Should bariatric surgery be performed in adolescents?

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Abstract

Adolescent obesity has markedly increased worldwide in both its extent and prevalence in recent decades and obesity prevention strategies are failing. As a result, effective treatment strategies are urgently needed. As behavioral and pharmacological treatment approaches have only moderate effects in severe obesity, bariatric surgery has begun to emerge as a treatment option. In this debate article, we offer arguments opposing and supporting bariatric surgery in the treatment of severe obesity in adolescents. Bariatric surgery has superior therapeutic outcomes with respect to weight loss and resolution of comorbid diseases over other existing treatments. However, long-term outcomes after bariatric surgery in adolescents are only just beginning to emerge. Furthermore, the procedures are generally considered irreversible, apart from gastric banding. Most importantly, not all adolescents seem to benefit greatly from bariatric surgery and we are not yet able to reliably identify those who stand to gain the greatest benefit. The authors agree that adolescent bariatric surgery should be offered exclusively within formal adolescent obesity programs, delivered by specialist multidisciplinary child/adolescent obesity teams, and within specialist centers, in order to optimize outcomes and minimize potential detrimental effects. Patients and their family/carers must be educated regarding the benefits and risks, potential side effects, expected changes in eating behavior and the lifelong requirement for regular medical follow-up after surgery. Before embarking upon a surgical treatment pathway in adolescents with severe obesity, it may also be beneficial to ensure compliance to treatment is demonstrated, in order to minimize the risk of nutritional deficiencies and associated potential complications.

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Introduction

Adolescent obesity has markedly increased in prevalence worldwide across the past three decades (1, 2, 3, 4). In the adolescent, obesity is associated with type 2 diabetes, increased cardiovascular risk (5, 6, 7) and early cardiovascular changes (6, 8). Furthermore, obesity in adolescents leads to a reduction in quality of life and global functional impairment (9, 10, 11, 12). Therefore, effective treatment strategies are urgently needed.

Many studies have cataloged the modest outcomes of conventional treatment for adolescent obesity, including behavioral and pharmacological approaches, which are mostly confined to the short term (13, 14, 15). Thus, bariatric surgery has emerged as a potential treatment

option, and the number of adolescents undergoing bariatric surgery is increasing in Europe (16), the United States (17) and beyond (18).

In this debate article, we offer arguments opposing and supporting bariatric surgery in the treatment of adolescent obesity.

The case against bariatric surgery for adolescent obesity

Weight loss is much greater in patients after bariatric surgery compared to patients with lifestyle intervention (19, 20, 21, 22). Quality of life and other psychological

Table 1 Reported side effects of bariatric surgery in adolescents.

Outcome	Adolescent bariatric surgery (%) (16, 21, 22, 26, 27, 80)	Adult bariatric surgery (%) (101, 114, 141, 142, 143, 144)	Healthy adolescent population (%) (22, 113, 145, 146)
Mortality (30-day)	0°	0.08–0.31	N/A
Minor complications	3–48	10–17	N/A
Additional operations	13–17*	6–7*	–
Low ferritin	39–57	23.5–28	21
Low folate	8	16–35	53
Low vitamin B ₁₂	8–13	58–61.8	0
Low vitamin D (25-OHD)	43	52	42
Low vitamin A	13	17	6^

°One case reported as a stand alone case report in the literature; *excluding gastric band explantation, which has been reported in approximately a quarter of adolescents and half of adults; ^preoperative adolescent obesity group.

outcomes frequently improve after bariatric surgery (23, 24), and its short-term side effects and mortality are low in specialized centers (16, 19, 20, 21, 22). However, there are some concerns regarding bariatric surgery in adolescents. These mainly relate to side effects, uncertainty about long-term outcomes and ethical considerations surrounding adolescents agreeing to bariatric surgery procedures, which are predominantly irreversible.

The known side effects of bariatric surgery in adolescents are largely informed by four registries of bariatric surgery in adolescents: the Teen-Longitudinal Assessment of Bariatric Surgery (Teen-LABS) study from the United States (22, 25, 26), Adolescent Morbid Obesity Surgery (AMOS) study in Sweden (27), the Germany Obesity Registry (16) and a series from Saudi Arabia (18). The known complications are summarized in Table 1. In the first three years after bariatric surgery, the number of side effects is relatively low. However, it should be mentioned that the low complication rates in bariatric surgery in adolescents in these registries are derived from highly experienced surgeons. Owing to the effect of a learning curve in surgical procedures, centers planning to initiate bariatric surgery in adolescents should ensure that the operating surgeons are of sufficient experience, much of which may be from surgery in adults, to minimize the impact of their learning curve on the mortality and morbidity outcomes of operated adolescents. Dual-operating between pediatric and adult bariatric surgeons should be considered.

