Bariatric Surgery in Adolescents

Subjects: Pediatrics

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Pediatric obesity is a multifaceted disease that can impact physical and mental health. It is a complex condition that interweaves biological, developmental, environmental, behavioral, and genetic factors. In most cases lifestyle and behavioral modification as well as medical treatment led to poor short-term weight reduction and long-term failure. Thus, bariatric surgery should be considered in adolescents with moderate to severe obesity who have previously participated in lifestyle interventions with unsuccessful outcomes.

Keywords: pediatric obesity ; bariatric surgery ; adolescents ; nutritional status ; weight loss ; laparoscopic sleeve gastrectomy ; multi-disciplinarity ; complications

1. Obesity, Cardiometabolic Complications and Medical Treatment

Childhood obesity represents a troublesome public health problem which affects the majority of developed countries [1]. There are currently three major classifications used to assess overweight or obesity in children/adolescents. The cut-off points are based on growth curves according to the World Health Organization (WHO), the International Obesity Task Force (IOTF), and the US Centers for Disease Control (CDC). Concerning WHO classification, children aged between 5–19 years are classified as overweight or with obesity when body mass index (BMI)-for-age and sex is at or above the 85th percentile and below the 97th percentile, or above the 97th percentile, respectively [2]. According to CDC overweight is defined as a BMI at or above the 85th percentile and below the 95th percentile for children and teens of the same age and gender; obesity is defined as a BMI at or above the 95th percentile [3]. The IOTF system uses smooth gender-specific BMI curves, constructed to match the values of ≥25 kg/m^2 (Overweight) and ≥30 kg/m^2 (Obesity) at 18 years, thus providing age and gender BMI cut-offs for overweight and obesity, based on large data sets from six countries or regions covering different races/ethnicities [4].

It is well known that obesity-related complications and diseases are numerous, including metabolic and cardiovascular complications (Table 1).

Table 1. Obesity related co-morbidities in children and adolescents. Kansra et al. [5], modified.

Cardiovascular **Hypertension** **Dyslipidemia**	**Endocrinology** **Type II Diabetes Mellitus** **Precocious puberty** **Insulin resistance** **PCOS** **Menstrual irregularities**
Gastrointestinal **Gastroesophageal reflux disease** **Gallstones** **Non-alcoholic fatty liver disease**	**Orthopedics** **Slipped capital femoral epiphysis** **Ankle sprains** **Blount's disease** **Arthritis** **Join pain** **Tibia vara** **Flat feet**
Neurological **Pseudotumor cerebri** **Headache**	**Renal** **Glomerulonephritis** **Nephrotic Syndrome**

Respiratory **Asthma** **Obstructive sleep apnea**	
Psychological **Depression** **Anxiety** **Poor-self-Esteem** **Poor Body Image** **Eating disorder** **Sleep Disturbance**	**Dermatological** **Acanthosis Nigricans** **Striae** **Hidradenitis Suppurativa**

Metabolic complications develop early in children and adolescents with obesity and worsen as the obesity degree increases. In addition, the prevalence of metabolic syndrome (MetS) in children and adolescents has increased with increasing prevalence of obesity [6]. MetS refers to a clustering of co-incident and inter-related risk factors that place an individual at high risk of developing cardiovascular disease and type 2 diabetes with increased mortality risk.

In the scientific literature, there are currently no standardized diagnostic criteria for MetS in pediatrics. As reported in Table 2, different classifications have been proposed; thus, a wide range of MetS prevalence rates is reported.

Table 2. Diagnostic criteria for metabolic syndrome (MetS) in adolescent children aged 10 to 16 years according to International Diabetes Federation (IDF) versus IDEFICS study criteria, those recommended by Cook et al. [7], and those proposed by De Ferranti et al. [8].

