to assess anatomy which may lead to weight regain. Anatomical abnormalities that may contribute to weight regain include a dilated gastric sleeve or gastrogastic fistula.

Follow Up

Close follow up with the multidisciplinary team including the bariatric surgeon, pediatrician, dietitian, and pediatric psychologist is strongly recommended. Patients are typically followed by a pediatrician to ensure ongoing continuity of care. It is important for the core providers to have access to pediatric specialists including endocrinology, gastroenterology/hepatology, and pulmonology as needed in those with complications of obesity that require ongoing monitoring or management. Additionally, a gynecologist for contraception counseling may be required for female patients. The transition from pediatric to adult medicine can be challenging in patients with chronic medical conditions and frequently requires assistance from multiple members of the team for transition care coordination and preparation as well as to ensure adequate communication, support, and education (64-66).

OUTCOMES

Percent BMI Loss

Both SG and RYGB have resulted in clinically significant weight loss in adolescents. The efficacy of both procedures appears to be similar in the adolescent population(67). In a large, multicenter analysis of 177 adolescents who underwent RYGB and 306 adolescents who underwent SG, there was a three-year postoperative average percent BMI loss of 29% (95% CI, 26 to 33) and 25% (95% CI, 22 to 28) for RYGB and SG, respectively (38). Similar results were seen in the Teen Longitudinal Assessment of Bariatric Surgery (Teen-LABS) the largest prospective, observational study to date of 228 adolescents undergoing either RYGB or SG. The three-year analysis showed an average 28% reduction in BMI following RYGB compared to 26% reduction following SG (62). In the 10 year analysis of Teen-LABS data for Roux-en-Y gastric bypass (RYGB, n = 161) and sleeve gastrectomy (SG, n = 99), 83% of those eligible for 10 year follow up completed the full

decade of data collection (68). The findings revealed long-term BMI reductions for both procedures, with RYGB showing a 20.6% decrease and SG a 19.2% decrease. Furthermore, initial BMI loss (within the first six months) proved to be a strong predictor of 10-year outcomes. It is noteworthy that some smaller, single center studies have demonstrated long term (7-14 year) BMI reductions after RYGB up to 30% in patients who underwent surgery in their adolescence (69-71).

Complications of Obesity

TYPE 2 DIABETES MELLITUS

Multiple studies have demonstrated improved glycemic control, even remission as well as prevention of T2DM following MBS, making a compelling case of MBS as a treatment for T2DM (40, 70, 72-75). Of the 242 adolescents enrolled in Teen-LABS, 29 had T2DM at baseline. By 3 years after the procedure, remission of T2DM occurred in 95% (95% CI, 85-100) of participants with no new cases of T2DM in those without the condition at baseline (62). Additionally, 19 participants had prediabetes at baseline with a 76% (95% CI, 56-97) rate of remission at 3 years (62). These remission rates in Teen-LABS were compared to adults who underwent MBS. The Teen-LABS study's 10-year metabolic findings demonstrated sustained improvements in comorbidities for most participants, with a remission rate of 55% for type 2 diabetes (68). In contrast to adult studies, diabetes outcomes when surgery was used in adolescents were comparable between RYGB and SG. It is also worth mentioning that the long-term remission rate for type 2 diabetes (55% at 10 years) significantly exceeds that observed in adults undergoing bariatric surgery for diabetes, where long term remission rates have been estimated to be around 15% (76). These results highlight the durability of both weight loss and diabetes remission in adolescents undergoing RYGB. Finally, among those who underwent RYGB, adolescents were more likely to have remission of T2DM at 5 years with a remission rate of 86%

compared to 53% in adults (77). These data underscore that the health benefits of bariatric surgery may be more pronounced in adolescents than in adults.

Similar findings were demonstrated in another study of 226 adolescents undergoing SG, of which 23% of patients were found to have T2DM. Eighty-five percent of patients with T2DM were on medication for diabetes prior to surgery and 89% achieved normal fasting plasma glucose and hemoglobin A1c levels without the use of medication postoperatively (61).

To compare surgical versus medical therapy for T2DM in adolescents with severe obesity, data from participants with T2DM enrolled in the Teen-LABS study were compared to participants of similar age and racial distribution from the Treatment Options of Type 2 Diabetes in Adolescents and Youth (TODAY) studies. Teen-LABS participants underwent MBS. TODAY participants were randomized to metformin alone or in combination with rosiglitazone or intensive lifestyle intervention, with insulin therapy given for glycemic progression. At two years, mean hemoglobin A1c concentration decreased from 6.8% to 5.5% in patients who underwent MBS compared to an increase from 6.4% to 7.8% in those enrolled in the TODAY study. Compared to baseline, average BMI decreased by 29% in Teen-LABS participants while the average BMI increased by 3.7% in TODAY participants (78). Cardiovascular disease (CVD) risk reduction was also explored in a secondary analysis of this study and despite higher pretreatment risk for CVD, treatment with MBS resulted in reduction of estimated CVD that were sustained at 5-year follow-up where medical therapy was associated with an increase in risk of CVD in adolescents with T2DM and severe obesity (79).

