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REVIEW ARTICLE

Short- and long-term safety and efficacy of bariatric surgery for severely obese adolescents: a narrative review

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The selection criteria, safety, and efficacy of bariatric surgery are well established in adults but are less well defined for severely obese adolescents. The number of severely obese adolescents who could benefit from weight loss surgery is increasing, although referral rates have plateaued. Surgical options for these adolescents are controversial and raise several questions. Recent studies, including the prospective Teen-Longitudinal Assessment of Bariatric Surgery Study and the Adolescent Morbid Obesity Surgery Study, help answer these questions. Early bariatric surgical intervention improves body mass index but, more importantly, improves cardiovascular and metabolic co-morbidities of severe obesity. A review of the medical, psychosocial, and economic risks and benefits of bariatric surgery in severely obese adolescents is a step toward improving the management of a challenging and increasing population. We describe the current knowledge of eligibility criteria, preoperative evaluation, surgical options, outcomes, and referral barriers of adolescents for bariatric surgery.

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INTRODUCTION

Obesity is projected to decrease the life expectancy of Americans.[1,2] In children aged 2–19 years, obesity is defined as body mass index (BMI) ≥ 95th percentile for age and sex[3] while severe obesity is defined as a BMI ≥ 99th percentile[4] or as a BMI ≥ 120% of the 95th percentile or as a BMI ≥ 35 kg/m^2, whichever is lowest.[4] In 2016, 19% of American children aged 2–19 years were obese.[5] From 1980 to 2015, the prevalence of obesity doubled in >70 countries.[6] The increase in obesity rates among children now exceeds than that among adults.[6] Obesity in childhood correlates with obesity in adulthood.[7–9] An analysis of five longitudinal US studies concluded that 57% of children were predicted to be obese by age 35 years, and in 50% of these children, obesity will begin before adulthood.

Adolescence is the time when aggressive obesity management must be considered. Currently, there are no singularly effective medical options for long-term weight loss in severely obese adolescents. Non-surgical interventions, including lifestyle modification and family-based behavioral therapy, have been modestly successful in children with mild-to-moderate obesity but not in severely obese adolescents.[10] Early intervention is imperative because severely obese adolescents are likely to remain obese with markedly higher rates of morbidity and early mortality.[11]

Given the ineffectiveness of non-surgical interventions in severely obese adolescents, surgical interventions should be considered. First performed in severely obese adolescents in the US in the 1980s,[12] bariatric surgery has been the subject of research ever since. During the first year after such surgery, severely obese adolescents typically lose 50–60% of their excess weight. During the second year, they can lose up to 75% of their excess weight.[13] Bariatric surgery can provide enduring reductions in weight, risk factors for weight-related co-morbidities, and the stigma of obesity in adolescence.

Despite these benefits, pediatricians remain reluctant to refer adolescents for surgery. To address this reluctance, we describe here the results of the Teen-Longitudinal Assessment of Bariatric Surgery (Teen-LABS) Study and the Adolescent Morbid Obesity Surgery (AMOS) Study. We address patient selection, preoperative evaluation, advantages, risks, and outcomes of each procedure and barriers to referral.

METHODS

We conducted a focused PubMed search of the English language literature published between 2000 and 2019 on bariatric surgery in severely obese children and adolescents. Search terms included “adolescents,” “bariatric surgery,” and “severe obesity.” The goal was to examine the most prevalent types of bariatric surgery used in adolescents, including Roux-en-Y gastric bypass (“bypass”), adjustable gastric banding (“banding”), and vertical sleeve gastrectomy (“gastrectomy”). Articles were selected if they addressed specific research questions about patient selection criteria, preoperative evaluation, advantages and risks of each procedure, short- (1 year) and long-term (>1 year) outcomes, surgical psychosocial effects, and referral barriers. Study types included randomized controlled trials, prospective and retrospective cohort studies, meta-analyses, case reports, systematic reviews, narrative reviews, and expert opinion. Recent media publications were

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reviewed to better understand patient, parental, and societal perception of adolescent bariatric surgery to evaluate social barriers.