It has to be highlighted that one perioperative death has been reported in the literature (28), demonstrating that the mortality is above zero. Subsequent bariatric surgery procedures are frequently necessary, especially after gastric banding (21). Most importantly, the morbidity and mortality after 3 years are currently unknown. However, it can be expected that severe side effects will occur in some patients, especially after the more invasive procedures.

An example side effect is the dumping syndrome, which comprises a combination of gastrointestinal symptoms, such as abdominal pain, diarrhea, nausea, bloating, alongside vasomotor symptoms, such as fatigue, palpitations and hypotension (29). The dumping syndrome is divided into early dumping, with gastrointestinal symptoms, and late dumping, typically occurring 1–3 h after a meal without gastrointestinal symptoms (30). Dumping has been reported in adolescents after Roux-en-Y bypass (31, 32). Furthermore, all techniques involve a risk of vitamin and micronutrient deficiency, which some worry could lead to a degree of growth retardation. The prevalence of decreased vitamin levels and ferritin levels in the first 3 years after bariatric surgery points in this direction (Table 1). Supplementation of vitamins and micronutrients is routine, especially after sleeve gastrectomy and gastric bypass procedures, to avoid rare irreversible side effects such as polyneuropathy associated with vitamin B12 deficiency (33). Finally, refeeding syndrome with Wernicke's encephalopathy, due to thiamine deficiency has been reported after obesity surgery (34), although it is exceptionally rare (33). Refeeding syndrome is an important complication of parenteral or enteral resumption of nutrition after malnourishment and reflects the change from catabolic to anabolic metabolism. It presents with a fall in serum levels of phosphate, potassium and magnesium. This severe electrolyte disturbance can cause a life-threatening condition, and early recognition is vital to reduce morbidity and mortality (35). Prevalence data in adolescents with bariatric surgery are not known so far. To detect these important side effects of bariatric surgery, regular check-ups of vitamin, electrolytes and hemoglobin levels are necessary. Therefore, lifelong treatment adherence is an important requirement for successful long-term intervention with bariatric surgery.

After bariatric surgery, eating behavior has to change toward consuming small portions. Additionally, sparkling

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Table 2 Arguments against bariatric surgery.

Argument against bariatric surgery	Counter-argument
In adolescents with non-severe obesity, lifestyle interventions are effective to improve cardiovascular risk factors and quality of life with few side effects	Adolescents with non-severe obesity are ineligible for bariatric surgery
The long-term (>3 years) effects of bariatric surgery on mortality and morbidity have yet to be quantified	A mature body of literature demonstrates overwhelmingly positive long-term implications on mortality and morbidity after bariatric surgery in adults. The growing body of literature in adolescents concurs thus far. Robust ≥ 5 -year European (AMOS) and US (FAB55+) adolescent outcomes are imminent
The long-term (>3 years) effects of bariatric surgery on micronutrient and vitamin deficiencies are not known	Many nutritional abnormalities are present in non-surgical adolescents with obesity, but additional deficiencies arise after bariatric surgery. The adult literature demonstrates that these are rarely irreversible. Careful monitoring and supplementation are essential core components of a bariatric surgical program
The long-term (>3 years) effects of bariatric surgery on the risk of development of other disease processes, pathological eating behavior or other relevant side effects have not yet been reported robustly	The adult literature demonstrates a 30–80% reduction in cancer risk after bariatric surgery within just 5–10 years of follow-up. In adults and adolescents, pathological eating appears uncommon and side effects have been well tolerated
The long-term (>3 years) effects of bariatric surgery on quality of life have yet to be quantified	Outcomes in the short and medium term have been promising. Two major studies (AMOS and FAB55+) will imminently publish quality of life outcomes at ≥ 5 years
We do not know which adolescents stand to benefit most from bariatric surgery and not all adolescents benefit psychologically from bariatric surgery	Most adolescents gain significant physical and psychological benefit from their bariatric surgery. We must continue to actively seek ways of identifying those who will do well and those who will either need additional support or in whom surgery may be inappropriate
The prevalence of eating disorders and other psychiatric diseases among adolescents with severe obesity is not well quantified and, if uncontrolled, these may represent relative contraindications for bariatric surgery	Reports in adolescent bariatric surgery describe careful psychological and dietetic assessment. Guidance is explicit in its eligibility requirement that any psychiatric condition must be under control
Many adolescents are unable to adhere to the lifestyle interventions that guidelines state should be followed prior to entry into bariatric surgery programs. This raises a question of whether such individuals are truly eligible for surgery, in line with guidance	Guidance requires that candidates demonstrate an ability to comply with treatment regimens and medical therapy. Those failing to do so are considered ineligible for bariatric surgery