While these initial results are promising of the beneficial effects of MBS for the treatment of T2DM, no studies have prospectively compared the efficacy of MBS with that of medical therapy for the treatment

of T2DM in adolescents with obesity. Additionally, the majority of initial MBS data in adolescents were from those who underwent RYGB which is no longer the primary MBS procedure performed in adolescents due to its inferior safety profile. In 2019, the National Institute of Health funded the Surgical or Medical Treatment for Pediatric T2DM (ST₂OMP) trial which will compare SG to advanced medical therapy (80, 81).

OTHER COMORBIDITIES

In the Teen-LABS study described above, a mean 74% (95% CI, 64 to 84) remission of hypertension (HTN), 66% (95% CI 57 to 74) remission of dyslipidemia, and 86% (95% CI 72 to 100) resolution of abnormal kidney function was found at 3 years (62). In a secondary analysis of Teen-LABS and TODAY data, medical management of adolescents with obesity was associated with higher odds of diabetic kidney disease when compared to MBS (82). Greater weight loss after MBS in adolescents has also been associated with greater remission of T2DM, HTN, and dyslipidemia (63, 83). In a comparison of adolescents and adults who underwent RYGB, adolescents were more likely to have remission of HTN at 5 years compared to adults (68% vs 41%) (77).

Additional studies have demonstrated a 66% to 84% remission of obstructive sleep apnea as well as improvements in liver disease and polycystic ovarian syndrome (8, 61, 84). Improvements in functional mobility as well as reduction in musculoskeletal pain have also been well described (85, 86).

Mental Health

Multiple studies have reported higher rates of depression, emotional and behavioral disorders, and suicidal ideation in adolescents with obesity (87-90). Additionally, binge and loss of control eating is prevalent among more than one quarter of

adolescents with overweight and obesity (91, 92). A recent prospective study demonstrated that undergoing MBS in adolescence did not heighten or lower the risk of suicidal thoughts or behaviors following the initial 4 years after surgery (93). While still unclear whether obesity leads to psychopathology, or vice versa, the association highlights the need for appropriate psychological services in the pre- and postoperative period (87).

MBS can lead to improvements in psychosocial outcomes, although the improvements in some studies are transient. In the TEEN-Labs study, quality of life measured by the Impact of Weight on Quality of Life and Short Form 36 Health Survey improved after MBS (62, 86). When compared to a nonsurgical control, Teen-LABS participants also demonstrated significantly higher levels of self-worth and romantic self-perceptions 6 years after surgery (94). Several studies have demonstrated improved depressive and anxiety symptoms in the months following MBS, although the results were not maintained after the first postoperative year (95, 96). In a multisite study assessing two year follow up of psychopathology prevalence in adolescents undergoing MBS, most patients retained their symptomatic or non-symptomatic psychopathology status at two years, although remission of symptoms was more prevalent than the development of new symptoms (97). These results emphasize the need for long-term psychosocial monitoring following MBS as well as early treatment in those with psychopathology.

Substance and alcohol abuse have been observed in post-MBS adolescents and adults. Pre and postoperative screening and education regarding substance and alcohol addiction should be integrated in long-term follow up care (98).

Short-Term Complications

Short-term complications (<30 days after surgery) in adolescents undergoing MBS are similar to those

seen in adults. Early postoperative complications, though rare, include surgical site infections, bleeding, leak, strictures, and pulmonary embolism. In a retrospective review of 21,592 adolescents and young adults who underwent SG or RYGB between 2015 and 2018, 3.7% of patients required readmission, 1.1% of patients required reoperation, and 3.3% required percutaneous, endoscopic, or other intervention (28). Major complications were rare; the most common complication was bleeding (0.4%), followed by leak (0.4%), and deep surgical site infections (0.2%). RYGB was associated with higher rates of reoperation (2.1% vs. 0.8%), readmission (6.3% vs. 3.0%), and serious complications (5.5% vs. 1.8%) compared to SG. Mortality occurred in 0.05% of patients and there were no differences in mortality noted between groups (28). Similar complication rates were found in a more recent analysis of the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program database in patients aged 10-19 years old (99). In an additional retrospective review of 483 adolescents (SG n=306, RYGB n=177) no perioperative deaths occurred and the rate of major adverse events were too rare for statistical comparison. VTEs occurred in only 0.4% of patients and failure to discharge in 30 days was observed in 0.7% of patients (38).