Patient selection criteria

The American Society for Metabolic and Bariatric Surgery (ASMBS) criteria for weight loss surgery in adults are a BMI of ≥40 kg/m^2 or a BMI of ≥35 kg/m^2 and ≥1 obesity-related co-morbidity.[14] Compared to guidelines for adults, adolescent guidelines were initially more conservative. The current ASMBS pediatric surgical criteria match the adult criteria but include adolescent-specific obesity-related co-morbidities[15] (Table 1). The 2018 guideline changes embody a substantial transformation in managing severely obese adolescents. Lifestyle modifications, pharmacotherapy, and surgical options are recommended as complimentary treatment strategies.[15]

Surgical timing and the minimum referral age continue to be debated.[16,17] ASMBS guidelines recommend a minimum age of 10 or 11 years[15,18] and argue that Tanner stage and bone age should not be considered when evaluating surgical candidacy.[15] The European Society of Endocrinology and the Pediatric Endocrine Society do not support bariatric surgery in preadolescents and state that Tanner stage 4 or 5 pubertal development and final or near-final adult height should be attained before considering surgery.[19] Others argued that chronological age may be less important for surgical readiness than emotional maturity.[20] Longer-term outcome data are needed to clarify the minimum age for referral.

Internationally accepted contraindications to bariatric surgery remain unchanged (Table 2).[21–24] Adolescents with developmental delays, autism spectrum disorders, or syndromic obesity should not be uniformly excluded from bariatric surgery.[15]

Patient evaluation

Evaluating children for bariatric surgery requires a team approach.[25] The 2018 ASMBS guidelines reaffirm prior recommendations: a surgeon experienced in bariatric surgery, pediatrician, and mental health specialist should evaluate potential candidates.[15] A program coordinator, registered dietician, and exercise physiologist are also recommended.[15,22,26] Specialized bariatric surgery units offer treatment tailored to the unique considerations of developing adolescents and support participation in clinical trials. A review concludes that the benefit of bariatric surgery in carefully selected adolescents and performed in the appropriate medical center appears to outweigh the risk.[27]

Table 1. Patient selection criteria for bariatric surgery in adolescents

Body mass index	Obesity class	Comorbidity
≥35–40 kg/m^2	120% of the 95th percentile (II)	At least one of the following: • Obstructive sleep apnea • Hyperlipidemia • Insulin resistance • Type 2 diabetes • Idiopathic intracranial hypertension • Non-alcoholic fatty liver disease • Gastroesophageal reflux disease • Orthopedic disease • Hypertension • Low health-related quality of life
≥40 kg/m^2	140% of the 95th percentile (III)	None required

Table 2. Contraindications to bariatric surgery in adolescents

Contraindication
Medical
Medically correctable cause of obesity
Condition impairing adherence to postoperative diet/medication regimen
Pregnancy
Lactation
Unresolved eating disorder
Active malignancy
Psychiatric
Substance abuse
Psychiatric condition that would impair adherence to postoperative diet/medication regimen
Social
Poor social support
Inability to comprehend risk/benefit of surgery

Indications, consent, and assent for bariatric surgery

The unique characteristics of adolescents must be considered in the selection process and in obtaining informed assent and consent for surgery. Adolescents' maturation, psychological health, coping skills, and family influence must be considered[20] including their motivation to undergo weight-loss surgery, eating habits, and family relationships.[28] Obesity is related to psychosocial co-morbidities, including anxiety, depression, impaired self-esteem, and impaired social relationships.[29] Adolescents are still developing advanced reasoning skills, abstract thinking, and formal operational thinking.[30] These factors can affect long-term postsurgical success.