drinks should be avoided to minimize symptoms risk of gastroesophageal reflux and the potential for esophagitis after sleeve gastrectomy and gastric banding (36). Furthermore, esophagitis is a risk factor for esophageal cancer and adenocarcinoma of the gastroesophageal junction has been reported after bariatric surgery (37).

In the context of avoiding large food portions because of associated malaise, development of pathological eating behavior has been reported occasionally after bariatric surgery, especially when eating is an ‘addiction’. Examples of this include consuming large volumes of high-caloric drinks or drinking melted chocolate. So far reports suggest that eating behavior adapts in a healthy direction after bariatric surgery in adolescents (38). However, it is unknown if this is true for all adolescents receiving bariatric surgery. It is likely that, especially in adolescents with eating disorders based on deteriorations in the satiety regulation such as melanocortin 4 receptor (MC4R) mutation, leptin resistance or Prader–Willi syndrome (PWS), the eating behavior will not

be normalized after bariatric surgery. Therefore, these adolescents may be at high risk for suboptimal weight loss or possibly even continued weight gain after bariatric surgery. Furthermore, if eating is restricted as a result of surgery, these adolescents may experience deterioration of their quality of life.

Of interest, there were two cases of attempted suicide reported after bariatric surgery in the AMOS study in Sweden (23, 39). Furthermore, not all adolescents demonstrated improved anxiety scores and improved depression scores after bariatric surgery in this registry (23, 39). Sixteen percent of the adolescents treated with bariatric surgery had deteriorated on two or more inventories in the Beck Youth Inventory (BYI) (23, 39). Additionally, five cases of drug abusers were reported after bariatric surgery (23, 39). These findings suggest that not all adolescents benefit psychologically from bariatric surgery. Therefore, screening potential candidates before the irreversible procedure of bariatric surgery seems appropriate to identify those adolescents who will

benefit most from this kind of intervention. However, instruments to accurately elucidate this pre-operatively are not yet available.

Apart from the known side effects of bariatric surgery in adolescents, there may be further side effects in the long run, of which we have yet to become aware as these procedures were not performed 30 years ago in adolescents. Observations in adults show that the prevalence of some diseases can be greater several years after bariatric surgery than that in control patients, an example being renal lithiasis (40), although it should also be mentioned that data thus far suggest that bariatric surgery improves renal function in adolescents, at least in the short term (41).

Overall, three areas in bariatric surgery in adolescents raise ethical issues: the long-term morbidity and mortality are unknown as yet; apart from gastric banding, the procedures are irreversible and most importantly, not all adolescents seem to benefit from these procedures (see Table 2; (20)).

To evaluate whether the impressive effects of bariatric surgery on weight loss in adolescents with obesity justify the known and suspected side effects, it is necessary to compare the effects and side effects between bariatric surgery and lifestyle interventions. Lifestyle interventions based on behavioral strategies are regarded as the therapy of choice in adolescents with obesity (42). The efficiency of lifestyle intervention for childhood and adolescence obesity has been proven by several randomized controlled trials (RCT) and meta-analyses (42). Two meta-analyses summarizing the findings of >60 RCTs with >5500 children reported in concordance that combined behavioral lifestyle interventions are more effective in reducing obesity in children than standard care or self-help at 6- and 12-month follow-up (43, 44). The mean reduction of body mass index standard deviation score (BMI-SDS) in lifestyle interventions for children with obesity 12 months after onset of intervention ranged from -0.29 to -0.63, with better results in children aged 8–12 years and those being less overweight (43, 44, 45, 46, 47, 48). The BMI reduction is much lower in lifestyle intervention than that in bariatric surgery (19, 20, 21, 22). Although long-term outcome data after bariatric surgery are missing, there are few studies in children and adolescents demonstrating the changes of weight status ≥ 5 years after end of lifestyle intervention. However, consensus from existing long-term studies suggests that the weight loss achieved in the lifestyle intervention was sustained for 5–10 years (43, 49, 50, 51). Lifestyle interventions in children and adolescents have been reported to be associated with an improvement of cardiovascular risk factors such as the components of