Multiple studies have also suggested that MBS may be safer in adolescents when compared with adults. In a large study evaluating perioperative outcomes of MBS between 309 adolescents and 55,192 adults, the overall 30-day complication rate was significantly lower in adolescents (5.5%) as compared with adults (9.8%). No in-hospital mortalities occurred in the adolescent group compared to 0.2% in the adult group. The 30-day morbidity for adolescents following SG was zero compared to 4.3% following RYGB (100). In an additional study evaluating 1047 adolescents, 10,429 college-aged individuals, and 24,841 young adults who underwent SG or RYGB, there were no differences in 30-day complication rates between age groups (101).

Long-Term Complications

NUTRITIONAL DEFICIENCIES

Long-term complications after MBS in adolescents are primarily nutritional. Patients are particularly at risk for deficiencies in iron, vitamin B12, and vitamin D. Iron deficiency is common in premenopausal females due to menstruation. Some patients may require iron infusion if oral supplementation is not adequate. Symptomatic thiamine deficiency following MBS is rare, however can have serious consequences (102-104). These risks are higher for patients who undergo RYGB compared to SG due to potential malabsorption. In a Teen-LABS study evaluating nutritional deficiencies at 5 years postoperatively, low serum ferritin levels were seen in 71% of patients who underwent RYGB compared to 45% following a SG indicating iron deficiency (102). Iron deficiency anemia can occasionally be severe in adolescent women following MBS which can be compounded by menstruation and challenges in recognizing symptoms therefore daily supplementation and routine nutritional monitoring is essential following MBS.

Vitamin B12 deficiency was seen in approximately 12% of patients after either procedure. Approximately 40% of patients had low vitamin D levels at baseline with no significant change at follow up. Parathyroid hormone concentrations increased in patients undergoing RYGB from an average baseline concentration of 44 pg/ml to 59 pg/ml at 5 years with the risk of abnormal parathyroid hormone levels nearly sixfold higher after RYGB compared with SG (102). Elevated parathyroid hormone is utilized as a surrogate for calcium deficiency and raises concerns about long-term bone health. In adolescents, reduced bone mass has been noted 5-11 years after MBS, whether this increases long term fracture risk remains unclear.(105, 106). Concerns of growth retardation after MBS have been refuted and the most recent adolescent ASMBS guidelines have removed the

recommendation of patients reaching physical maturity prior to MBS (4, 30).

The risk of nutritional deficiencies decreases with adherence to prescribed micronutrient supplements and increases with pregnancy (102). Given the high prevalence of nutritional deficiencies, lifelong micronutrient supplementation is required following surgery. One concern emphasized in the adolescent population is adherence to regular multivitamin use. In a prospective study of 41 adolescents who underwent MBS, multivitamin adherence was only 29.8% \pm 23.9 (107).

WEIGHT REGAIN

Current data demonstrates satisfactory maintenance of weight loss at long-term follow up with both SG and RYGB (38, 71, 108), but in other detailed analysis of weight regain trajectories, there are distinct groups that emerge in a large enough dataset. The Teen-LABS data at 10 years showed that 38% of the cohort experienced moderate weight regain. One trajectory group experienced a nadir of 25% weight loss at five years but only maintained 13% loss at 10 years. Another group (11% of the cohort) showed poor results with a weight loss peak at 20% at five years, but then proceeding to regain all weight from 5-10 years, resulting in a 7% BMI increase (above baseline) by 10 years (68). Some adult studies have demonstrated utility of anti-obesity medications after MBS to mitigate weight regain after surgery, however this has not been thoroughly explored in the adolescent population (109, 110). More research is needed to fully understand the mechanisms behind long-term weight maintenance after MBS.

OTHER COMPLICATIONS

Cholelithiasis is a common complication due to rapid weight loss following MBS in both adolescents and adults. In the Teen-LABS study, cholecystectomy was

required within three years in 9.9% of adolescents who underwent RYGB and 5.1% who underwent SG (62). Five percent of Teen-LABS participants required other abdominal operations including lysis of adhesions, gastrostomy, ventral hernia repair, or internal hernia repair (62). Symptoms of GERD, nausea, bloating, and diarrhea can also increase following MBS. During five years of follow up, the incidence of GERD increased from 2% to 8% in adolescents who underwent RYGB and from 11% to 24% in those who underwent SG. At five years postoperatively, the SG group had more than fourfold greater odds of having gastrointestinal distress symptoms when compared to RYGB (41). Dumping syndrome can be seen after both procedures, however it is much more common after RYGB compared to SG (111, 112). The incidence of dumping syndrome (~12%) in adolescents after RYGB was similar to adult patients two years after surgery(113).