Obtaining consent and assent for bariatric surgery must also address unique circumstances because shared decision-making is required to approve surgery.[31] For ethical reasons, the decision to proceed with surgery must be the adolescent's alone. The adolescent must have the emotional maturity to fully understand the risks and benefits of the procedure, potential long-term complications, and the need to adhere to dietary and lifestyle changes. Nevertheless, parental consent continues to be a major determinant of success.[32] Parental support of adherence with appointments and recommended lifestyle modifications increases the probability of a positive outcome and improved postsurgical adherence.[33–36]

Common bariatric operations

The most common weight-loss surgery procedures performed in children are Roux-en-Y laparoscopic gastric bypass, adjustable gastric banding, and vertical sleeve gastrectomy, which is becoming more common in children.[37–39] No recommendations currently support a specific procedure for a given patient.[11,21,40]

Roux-en-Y gastric bypass surgery. Bypass surgery is the most extensively studied option in adolescents.[11,41] A small stomach pouch, 30 mL in volume, is created by dividing the top from the remainder of the stomach. The jejunum is divided and the distal end is then attached directly to the newly made, markedly smaller, stomach pouch creating a restrictive component. The proximal jejunum is reconnected to the small bowel 3–4 feet distal to the gastrojejunostomy.[14] This rerouting induces hormonal changes that promote satiety, suppress hunger, and decrease uptake of certain micronutrients.[42]

Adjustable gastric banding. In banding, an inflatable band is placed around the upper stomach to constrict it, creating a small pouch above the band and restricting the passage of food into the lower stomach to delay gastric emptying and promoting satiety.[14] The adjustable gastric banding device is not approved by the Food and Drug Administration for patients aged <18 years.[22]

Sleeve gastrectomy. In gastrectomy, 80% of the stomach is surgically removed leaving a segment of the stomach that is tubular in shape.[14] Vertical sleeve gastrectomy is the most prevalent operation for both adults and adolescents.[43–45] This procedure may prove to be the safest option as it reduces the risk of both nutritional deficiencies and surgical mortality.[15,44]

Operative trends

All three procedures provide adolescents with sustainable weight loss for up to 10 years (Table 3).[23,46–54] Sustainability is imperative to reducing the incidence of metabolic derangements associated with obesity.[23,47,51] Data from the Bariatric Outcomes Longitudinal Database of 890 adolescents in the US (ages 11–19 years) between 2004 and 2010 found that the 1-year mean weight loss after bypass was more than double than that achieved after gastric banding (48.6 vs. 20 kg, $P < 0.001$).[55] However, data from the Kids' Inpatient Database (KID) and the National Inpatient Sample indicate that the type of bariatric surgery performed in adolescents is changing. Vertical sleeve gastrectomy was performed in 70.6% of patients in 2014, vs. <10% in 2005. In 2014, gastric banding was performed in <10% of cases and only 27.7% of adolescents undergoing bariatric surgery had a bypass procedure.[56] Data from the PCORnet bariatric study show a marked change. Between 2005 and 2009, 13% of cases were gastrectomies, as compared to 83% in 2014–2015.[44] There were more patients undergoing surgery with an absolute increase from 52 patients in 2005–2009 to >100 cases per year after 2012.[44] Despite this increase and compelling data supporting its efficacy in adolescents, the incidence of bariatric surgeries has plateaued after rising from 0.8 per 100,000 cases in 2000 to 2.3 per 100,000 cases in 2003, with subsequent incidence rates including 2.2 per 100,000 cases in 2006 to 2.4 per 100,000 cases in 2009.[32]

Table 3. Summary of weight-loss outcomes in studies of morbidly obese adolescents, by procedure