International Diabetes Federation	IDEFICS Study	Cook et al.	de Ferranti et al.
Waist circumference ≥90th percentile for age and sex associated with at least 2 of the following: (1) Fasting blood glucose ≥100 mg/dL (≥5.6 mmol/L) (2) Triglyceride level ≥150 mg/dL (≥1.7 mmol/L) (3) HDL cholesterol ≤40 mg/dL (4) Systolic blood pressure ≥130 mmHg or diastolic blood pressure ≥85 mmHg	**≥3 of the 4 following criteria:** (1) waist circumference ≥90th percentile (monitoring level) or ≥95th percentile (action level) (2) Systolic and/or diastolic blood pressure ≥90th percentile (monitoring level) or ≥95th percentile (action level) (3) Triglycerides ≥90th percentile (monitoring level) or ≥95th percentile (action level) or HDL cholesterol ≤10th percentile (4) HOMA-IR or fasting plasma glucose ≥90th percentile (monitoring level) or ≥95th percentile (action level)	**≥3 of the 5 criteria below:** (1) waist circumference ≥90th percentile (2) Blood Pressure ≥90th percentile (3) Triglycerides ≥110 mg/dL (4) HDL-cholesterol ≤40 mg/dL (5) Impaired fasting glucose (≥110 mg/dL)	**≥3 of the 5 criteria below:** (1) waist circumference ≥75h percentile (2) Blood Pressure ≥90th percentile (3) Triglycerides ≥100 mg/dL (4) HDL-cholesterol ≤50 mg/dL (5) Impaired fasting glucose (≥110 mg/dL)

In a recent review by Reisinger et al. [9], the prevalence of MetS in pediatric age ranged from 0.3% to 26.4%. The lowest prevalence (0.3%) was found, according to the IDF definition [10], in the Colombian pediatric population, whereas the highest prevalence (26.4%) was observed among Iranian children [11] and adolescents according to the criteria of de Ferranti et al. The median prevalence value of the entire dataset was 3.8%. These data have to be seriously considered in order to assess the potential future health risk, taking into account the young age [12] of the examined subjects. Children with MetS have an increased risk of continued MetS in adulthood with a high likelihood of type 2 diabetes mellitus and cardiovascular disease [13]. For this reason, it is necessary to intervene decisively and effectively obesity in adolescents to prevent future related health complications and impaired quality of life.

It is clear that the first step in the treatment of obesity and metabolic syndrome in children is lifestyle medicine by means of dietary counseling, physical activity, and behavioral changes. The Endocrine Society Clinical Practice Guidelines recommend a minimum of 20 min of moderate-to-vigorous physical activity daily, independent of the grade of adiposity, in order to obtain weight loss and improve insulin sensitivity by counteracting the insulin resistance secondary to obesity [14][15][16].

In addition, a balanced and high-fiber diet is strongly recommended and appears to correlate with increased peripheral insulin sensitivity [17][18] lower risk of developing MetS in children and adolescents, lower systolic blood pressure and fasting blood glucose [19], as well as a healthier composition and diversity of gut microbiome, which may affect nutrient metabolism and energy balance [20]. In contrast, many studies have shown that high fat intake impairs insulin-sensitivity [21][22] regardless of adolescents' adiposity [23]. Moreover, if high intake of saturated fats is also accompanied by excessive intake of refined grains, simple sugars, salt, and inadequate intake of fiber, as in the Western diet [24][25] this promotes inflammation [25] and changes of the gut microbiome profile, from healthy to a pattern more common in obesity [26][27]. The Western diet also influences the development of hypertension; the American Academy of Paediatric (AAP) recommends adoption of the Dietary Approaches to Stop Hypertension (DASH), which includes a diet rich in fruits, vegetables, low-fat dairy products, whole grains, fish, poultry, nuts, lean red meat and low in sugar, sweets, and sodium, for children and adolescents with hypertension [28]. If necessary, in addition to lifestyle and dietary modifications, prescription of approved medications for weight loss can be recommended.