There are no current established guidelines for surveillance of Barrett's esophagus after SG for adolescent patients, however routine screening is recommended for adult patients after SG, therefore it would be prudent for adolescent patients to undergo intermittent surveillance also as the length of possible

GERD exposure is theoretically longer (114). Similarly, there are no established guidelines for monitoring of bone density following use of MBS in adolescence, but due to inadequate vitamin D levels and rising PTH at least in those who underwent RYGB, periodic monitoring with DEXA may be prudent.

Emerging Evidence

Current evidence evaluating the outcomes and efficacy of adolescent MBS is generally limited to ≤10 years of follow up. Smaller, long-term studies with data available for up to 18 years post-operatively in patients who primary underwent RYGB demonstrate the durability of weight loss and similar rates of complications, although inference is limited due to small sample sizes with reduced attrition rates (70-72, 115, 116). Characteristics including study size, length of follow up, and attrition rate of available studies on MBS published from 2012 to present are available in Table 4. As SG is now the most predominate MBS procedure performed in the United States long-term data with this procedure is required. While some longitudinal studies are ongoing (Table 4), there remains a paucity of long-term data in the adolescent population.

Table 4. Characteristics of Studies on MBS, 2012 – Present

Author; Year	Study Design	Sample Size (N)	Type of MBS		Longest follow up	N (1 yr)	N (3 yr)	N (5 yr)	Comments
			RYGB	SG					
Inge; 2018 (38)	RO	483	177	306	5 yr	466 (96%)	153 (32%)	41 (8%)	The PCORnet bariatric study (2005 – 2015)
Olbers; 2017 (69)	CC	81	81	0	5 yr	81 (100 %)	n/a	81 (100 %)	Adolescent Morbid Obesity Surgery (AMOS) study
Inge; 2017(70)	PO	74	74	0	12.5 yr	n/a	n/a	58 (81%)	Adolescent Bariatric Surgery at 5 Plus Years (FABS-5+) study (2001-2007);

									mean follow up 8.0 yr
Inge; 2016 (62)	PO	228	161	67	3 yr	205 (90%)	194 (85%)	n/a	Teen-Longitudinal Assessment of Bariatric Surgery (Teen-LABS) study; (2007-2012)
Vilallonga; 2016 (72)	RO	19	19	0	10.2 yr	n/a	n/a	n/a	Mean follow up 7.2 years; (2003-2008)
Al-Sabah; 2015 (73)	RO	125	0	135	4 yr	54 (40%)	n/a	n/a	2 yr follow up: 46 (34%); (2008-2012)
Cozacov; 2014 (115)	RO	18	8	10	7 yr	15 (83%)	10 (56%)	n/a	7 yr follow up: 3 (17%); (2002 – 2011)
Messiah; 2013 (84)	PO	454	454	0	1 yr	108 (24%)	n/a	n/a	Bariatric Outcomes Longitudinal Database (BOLD) (2004-2010)
Alqahtani ; 2012 (31)	RO	108	0	108	2 yr	41 (38%)	n/a	n/a	2 yr follow-up: 8 (7%); (2008 – 2011)
Nijhawani ; 2012 (116)	RO	25	25	0	9 yr	n/a	n/a	20 (80%)	Study dates not provided
de la Cruz-Muñoz; 2022 (71)	RO	96	87	1	18 yr	n/a	n/a	n/a	Mean follow up 14.2 years (2002-2010).

RO- Retrospective observational; CC- Case-control; PO- Prospective observational

CONCLUSION

Surgical weight loss is an appropriate consideration for adolescents with severe obesity and/or complications of obesity who have failed to lose weight through other obesity management options. It is essential that adolescents undergoing evaluation for MBS do so in the context of a multidisciplinary program with specific expertise in adolescent medicine and MBS. SG and RYGB are safe and effective treatment options in adolescents. Weight loss

outcomes are comparable between SG and RYGB. Both procedures also result in substantial improvement in complications of obesity, including T2DM. SG appears to have an improved safety profile when compared to RYGB and is now the most common adolescent bariatric procedure performed in the United States. Emerging evidence demonstrates advantages of earlier surgical intervention in those with obesity including improved weight loss, increased resolution of comorbidities, and decreased adverse events when compared to adults (77, 117). Perioperative complications in adolescents

undergoing MBS are similar to those in adults but occur less frequently (100, 101). Long-term complications are primarily nutritional and life-long vitamin and mineral supplementation is recommended. Regular follow up is required following

MBS and it is important for patients to have access to appropriate medical, dietary, and psychological care.

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