Study	*N*	Duration, months	Outcome
Gastric bypass			
Bondada et al.[46]	131	12	BMI reduction ≥35%
Nijhawan et al.[47]	20	60	Mean EWL 78%
Widhalm et al.[48]	9	12	Mean WL 31 kg
		42	Mean WL 36 kg
Gastric banding			
Zitsman et al.[49]	137	12	Mean EWL 28%
		24	Mean EWL 36%
		36	Mean EWL 41%
Khen-Dunlop et al.[50]	49	6	Mean EWL 32%
		12	Mean EWL 42%
		24	Mean EWL 59%
Beamish et al.[51]	82	24	Mean EWL 32%
	78	60	Mean EWL 50%
Wasserman et al.[23]	20	60	Weight reduction 37%
	14	120	Weight reduction 35%
Paulus et al.[52]	10	64 (range, 52–84)	Mean BMI reduction 10.7 kg/m^2
Gastrectomy			
Raziel et al.[53]	32	1	Mean EWL 28%
		3	Mean EWL 41%
		6	Mean EWL 63%
		9	Mean EWL 79%
		12	Mean EWL 82%
		24	Mean EWL 71%
		36	Mean EWL 75%
		48	Mean EWL 103%
		60	Mean EWL 102%
Boza et al.[54]	51	6	Mean EWL 95%
		12	Mean EWL 96%
		24	Mean EWL 93%

BMI body mass index, *EWL* excess weight loss

Surgical complications

In adolescents, bariatric surgery has low mortality and reoperation rates (Table 4).[46,50,55,57–60] In patients aged 18–21 years, data from the National Surgical Quality Improvement Program demonstrated a total complication rate of 2.4% in the first 30 days after undergoing bariatric surgery. Most complications included superficial surgical site infections (0.7%), urinary tract infections (0.7%), and organ-space infections (0.4%). The reoperation rate was 1.5% and the readmission rate was 4.1%.[45]

In one study of medical complications ≤1 year after surgery, 51% of patients (454 of 890) underwent corrective bypass and 49% (436 of 890) underwent corrective banding. One death occurred from cardiac failure 5 months after bypass surgery. Frequent complications of both procedures included gastrointestinal complications, such as nausea, vomiting, bleeding, diarrhea, and gallstones ($n = 29$ for bypass, $n = 9$ for banding); nutritional deficiencies in bypass patients ($n = 24$); and device concerns in banding patients ($n = 5$). Forty-five of the bypass patients were readmitted for 29 reoperations, and 10 banding patients were readmitted for 8 reoperations.[55]

No deaths occurred among the 242 participants in the Teen-LABS study within 30 days after surgery. Major complications, defined as life-threatening, capable of causing permanent harm, or resulting in reoperation, occurred in 19 (8%) of all patients (bypass 9.3%, gastrectomy 4.5%, banding 7.1%). Minor complications, defined as unplanned events, additional testing, or non-oral enteral or parental nutrition at the time of discharge, occurred in 36 (15%) of all patients (bypass 16.8%, gastrectomy 11.9%, banding 7.1%).[61] Overall, these operations were well tolerated, with a low risk of serious adverse perioperative and postoperative follow-up outcomes.[46,62,63]

Table 4. Complications in morbidly obese adolescents undergoing bariatric surgery, by procedure

Procedure	Study	Death, % (*n/N*)	Conversion or reversal, % (*n/N*)
Bypass	Sugerman et al.[57]	6 (2/33)	6 (2/33)
	Messiah et al.[55]	0.2 (1/454)	6.4 (29/454)
Banding	Angrisani et al.[58]	0 (0/58)	10 (6/58)
	Widhalm et al.[48]	0 (0/50)	0 (0/50)
	Khen-Dunlop et al.[50]	0 (0/15)	7 (1/15)
	Osorio et al.[59]	0 (0/14)	0 (0/14)
	Messiah et al.[55]	0 (0/436)	3 (14/436)
Gastrectomy	Alqahtani et al.[60]	0 (0/108)	0 (0/108)

OUTCOMES

Metabolic outcomes

The metabolic derangements associated with obesity are well documented.[18,24,64–66] Elevated BMI in adolescents is associated with increased cardiovascular risk.[9,67–72] In children as young as 6 years, waist circumference is a risk factor for metabolic syndrome, putting them at greater cardiovascular risk.[73] Obesity in children has several associated co-morbidities, including hypertension, insulin resistance, glucose intolerance, dyslipidemia, pediatric metabolic syndrome, and increased risks of type 2 diabetes and cardiovascular disease.[74–77] Additional obesity-related co-morbidities include orthopedic problems,[15,78,79] polycystic ovarian syndrome,[80] sleep apnea,[4] nonalcoholic fatty liver disease,[81] gastroesophageal reflux disease,[15] anxiety, and depression.[82] Along with obesity, these co-morbidities often continue into adulthood.[6,83,84]