At the moment, there are no singular effective medical strategies available for long-lasting weight reduction in adolescents with severe obesity. Weight loss medications, while effective, have low popularity, are cost prohibitive as they are not covered by National Health Care, and there are safety concerns due to historical issues associated with weight loss drugs [28]. Moreover 3–44% of patients on weight-loss medication may experience side effects [29][30]. However, recent data on the use of weight loss medications shows promise in the pediatrics population [31][32].

Approved pharmacological treatments for obesity in pediatric age are limited. Orlistat, which acts as an inhibitor of intestinal lipase for adolescents aged ≥12; phentermine, a sympathomimetic amine, approved in teenagers aged ≥16 years and liraglutide, a glucagon-like peptide-1 receptor. (GLP-1) agonist, in pediatric (7–11 years) have been approved by the Food and Drug Administration (FDA). Liraglutide was also approved this year by the European Medicines Agency (EMA) in 12–17 old children [33].

For the treatment of insulin resistance, pharmacological intervention in pediatric age consists of off-label drugs use, since no drug has been specifically approved for this population. Metformin, a biguanide, represents the first-choice medication. It is administered orally and acts to reduce glucose levels, inhibiting the process of hepatic gluconeogenesis and promoting intestinal absorption of glucose [34][35][36]. Although metformin does not often result in significant body weight loss, it appears to prevent or delay alteration of glucose homeostasis in children at high risk of developing type 2 diabetes mellitus [37]. There are studies showing that metformin improves insulin sensitivity in adolescents with type 2 diabetes and polycystic ovary syndrome (PCOS) [38].

In addition to metabolic irregularities, there are cardiovascular irregularities such as dyslipidemia which warrant early diagnosis and management [39]. The treatment of dyslipidemia in childhood starts with lifestyle modification: low saturated fat and simple sugars dietary intake, adequate physical exercise and, if necessary, weight reduction. The AAP recommends prescription of medications (along with lifestyle modifications) in patients 8 years or older with LDL cholesterol (LDL-C) ≥190 mg/dL, or ≥160 mg/dL if there is a positive family history of premature cardiovascular disease and/or presence of other risk factors, also when LDL-C is ≥130 mg/dL if there is diabetes mellitus. For children younger than 8 years of age, the use of medication is only recommended when LDL-C values are ≥500 mg/dL [40]. According to the National Heart Lung and Blood Institute (NHLBI) children younger than 10 years of age should not be treated pharmacologically unless they have severe primary hyperlipidemia or high-risk condition associated with severe medical morbidity (homozygous hypercholesterolemia, LDL cholesterol level ≥400 mg/dL, primary hypertriglyceridemia with a triglyceride level ≥500 mg/dL, and cardiovascular disease evident in the first 2 years of life after cardiac transplantation). It is also necessary to initiate drug treatment in children older than 10 years, if LDL cholesterol levels consistently exceed 190 mg/dL, after a 6-months lifestyle intervention attempt [40][41]. Statins, HMG-CoA reductase inhibitors, are recommended as first-line approach in pediatric patients [41].

With regards to hypertension, the AAP Clinical Practice guidelines for screening and management of high blood pressure in children and adolescents, published in 2019, recommend initiating drug therapy with a single medication for children remaining hypertensive despite lifestyle modifications, or who have symptomatic hypertension, stage 2 hypertension without a clearly modifiable factor (e.g., obesity), or any stage of hypertension associated with type 1 diabetes mellitus or chronic kidney disease [40][42]. Recommended pharmacologic treatment includes the use of angiotensin-converting enzyme (ACE) inhibitor or angiotensin II receptor blocker (ARB), long-acting calcium channel blocker or thiazide diuretic. Obesity grade correlates with mortality risk secondary to cardiovascular disease; in fact, children with BMI >95th percentile have three- to five-fold increased risk of cardiovascular (CVD) mortality by age of 50 [43].