the metabolic syndrome: hypertension, dyslipidemia and disturbed glucose metabolism (52, 53). Interestingly, cardiovascular risk factors ameliorated to a similar degree in the only existing randomized trial comparing bariatric surgery (adjustable gastric band) and a lifestyle intervention, even though weight loss was much greater in the gastric banding group (21). Non-alcoholic fatty liver disease (NAFLD) improves after lifestyle intervention (54), transaminase levels falling almost as much as has been observed after RYGB (27). Polycystic ovarian syndrome (PCOS) has also been shown to improve after a lifestyle intervention (54), evidence of which is limited thus far after bariatric surgery (55). Moreover, quality of life ameliorated in lifestyle interventions independently from the degree of weight loss (56, 57) and similar to the effects of bariatric surgery (23). One perioperative death has been reported after adolescent bariatric surgery (28), and three patient deaths, reportedly unrelated to the surgical procedure, have been documented in the long term (22, 55). In contrast, no mortality has been reported in lifestyle interventions (43, 44). Growth failure in weight loss attributable to lifestyle intervention has been excluded, and few studies have reported eating disorders in association with lifestyle interventions, the great majority of studies reporting no side effects (43, 44, 58). However, unsuccessful participation in a lifestyle intervention could reduce participants' self-confidence because the adolescent with obesity learns that they cannot lose weight.

Beyond considering the evidence from randomized trials and meta-analyses of a considerable effect of lifestyle intervention on BMI and cardiovascular risk factors in children with obesity, some important concerns in everyday practice should be mentioned. Most adolescents with obesity do not want to participate in lifestyle interventions (59). The success rate (as defined by a reduction of >0.25 BMI-SDS) of 129 centers in Europe specialized in outpatient pediatric obesity care and treating >20,000 children with obesity was just 7% after 24 months in an intention-to-treat analysis (48). Most participants (92%) were lost to follow-up in this study. However, in this observational study, some treatment centers achieved a success rate of ~50%, which demonstrates the great heterogeneity in the success rate. Of interest, the treatment centers with the best success rates included only motivated children and adolescents. It is well known that treatment adherence determines the success rate (60, 61).

Most importantly, adolescents with extreme obesity (BMI ≥ 35 kg/m²), in contrast to those with Class I obesity (BMI 30–35 kg/m²), did not reduce their BMI (13, 14). This

suggests that lifestyle interventions are the treatment of choice for adolescents with non-severe (i.e. Class I) obesity. Bariatric surgery is not indicated in this group, and as such, has not been formally studied as it is currently felt that the effectiveness concerning cardiovascular risk factors may be similar to lifestyle interventions, and the risk of intervention-related complications and side effects does not appear warranted. As adolescents with severe obesity do not respond to lifestyle interventions, bariatric surgery should be a treatment option for this group. Accordingly, US, European and German guidelines suggest bariatric surgery should be considered only in adolescents with BMI ≥ 35 kg/m² (25, 62, 63, 64).

These guidelines recommend that bariatric surgery should be considered only in adolescents with severe obesity who have participated in lifestyle interventions previously (62, 63, 64). Furthermore, psychiatric diseases such as binge-eating disorders, emotional eating, drug abuse, schizophrenia, severe depression, suicidal tendency, severe borderline personality disorder, post-traumatic stress disorders, bulimia nervosa and other disorders have to be excluded or controlled within formal psychiatric treatment (62, 63). Psychiatric diseases are also considered exclusion criteria if, despite being treated, they prevent adherence to elements of the bariatric surgery pathway, such as nutritional supplementation, changing eating behavior, or reaching a balanced decision regarding obesity treatment. This diagnostic work-up is important as psychiatric diseases such as depression are common among adolescents with severe obesity, reported at 27% (23) to 39% (65). However, it is sometimes difficult in clinical practice to determine whether a psychiatric disease will benefit from the effective weight loss resulting from bariatric surgery (for example, major depression caused by extreme obesity) or whether the same psychiatric disease will cause difficulties in the long run with respect to treatment adherence.