In Denmark, 62,565 men had their weights and heights measured at ages 7 and 13 years and as young adults. Being overweight in childhood and adolescence was associated with an increased risk of type 2 diabetes in adulthood. In men whose obesity resolved by age 13 years, the risk of type 2 diabetes developing in adulthood was similar to that of normal-weight men (hazard ratio, 0.96; 95% confidence interval (CI), 0.75–1.21). Compared to normal-weight peers, men overweight at age 7 and 13 years but not in adulthood nevertheless had an increased risk of type 2 diabetes (hazard ratio, 1.47; 95% CI, 1.10–1.98).[85] These data illustrate the potential benefit of resolving obesity in childhood to prevent obesity-related co-morbidities in adulthood.

In severely obese adults, bariatric surgery is the only intervention that reliably decreases weight with long-lasting efficacy and resolves many co-morbidities.[23,66,86–97] Of the 126 adults undergoing bariatric surgery, 50 substantially reduced their BMI and returned their liver proton density fat fraction to normal within 6–10 months after surgery.[81] Obesity related co-morbidities tend to resolve in adolescents who undergo bariatric surgery (Table 5). In a multi-center 1-year outcome study, severely obese adolescents treated with gastric bypass surgery reduced their mean BMI by 37% and greatly reduced their components of the metabolic syndrome.[98] Type 2 diabetes resolves in anywhere from 50 to 100% of patients who undergo bariatric surgery, dyslipidemia in 23–100%, and hypertension in 54–100%. Given that these co-morbidities continue into adulthood and that, in the absence of treatment, reduce longevity, the potential benefit of referring adolescents for bariatric surgery is compelling.[7,99]

The Swedish AMOS study found that in addition to a BMI significantly lower than that in age-matched medical-managed controls, bypass surgery provided substantial improvements in cardiovascular risk factors, including glucose metabolism, blood lipid concentrations, inflammatory marker concentrations, and systolic and diastolic blood pressure.[10,52,100] However, 25% of the 81 patients in this study required additional surgeries and 72% had nutritional deficiencies related to bypass surgery.[100] Nevertheless, co-morbidities, specifically type 2 diabetes, resolved completely, and the results were better than those reported in adults.[41]

Procedures that alter gastrointestinal anatomy and hormonal production, such as gastric bypass, are more likely to resolve diabetes than are purely restrictive procedures, such as banding. Owing to complications specific to gastric bypass, such as nutritional deficiencies, gastrectomy is becoming an increasingly attractive option.[101] A review of patients who had undergone weight loss surgery reported improvements in echocardiographic measurements of the myocardium, as indicated by decreases of elevated left ventricular mass to more normal values, decreased geometric alterations, and ameliorated left ventricular diastolic dysfunction.[23]

The adverse cardiovascular effects of obesity are not limited to adults. Obesity is also associated with heart failure in children,[102,103] where it leads to concentric left ventricular hypertrophy and diastolic dysfunction.[104,105] An important outcome of gastric bypass in adolescents is a reduction in the abnormally increased left ventricular mass leading to improved left ventricular diastolic function.[104]

Obese adults have lower rates of death and hospitalizations for heart failure than do patients of normal weight; a contradiction termed the obesity paradox.[105,106] In 904 children with dilated cardiomyopathy in the National Heart, Lung and Blood Institute-funded Pediatric Cardiomyopathy Registry, 120 (13.3%) were obese. Transplant-free survival in obese children was lower than in normal-weight children (86.2% transplant-free survival vs. 91.8%, respectively). Obese children had a higher risk of death or heart transplantation than normal-weight children (55.9 vs. 67.4% in 2-year transplant-free survival and 248 vs. 132.8 events/1000-person years).[107] Thus obesity does not protect children with heart failure from death or heart transplant.