The first step in treating pediatric obesity should focus on lifestyle changes, particularly with a structured weight-management program and multidisciplinary approach [44]. Both intensive medical and lifestyle interventions for obesity treatment have demonstrated an average weight loss of around 5–15%, with variable results in compliance [45][46] and high percentage of drop out. Unfortunately, the probability that adolescents will attain a normal weight is very low and weight cycling was most common among subjects with baseline body mass indexes in the severe obesity category, as well as underdiagnosed binge eating that negatively impacts on treatment outcomes if not exhaustively addressed [47][48][49].

Weight loss interventions rarely resulted in substantial and sustained BMI reduction or resolution of co-morbidities for adolescents who have severe obesity [48][50].

Failure of lifestyle treatments and their risks for early complications of severe obesity poses bariatric surgery as the most effective weight loss treatment for severe obesity and its comorbidities in adolescents.

2. Eligibility Criteria for Bariatric Surgery

The use of bariatric surgery in children with severe obesity has received considerable recent attention, even if the surgery has not been widely accepted. In the adult population, combined multi-disciplinary interventions are often required in conjunction with bariatric surgery to achieve long-term satisfying results [51]. This is also reflected in the more recent trend to perform bariatric surgery as a strategy in adolescents with severe obesity [52]. However, many surgeons are still reluctant to embrace bariatric surgery in adolescent patients; they state that it is irreversible, invasive, and has potential life-long alterations [51]. Arguments in favor of an early surgical approach are based on the evidence that the efficacy of surgery is reduced over time and that adolescent obesity is more intractable and sustained than obesity in adults [53][54]. The recent American Society of Metabolic and Bariatric Surgery (ASMBS) guidelines outline the inclusion criteria for pediatric and adolescent bariatric surgery; with the significant improvement in long term data, they are less controversial than previous guidelines which often presented ethical concerns and scarcity of long-term data [45][55]. It must be noted that the criteria for being considered for metabolic and bariatric surgery as a pediatric patient are stricter than those used for adults. Bariatric surgery is proposed in adolescents with BMI ≥ 35 kg/m^2 (moderate obesity) with major comorbidities or with a BMI ≥ 40 kg/m^2 (severe obesity) with minor comorbidities [56].

The European Association for Endoscopic Surgery has recently developed a list of clinical practice guidelines on bariatric surgery which mirrors those proposed by ASMBS. Surgery should be considered for patients with BMI ≥ 40 kg/m^2, for patients with BMI ≥ 35–40 kg/m^2 with associated comorbidities and for patients with ≥ BMI 30–35 kg/m^2 and type 2 diabetes and/or arterial hypertension with poor control despite optimal medical therapy [56].

According to the “Interdisciplinary European Guidelines on Metabolic and Bariatric Surgery”, BMI ≥ 40 kg/m^2 (or 99.5th percentile for respective age) with associated comorbidities is not the only surgical criterion.

BMI criterion must also be associated with all of the following:

- at least 6 months of lifestyle treatment for weight loss in a specialized center

- complete skeletal and sexual maturation

- ability to give informed consent with adequate understanding of the procedure

- ability to commit to comprehensive medical and psychological evaluation before and after surgery

- willing to participate in a post-surgery multidisciplinary program

- surgery access in a unit with specialist pediatric support

In 2015, the European Society for Paediatric Gastroenterology Hepatology and Nutrition (ESPGHAN) Position Statement provided additional criteria for surgery [57] in adolescents: BMI ≥ 40 kg/m^2 with severe comorbidities (type 2 diabetes mellitus; moderate-to-severe sleep apnea, pseudotumor cerebri, NASH with advanced fibrosis—ISHAK score>1) or BMI ≥ 50 kg/m^2 with mild comorbidities (e.g., hypertension, dyslipidemia, mild obstructive sleep apnea, chronic venous insufficiency, panniculitis, urinary incontinence, impairment in activities of daily living, NASH, gastroesophageal reflux disease, severe psychological distress, arthropathies related to weight). Moreover, patients are strongly recommended to avoid pregnancy for 1 year after surgery and are driven to adhere to nutritional guidelines after surgery.