We have analyzed the feasibility of these recommendations in our obesity department. Between the years 2012 and 2016, a total of 283 adolescents with severe obesity aged 14–18 years consulted our obesity treatment center with a BMI ≥ 35 kg/m² (mean BMI 41.4 kg/m²; mean age 16.2 years, 55.5% male). All these adolescents with severe obesity were offered a standardized lifestyle intervention (66). However, only 76 (26.9%) started and only 37 of these 76 adolescents (48.7%) completed the lifestyle intervention. If the individuals desired bariatric surgery, they were offered a two-month manual-based pre-operative information program after participating in the lifestyle intervention. This was to ensure that the adolescents knew the potential risks and

benefits of different bariatric surgery procedures. The content of this bariatric surgery preparation course has been published previously in a training manual (67). Ten (3.5%) adolescents with severe obesity participated, and all of them completed this bariatric surgery preparation course. Two (20%) of these ten adolescents with severe obesity refused bariatric surgery after the course. After the training course, an individual psychiatric examination was performed to exclude contraindications for bariatric surgery (such as binge-eating disorders, emotional eating, drug abuses, schizophrenia, severe depression, suicidal tendency, severe borderline personality, post-traumatic stress disorders or bulimia nervosa). The psychological examination was helpful to identify psychiatric conditions in two (20%) adolescents, which represented contraindications for bariatric surgery (58, 59, 60). Six (60%) of the 10 adolescents fulfilled the three criteria: (a) completion of lifestyle intervention, (b) completion of bariatric surgery preparation course and (c) exclusion of somatic and psychiatric contraindications to bariatric surgery. Five of them underwent bariatric surgery, and in one case, health insurances denied financial imbursement. In summary, only six of 283 adolescents with severe obesity (2.1%) presented in our institution wanted and were suitable for bariatric surgery according to guidelines (25, 58, 59, 60).

The main problem in our experience is that the great majority of adolescents with severe obesity get lost to follow-up. The low treatment adherence fits well with previous studies in adolescents with severe obesity (13, 14, 15). Treatment adherence is a well-known problem in many chronic diseases such as obesity, especially in adolescents, and treatment outcome depends largely on adherence (60, 68, 69). Adolescent patients often present greater challenges given the unique developmental, psychosocial and lifestyle issues implicit in adolescence (60, 70).

One could question whether it is meaningful to demand ineffective lifestyle intervention in adolescents with severe obesity before bariatric surgery. On the other hand, do we believe that adolescents with severe obesity who drop out of lifestyle interventions will visit the medical system after bariatric surgery and take their vitamin supplements regularly? This is of importance as vitamin and micronutrient supplementation is a requirement after bariatric surgery to avoid nutritional complications and side effects. Adolescent compliance with supplementation has been shown to be problematic after RYGB (27), and we do not have a reliable method of pre-operatively predicting likely compliance.

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Table 3 Eligibility for bariatric surgery.

BMI category	Comorbid state	Example comorbidities
$\geq 40 \text{ kg/m}^2$	Minor comorbidities	Body size precluding ambulation Dyslipidemia Gastro-esophageal reflux disease Hypertension Impaired activities of daily living Impaired fasting glucose Impaired glucose tolerance Mild obstructive sleep apnea Panniculitis Severe psychosocial morbidity Steatohepatitis Urinary incontinence Venous stasis
$\geq 35 \text{ kg/m}^2$	Major comorbidities	Weight-related joint disease Benign intracranial hypertension Heart failure due to obesity Moderate-severe obstructive sleep apnea Type 2 diabetes mellitus
$< 35 \text{ kg/m}^2$	Exceptional circumstances	Life-threatening obesity-related condition

As lifelong follow-up is necessary after bariatric surgery to monitor vitamin and micronutrient supplementation, effective transition models have to be developed involving general practitioners. Education should be provided to enable not only monitoring for potential nutritional complications but also to improve adherence to supplementation in the community.

One could argue that drugs for weight loss should be used before bariatric surgery. Using drugs would confer the advantage that treatment could be stopped in response to serious side effects. However, the only approved weight loss drug for adolescents (orlistat) has a moderate effect on weight, which is comparable to lifestyle interventions (71). The new drugs in the pipeline such as GLP-1 agonists, which are not approved for adolescents so far, have a greater effect on weight loss but the safety profile on the long run is not known yet (72). Several weight loss drugs, such as sibutramine and rimonabant, have been withdrawn from the market due to severe side effects, which have been recognized only after years of use.

Table 4 Exclusion criteria for bariatric surgery.