The Teen-Longitudinal Assessment of Bariatric Surgery study

The Teen-LABS study is a prospective trial of 242 adolescents who underwent bariatric surgery at 5 centers: 161 with gastric bypass, 67 with gastrectomy, and 14 with banding.[61,108,109] The mean (SD) age at the time of enrollment was 17 (1.6) years, and the mean BMI decreased from 52.5 kg/m^2 at study enrollment to 39 kg/m^2 at 36 months post-surgery. This decrease in BMI is substantial but still indicates a severely obese population. Preoperatively, 43.6% of patients had blood pressure measurements above normal for their sex and age. During the study, the mean systolic blood pressure dropped by 6 mm Hg and diastolic pressure by 5 mm Hg. The percentage of adolescents with elevated blood pressure decreased to 15.5% at 36 months and a similar reduction occurred in the percentage of adolescents with dyslipidemia (75.2% vs. 29.4% at 36 months).

In the Teen-LABS study, the percentage of adolescents with diabetes dropped from 12.6% preoperatively to 0.6% at 36 months after surgery supporting the utility of bariatric surgery at reversing the development of type 2 diabetes in severely obese adolescents. Diabetic control was compared between 30 participants of Teen-LABS and 63 participants in the Treatment Options of Type 2 Diabetes in Adolescents and Youth (TODAY) study. Adolescents in TODAY were randomly assigned to medical therapy, including

Table 5. Comorbidity resolution in morbidly obese adolescents undergoing bariatric surgery, by procedure

Procedure	Study	Diabetes, % (*n*)	Dyslipidemia, % (*n*)	Hypertension, % (*n*)
Bypass	Messiah et al.[55]	79 (53/79)	59 (39/66)	61 (72/118)
	Nijhawan et al.[47]	100 (3/3)	100 (10/10)	100 (3/3)
	Lawson et al.[98]	89 (8/9)	100 (2/2)	100 (1/1)
Banding	Messiah et al.[55]	59 (38/64)	23 (14/61)	54 (43/80)
	Widhalm et al.[48]	100 (5/5)	100 (4/4)	92 (11/12)
Gastrectomy	Alqahtani et al.[60]	94 (15/16)	70 (21/30)	75 (27/36)
	Boza et al.[54]	50 (1/2)	58 (7/12)	100 (4/4)

metformin alone or with rosiglitazone or lifestyle counseling. Insulin was provided to TODAY participants whose diabetes worsened throughout the study. In the TODAY patients, hemoglobin A1c increased from 6.4% (95% CI, 6.1–6.7%) to 7.8% (95% CI, 7.2–8.3%), whereas in the Teen-LABS patients, it decreased from 6.8% (95% CI, 6.4–7.3%) to 5.5% (95% CI, 4.7–6.3%) over a 2-year period. In addition, BMI increased by 3.7% (95% CI, 0.8–6.7%) in the TODAY patients but decreased by 29% (95% CI, 24–34%) in the Teen-LABS patients.[110]

The percentage of Teen-LABS participants with at least one cardiovascular disease risk factor was 97% at enrollment but only 48% 3 years later. Preoperatively, a third of participants had ≥3 cardiovascular disease risk factors. Three years after bariatric surgery, only 5% did. Co-morbidity resolution was correlated with the magnitude of weight loss: for each 10% of additional loss of excess weight, the likelihood of eliminating dyslipidemia increased by 24%, the likelihood of resolving elevated blood pressure increased by 11%, and the likelihood of no longer having diabetes increased by 13%. Lipid concentrations were less likely to return to normal in older Teen-LABS participants (relative risk, 0.93; 95% CI, 0.88–0.98), which supports surgery in earlier adolescence.[111] These data show that obesity-associated co-morbidities are reversible with sustained results in adolescents who undergo bariatric surgery.