According to the ASMBS guidelines, there are some contraindications for MBS:

- Obesity that can treated with medical therapy.
- Substance abuse within the past year.
- Current or planned pregnancy within 12–18 months of the scheduled surgical procedure.
- Concomitant eating disorders.
- Medical, psychiatric, psychosocial issues interfering with postsurgical recommendations and required lifestyle modifications

It is worth noticing that adolescents represent a vulnerable group of patients in a very susceptible transitional developmental stage of self-concept, influenced by relationships, social environment [58], and the educational system. As described above, adolescents with obesity often suffer from body dissatisfaction, low self-esteem, teasing, and symptoms of mood deflection in combination with a history of eating disorder symptoms such as binge eating (BE) that may support, or even worsen, the vicious cycle of obesity which could lead to negative outcomes in metabolic and bariatric surgery [59]. Loss of control (LOC) with snacking and binge eating (BE) is prevalent among adolescents (15–28%) seeking bariatric surgery [60], even if few studies have investigated prevalence of LOC and BE in this category of subjects [61][62]. Multidisciplinary assessment involving psychological evaluation is mandatory before surgery [63] and ASMBS pediatric guidelines recommend preoperative assessment for LOC and treatment with systemic family-based therapy, individual cognitive behavioral therapy, and, if necessary, medication [64].

3. Laparoscopic Sleeve Gastrectomy as Preferred Surgical Approach

Bariatric surgery options include Roux-en-Y gastric bypass (RYGB), biliopancreatic diversion with duodenal switch (BPD-DS), sleeve gastrectomy (SG) and adjustable gastric banding (AGB).

According to the pediatric metabolic and bariatric surgery guidelines, vertical sleeve gastrectomy (VSG) has become the most commonly used and recommended surgery procedure in adolescents with severe obesity, because of its near-equivalent weight loss and efficiency regarding co-morbidities to the RYGB, with fewer revision surgeries and better nutrient absorption [45].

A minimally invasive surgical approach has become the preferred technique in bariatric surgery. Laparoscopic sleeve gastrectomy (LSG) initially represented the first stage of the duodenal switch procedure in patients with severe obesity, but it has been rapidly used as a single procedure due to its technical ease and good results [65][66].

SG has recently gained attention both in the adult and adolescent bariatric population due to several longitudinal studies which demonstrate excess weight loss between 38% and 83%, and it is less technically complex when compared to RYGB with less malabsorption of specific nutrients [67][68][69]. Initial results of SG in adolescents are encouraging; they demonstrate results similar to adult studies and SG is the predominant choice in centers offering bariatric surgery within this age group [70][71][72][73].

LSG is considered the most commonly performed bariatric surgery worldwide. The safety of the LSG technique, together with high survival rates have been widely demonstrated and LSG has become the surgery procedure of first choice in patients with severe obesity worldwide both in adulthood and pediatric age [66][74][75][76][77][78][79], and in the adolescent population, LSG appears to have a higher safety profile than other bariatric operations [80]. The effectiveness of a single procedure in weight loss has been demonstrated in pediatric age [75].

LSG consists of forming a “sleeve” from the stomach by surgically stapling its edges. This technique is also referred to as “greater curvature gastrectomy”, or “vertical gastrectomy” or “pylorus preserving gastric tube”. The vertical resection involves the greater curvature and the fundus and leads to a gastric tuberization [75] Gastric resection includes approximately 80% of the stomach and the remnant gastric area has a capacity > 100 mL. Gastric reduction does not require a gastrointestinal anastomosis or bypass which makes it easier than RYGB or BPDDS [81][82].

This minimally invasive approach has become the preferred technique in bariatric surgery and the laparoscopic approach is commonly adopted in children and adolescents as the treatment of choice. Robotic surgery presents many advantages over the laparoscopic approach such as improvement of surgical ergonomics, shortened length of stay, decreased tissue damage, and decreased postoperative need of analgesia [83].