Exclusion criteria	Examples
Patient and family understanding	Inability to understand risks and benefits
Patient factors	Inability to assent/consent as appropriate Not fully committed to follow-up Ongoing addiction (alcohol, drugs and medication) Skeletal immaturity (tanner stage $\leq$ III) Treatable medical cause of obesity Unstable psychiatric condition

Finally, drugs have to be taken lifelong, which presents the same difficulty with treatment adherence, particularly in adolescents, as supplementation after surgery.

The case in support of bariatric surgery for adolescent obesity

It is important to be clear that bariatric surgery is not a first-line therapy for adolescent obesity and is supported only when non-surgical treatments have been unsuccessful. Neither is bariatric surgery advocated in all adolescents with obesity; rather, it is reserved for those young people whose obesity is classified as severe, and whose health is already detrimentally affected by their obesity. In fact, existing eligibility criteria (Tables 3 and 4), as discussed in the above argument, restrict the use of bariatric surgery to a limited group of adolescents, in whom the benefits appear, thus far, to significantly outweigh the drawbacks.

As mentioned previously, weight loss is far greater within adolescent bariatric surgical programs than that in dietary and lifestyle programs, and we have long been armed with the knowledge that current dietary and lifestyle interventions for obesity generally fail to achieve positive long-term results (73). Dieting has been shown to be ineffective in the long term, both in adults and adolescents (73, 74, 75, 76). Worse than this, subjects often gain weight across study periods (52, 76, 77). Typical weight loss in dietary and lifestyle programs for severe obesity equates to around $1\text{--}3 \text{ kg/m}^2$ (78, 79), compared with 13.5 kg/m^2 after surgical procedures

(9, 80). In addition, attrition rates are relatively high within dietary and lifestyle programs (43, 81, 82) and, even when these therapies are successful, many individuals' obesity will not resolve as the few kg/m² lost represent a small fraction of their overall BMI (83).

The adult bariatric literature demonstrates marked cardiovascular benefits after bariatric surgery. Cardiovascular risk factors improve after surgery: the risk of hypertension almost halves, the risk of dyslipidemia and type 2 diabetes mellitus (T2DM) reduces by two-thirds and inflammation is markedly reduced (84). This amelioration of cardiovascular risk leads to reduction in the risk of myocardial infarction, stroke and death, each by around 50% in adults (84). As a relatively new field of study, and as participants are young, there will be a substantial lag before the literature describing such outcomes in adolescents reaches maturity.

T2DM is a debilitating and progressive disease, which was almost unheard of in children before the turn of this century (85). Its prevalence in adolescents is rapidly rising, in parallel with a rising prevalence of obesity (86) and is likely underestimated by up to 50% (87, 88). Alarming evidence suggests that T2DM behaves far more aggressively when onset is in adolescence, with earlier failure of first-line drug pharmacotherapy and more rapid progression to insulin requirement (9, 89). A broad evidence base, comprising eleven randomized trials, now describes bariatric surgery as an effective therapy for T2DM in adults, leading not only to the glycemic control seen with pharmacotherapy but also to remission of diabetes in 33–90% of patients (90). No other therapy, including weight loss by other methods, has reliably achieved this endpoint, sparking the recent development of guidelines to help physicians appropriately utilize surgery as an effective treatment for T2DM and obesity (91). Similar adolescent trials are lacking thus far and are desperately needed (92), but existing studies have shown T2DM resolution in 79–100% cases after RYGB (22, 93), 50–94% after LSG (80) and 100% after LAGB (80).

Suggestions to delay surgical treatment for T2DM present a significant cause for concern when we consider evidence that delayed treatment in adults is far less likely to achieve remission, let alone lasting remission. Sjöström and coworkers (94) showed, in the Swedish Obese Subjects study, that when T2DM diagnosis was new (<1 year), bariatric surgery resulted in >90% remission, whereas established (diagnosed for >4 years) T2DM remitted in <40% of patients. Furthermore, remission at 15 years was almost 50% in the newly diagnosed group, compared with <10% in the established diagnosis group.

Furthermore, delaying surgical treatment influences not only the T2DM remission rate but also the outcome in respect to weight status. As Inge and coworkers have previously shown (95), the trough of BMI loss after RYGB is around 37% regardless of baseline BMI. Again, this raises the question of whether bariatric surgery should be offered before extreme BMI values (e.g. >45 kg/m²) are reached.

Many of the concerns identified in the case against adolescent bariatric surgery relate to side effects, both known and unknown. A significant and growing body of research has demonstrated that side effects are generally limited and well tolerated (16, 18, 26, 27). While considering side effects of surgery, it is noteworthy that adverse events occurred in 44% of patients treated non-surgically in the only existing randomized trial of bariatric surgery (21).