The Teen-LABS study also raises the important question of surgical timing because presurgical BMI predicts weight loss and co-morbidity resolution.[112] Sustained results were more likely in patients with lower initial BMIs (<50 kg/m^2) who tended to be younger.[111] In the Teen-LABS study, adolescents and adults did not differ in the amount of weight loss (−26% vs. −29%, $P = 0.08$). However, adolescents were much more likely to have resolution of both type 2 diabetes (86% vs. 53%; risk ratio, 1.27) and hypertension (68% vs. 41%; risk ratio 1.51) than adult bariatric surgery patients.[113]

Overall, as in adults, obesity-associated co-morbidities also improve or resolve after bariatric surgery in adolescents.[43,47,50,74,108,114–125] Improvements in metabolic outcomes are sustained at least up to 10 years after surgery.[46] Earlier surgery increases the likelihood of a longer and healthier life in these patients.[26,126,127] In contrast, intervening after adolescence likely increases the risk of cardiovascular disease and reduces the benefits of full weight loss.[13,128]

Postoperative psychological effects

Adolescents are vulnerable to mental health issues such as anxiety, depression, and poor self-esteem.[129,130] The stigma of obesity has been associated with dangerous activities, including not exercising, disordered eating, not seeking medical attention, and avoiding peer interaction. All can increase weight gain.[131] Low self-esteem can lead to high-risk behaviors,[132] which further increase cardiovascular risk. However, adolescents who undergo bariatric surgery have marked improvements in depression, health-related quality-of-life, and self-image.[10,129,133,134] Studies highlight the importance of the preoperative mental health evaluation to identify the severity of psychopathology and provide ongoing psychosocial support postoperatively.[129,134]

Although bariatric surgery can improve psychosocial outcomes, there are strong psychological contraindications to surgery, including suicidal ideation, acute psychoses, eating disorders, and drug abuse.[11,135] Disordered eating is a psychological concern that can affect outcomes. Following surgery, the amount and type of foods that can be consumed are restricted. In Teen-LABS participants, loss-of-control eating was reduced immediately after surgery relative to pre-surgery but increased over the next 6 months.[136] Further longitudinal studies are necessary to identify psychosocial interventions that optimize the sustainable weight loss benefit while minimizing associated adverse complications to improve the overall quality of life for these patients.

Economic outcomes of obesity and bariatric surgery

Costs of bariatric surgery may be a referral barrier; however, certain aspects should be considered. Long-term cost savings from improved metabolic profiles coupled with improved insurance coverage may help remove this barrier. Additional future studies are warranted to better understand the cost savings of bariatric surgery in adolescence compared with the cost of obesity into adulthood to better support the cost-effectiveness argument for bariatric surgery.

Studies of an administrative database reveal that obesity is associated with longer hospital stays (adjusted odds ratio, 1.4; 95% CI, 1.3–1.6).[137] Over the course of a child's life (estimated through age 64 years), the additional medical costs of obesity (compared to a normal-weight child at age 10 years) range from $12,660 to $19,630, accounting for weight gain through adulthood in the normal-weight comparison group.[137] These costs include expenses related to treating co-morbidities. While bariatric surgery may reverse or mitigate obesity-related co-morbidities, the initial cost of performing surgery in children may be a barrier. Data from the KID database show that private insurance covers bariatric surgery for 78–82% of adolescent patients.[12] Public Medicaid insurance has become an increasing reimbursement source for these procedures, going from 0% of cases in 1997 to 10% of the procedures performed in 2003.[12]

A study identified factors related to socioeconomic, demographic, and hospital characteristics that influence treatment and length of stay in adolescents.[138] Cost was affected by income, teaching hospital status, hospital size, and procedure type. Income, region, and procedure type affected the length of stay. Knowing the effect of these characteristics will help in selecting appropriate bariatric surgery use.