With regards to minimally invasive bariatric surgery, specific laparoscopic instrumentation must be used which includes longer trocars and longer instruments, and bougie devices (34–36 F) useful to accommodate the thicker abdominal wall of patients with obesity. The patient is placed in the supine position, 20′ tilted in reverse Trendelenburg. The procedure is performed with four trocars: a 12 mm trocar in the umbilicus for the 30-degree laparoscope, two operative trocars (5 and 15 mm) to the left and right of the umbilicus and a 5 mm trocar in the left hypo-condrium (or subxiphoid area) for liver retraction. The surgeon stands between the legs of the patient.

As first step, the dissection starts from the cardial region, dividing the peritoneal sheet and removing the fat in front of the hiatus until the left crus is exposed from behind. The dissection should proceed distally to the antrum. The site of the distal transection should preserve the antrum and should be placed nearly 2–6 cm proximal to the pylorus. The gastrocolic ligament is dissected with a vessel sealing device (Maryland Ligasure®) starting halfway at the greater curve. It is important to stay close to the gastric wall to avoid damaging surrounding tissues and vessels and to reduce the risk of portal vein thrombosis. Once the lesser sac is partially opened the posterior wall of the stomach is inspected and the dissection is extended posteriorly to take down all adhesions.

The dissection proceeds inferiorly to reach the marked point on the antrum, and superiorly, up to the cardia. The stapled sleeve gastrectomy is performed with an EndoGIA starting from the distal part. The bougie (34–36 F) is used after the first fire as a guide inside the stomach lumen (inserted from the mouth and directed to a point distal to the divided omental attachments, under laparoscopic surveillance). Gastrectomy is completed with two–four vertical firings. The last firing is performed with a lateral movement to partially maintain the gastro-phrenic ligament, to preserve the vascularization and to keep part of the muscular fibers over the cardia for gastro-esophageal junction competence (1 cm left of the gastro-esophageal junction, leaving a sort of “dog ear”). At the end, it is possible to complete the vessel dissection by dividing the short vessels. The air insufflation test can be performed to rule out a torsion of the sleeve. The specimen is then extracted from the umbilical access.

Data on short and middle term outcomes in pediatrics show no major complications and a low rate of minor complications (4.3% according to Alqahtani et al.) [84] after LSG, with no evidence of mortality [85][86][87].

Retrospective analysis from the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBASQIP) database (USA) confirmed that both LSG and RYGB are relatively safe, but the LSG is associated with a significantly lower rate of major complications in the first month after surgery [88] and with shorter operative times [82][89], especially in accredited centers [80].

In 2016, Pepper et al. [83] reported the results of a retrospective analysis showing the same results when comparing LSG and robotic sleeve gastrectomy in terms of safety and efficacy. Shorter length of stay and better postoperative pain control were considered potential benefits of the robotic approach [90].

As reported in Table 3, surgical complications are not excluded. In the immediate postoperative period, nausea, vomiting and dehydration, anastomotic leak and gastric tube twist as well as volvulus may occur; wound infection at the trocar site is also a recurrent complication described in patients with severe obesity (0.6%). In middle term outcome, major complications are described, but not recorded in pediatrics [84]. Long-term follow up is recommended for gastroesophageal reflux disease secondary to the risk of developing esophageal disease such as Barrett’s esophagus.

Table 3. Surgical and medical complications after laparoscopic sleeve gastrectomy (LSG).

General Complications	Insufficient Weight Loss and Weight Regain
Surgical complications (mostly minor complications)	**Acute post-operative** − Nausea, vomiting and dehydration − Anastomotic leak (unexplained tachycardia within the first post-operative week) − Gastric tube twist and volvolus − Wound infection at trocar site **At middle/long-term follow-up** − Hiatal hernia − Gastroesophageal reflux − Barrett's esophagus − Stricture (rare)
Nutritional risks	**Micronutrient deficiencies** − Iron deficiency and anemia − Vitamin B12 deficiency − Reduction of folate absorption − Hypo-ferritinemia − Hypoalbuminemia − Thiamine (vit B1) deficiency **Dehydration** **Adverse bone density and bone microarchitectural changes**

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