The three main bariatric procedures used in adults today have also been used in adolescents (80). However, the laparoscopic adjustable gastric band is not licensed for use in adolescents in the United States, and its use in adolescents is not widely supported, partly owing to high rates of reoperation for complications (64). Current evidence has demonstrated outcomes after laparoscopic sleeve gastrectomy (LSG) and RYGB to be similar to those in adults, leading to support for their use in adolescents (96). LSG is supported by a younger evidence base in comparison to the RYGB and is generally considered investigational. The most commonly used procedure to date is the RYGB, and guidance supports its use in adolescents (64, 97).

All surgical procedures should be expected to have, and respected as having, an associated mortality; it is simply a question of how many procedures one would need to perform to prove as much. Indeed, although the mortality of adolescent bariatric surgery is above zero (28), lethal complications of severe childhood obesity itself also exist (98) and increase with rising BMI (99). Therefore, it could be argued that the mortality of non-surgical interventions is, therefore, also above zero. Thankfully, the field of adult bariatric surgery has developed an impressive safety record, based upon significant advances in surgical technique, anesthetic practices, selection criteria and specialist multidisciplinary management of patients. This has led to a 97–99% reduction in the mortality of adult bariatric surgery from 8% (100) to 0.08–0.22% (101) across roughly 50 years, in a population generally presenting with existing comorbidities. Thus far, the occurrence of death within 30 days of adult bariatric surgery in RYGB is now comparable to that of an elective laparoscopic

cholecystectomy (102, 103), often performed solely for symptomatic benefit. All three reported deaths beyond 30 days after adolescent bariatric surgery were reported to be unrelated to the operation. One patient died over three years after surgery from hypoglycemia as a result of type 1 diabetes mellitus (22), and the remaining two also demonstrated significant pre-operative comorbidity, despite their youth, and died two and six years after surgery respectively, their exact causes of death unspecified (55).

It was previously hypothesized that problematic excess skin would be encountered less frequently after adolescent bariatric surgery as skin may retain elasticity and more readily normalize (104). However, data have shown that the requirement for plastic surgery is similar in adolescents as that in adults after bariatric surgery (104).

The dumping syndrome is often quoted, as mentioned previously, to be a major drawback of RYGB surgery (30, 32). In our unit, we have shown that most patients, including adolescents, do not experience any symptoms of dumping after RYGB (31), although the prevalence has been reported elsewhere at over 75% (105). The implication of this collection of symptoms takes on a very different meaning when we talk to patients. Of those experiencing symptoms, most actually find that the discomfort that follows consumption of high-calorie or high-sugar foods offers a powerful and desirable feedback mechanism to help avoidance of unfavorable, or 'naughty', eating habits (106). Of course, a small number of patients perceive their dumping as a significant burden, and one in ten patients experiences troublesome symptoms (105).

Concerns about potential growth retardation after bariatric surgery have not been founded upon any evidence to date. On the contrary, there is evidence that young people, whether prepubertal, adolescent or in young adulthood, experience normal growth velocity after sleeve gastrectomy (18). Compared with matched non-surgically treated controls, aged younger than 14 years increased in height by over 10mm/year more after LSG, equating to over 5 cm more across four years of follow-up (107). Such evidence is limited because patient selection criteria (64) for the most common procedure, RYGB, stipulate that candidates should generally have reached at least Tanner stage IV (108, 109) and 95% of estimated growth. Therefore, by definition, there is little outstanding growth to be affected in the majority of patients eligible for bariatric surgery in adolescence.

Similarly, concerns surrounding bone health in adolescents after bariatric surgery have not been proven. Evidence is currently limited to two-year follow-up, but shows that bone mineral content and density fall from

abnormally high-for-age pre-operative levels to normal-for-age levels after surgery (110, 111). Long-term effects on the skeleton have not yet been reported, but must be examined, including long-term vitamin D and calcium absorption. When considering post-operative vitamin D deficiency, we must bear in mind that deficiency is widespread, with prevalence in a variety of young healthy populations of around 30–50% (112), including 42% in healthy adolescents (113).