Quality-adjusted life years (QALYS) are a measure of a person's health that combine the quality of life with the length of life such that one QALY is the equivalent to a year of perfect health.[139] A 2017 cost-effectiveness economic analysis of bariatric surgery in severely obese adolescents found an incremental cost-effectiveness ratio of $154,684 per QALY over a period of 3 years, decreasing to $91,032 per QALY over 5 years with lower values indicating greater cost-effectiveness. Bariatric surgery is cost-effective at 5 years using a standard willingness-to-pay threshold of $100,000 per QALY.[140] Willingness-to-pay, defined by the World Health Organization, represents the value to society of a specific health benefit, in this case, 1 additional year of life while maintaining the same quality of life.[141]

Barriers to referral

Despite compelling evidence supporting the efficacy of bariatric surgery across a wide range of health measures, these procedures continue to be performed in only a small proportion of severely obese adolescents. Among 18,008 patients aged 14–15 years with severe obesity from 8 major medical centers, only 541 (3%) proceeded with bariatric surgery.[136]

Uncertainty related to the duration and requirements of a preoperative weight management program are common among referring physicians. A survey of British medical providers found that about half the respondents recommended completing a 12-month monitored weight-management program before surgery. Most respondents (21 of the 24 surgeons, 35 of the 45 physicians, 21 of the 25 nurses and dietitians) believed bariatric surgery to be acceptable for treating obese adolescents, yet only 4 physician respondents had referred an adolescent for this surgery.[33]

A survey of 184 general practitioners in the Netherlands found that 55% (102/184) had referred obese patients for lifestyle modifications. Ninety-five percent believed that conservative management was effective in about half of their obese patients. Only 43% said they would consider referral to bariatric surgery due to limited long-term outcome data.[142] Almost half the respondents feared that bariatric surgery is only symptomatic therapy, as opposed to a solution.[142] In a sample of US pediatricians and family physicians, about half would not refer an obese adolescent for bariatric surgery. In contrast to the ASMBS guidelines, the minimum age most respondents suggested for bariatric surgery was 18 years.[143]

A review recommends discussing bariatric surgical options early in the weight loss process. This allows time and opportunity for patients, parents, and providers to become familiar with the procedure and potential long-term clinical benefits.[144]

SUMMARY

In severely obese adolescents, bariatric surgery is a successful weight-management intervention.[34,145] Obese children are not equivalent to obese adults with respect to their preoperative evaluation and postoperative care. They require care teams with pediatric expertise. Important physical and psychosocial differences must be considered in selecting patients and obtaining assent. Given ongoing changes in surgical technique and the financing of bariatric surgery, future studies are needed to assess the comparative effectiveness of surgical approaches and to compare bariatric surgery and lifestyle or pharmacological interventions in randomized controlled trials. Mingrone et al. found in a single-center, non-blinded randomized controlled trial of 60 adult patients who underwent medical therapy vs. gastric bypass or biliopancreatic diversion surgery that there was a superiority in surgical intervention for diabetes remission with 0 patients in the medical group vs. 75% in the surgical bypass group and 95% in the surgical biliopancreatic diversion group.[146] Similar larger-scale comparative studies are needed for adolescent patients. Longitudinal data from the Teen-LABS study support surgical intervention in adolescents. Bariatric surgery can resolve obesity-related co-morbidities in patients during early adolescence.[126] Surgery can also improve psychological outcomes and yield sustainable weight loss. In considering when to intervene, earlier timing is likely more effective[9] because younger patients tend to have fewer and less-severe obesity-related co-morbidities. Further evidence is needed before consensus between medical and surgical providers can be established.

The sustainability of adolescent bariatric surgical outcomes >5 years is not currently well known. Data are becoming available from prospective observational studies, including the Teen-LABS study. Specialized care teams with consideration of the age-related issues of consent, physical development, psychology, and compliance must be part of the evaluation process.

Early prevention and societal changes are integral in reducing obesity among children and adolescents. Unfortunately, population-based changes are complicated and often slow to occur. The need to improve health outcomes in severely obese adolescents is urgent. The research described here supports the conclusion that bariatric surgery is currently the most effective treatment option for obesity in adolescents.

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L.A.S., S.E.L., and P.L.B. contributed substantially to concept, design, drafting of the article, and revision. C.H. and N.F.D.L.C.-M. provided important expertise and critically appraised and revised the manuscript. All authors approved the final version of the manuscript.

ADDITIONAL INFORMATION

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