Similar to vitamin D, other vitamin and nutrient deficiencies are well recognized in the short and long term after adult bariatric surgery (114). As a result, it is imperative that long-term formal monitoring is in place to identify and manage abnormalities. The suggestion that surgery should be postponed until adulthood in eligible adolescents is reached does not appear evidence based as rates of significant nutritional abnormalities generally appear comparable between adolescent and adult groups after bariatric surgery (Table 1). Note that although post-operative hypoferritinemia has been reported to be common in adolescents (22), iron stores actually increase after bariatric surgery in adolescents (27), suggesting the reversal of chronic inflammatory processes may be contributory to falling ferritin levels (115).

Refeeding syndrome, as described in the case against, is a potentially devastating complication of bariatric surgery. However, this is an exceptionally rare occurrence, with no cases reported in adolescents and only a single case reported in an adult following the extreme malabsorptive procedure, biliopancreatic diversion (34), which is not recommended in adolescents (64). Other serious consequences include beriberi or vitamin B1 (thiamine) deficiency. Beriberi is also rare and, with prompt recognition and thiamine supplementation, complete resolution can be achieved (116). These cases highlight the importance of effective follow-up to minimize the occurrence and impact of nutritional deficiencies.

Eating behavior does indeed change after bariatric surgery, with migration toward small portions after bariatric surgery (117). However, this reduction in portion sizes, observed following LSG and RYGB, is not brought about by a change in the patient's will power or commitment, nor does it appear to be predominantly a result of restriction of nutrient intake and passage through the gut. Rather, it is the hormonal effects of the procedures that lead to reduced hunger and earlier satiety, resulting in a tendency to eat smaller volumes and less frequently (117).

Gastrointestinal reflux is more common in obesity than normal weight (101). When present, significant

reflux will usually affect the surgeon's procedure recommendation as reflux symptoms significantly improve after RYGB, whereas the effects of LSG and LAGB on reflux are not conclusively understood (118, 119, 120). There is no evidence of a greater risk of dysplasia or neoplasia of the esophagus after bariatric surgery, and a recent systematic review reported only 11 cases reaching back as far as 1996 (121). Epidemiological data have shown that obesity is associated with an increased risk of esophageal cancer (122), along with cancers of the thyroid, colorectum, breast, endometrium, cervix, ovary, kidney, stomach, liver, gallbladder and pancreas (122, 123). Reversal of obesity using bariatric surgery in adolescence thereby actually reduces the duration and degree of exposure to this significant risk factor for a broad range of cancers. This has been demonstrated to translate to a one-third reduction in overall cancer risk among women across a median ten-year follow-up (124). Further than this, Christou and coworkers (125) observed that patients were 80% less likely to receive a diagnosis of cancer within five years of bariatric surgery than non-surgical controls and Adams and coworkers (126) reported 60% fewer deaths from cancer, and 40% fewer deaths from all causes, after a mean of seven years.

Patients whose obesity is related to specific genetic mutations, such as MC4R, or syndromes, such as Prader-Willi, represent a tiny minority of adolescents undergoing bariatric surgery, strictly as exceptions to recommended exclusion criteria (9). Reported outcomes in these patients have varied widely, but are often inferior to those in 'normal' adolescent obesity (127, 128, 129). The benefits and risks of surgery in these groups should be considered quite separately to those of the general adolescent population with obesity as the mechanisms of their obesity are different.

Obesity in adolescence is associated with significant and highly prevalent psychosocial impairment (130). The presence of an untreated psychiatric condition is a contraindication to bariatric surgery but, if appropriately controlled with treatment, mental health disorders do not preclude eligibility (64). Within the AMOS (27) and Teen-LABS (22) studies, rates of psychosocial impairment among adolescents undergoing surgery for severe obesity were as high as 68% (27), with depressive symptoms in 27% (23) to 39% (65). The fact that a small proportion of patients experienced psychosocial deterioration emphasizes the extreme vulnerability of this population. In the only existing non-surgical 10-year follow-up study, almost 10% of participants were hospitalized with psychiatric problems, two (3%) attempting suicide (50).

However, although bariatric procedures are not designed to improve psychosocial function, psychosocial outcomes after bariatric surgery have been grossly positive, with significant reduction of symptoms of anxiety, depression and anger, alongside improvements in self-esteem, self-concept and overall mood (65, 111). The exploration of methods for identifying those at greatest risk of post-operative psychosocial impairment should be a major focus in this field to ensure additional support is directed to these individuals.

The case against describes encountering major hurdles in enrolling patients into a bariatric surgical program as many dropped out of preceding lifestyle interventions. Rates of compliance with lifestyle programs prior to enrolment into bariatric surgical programs are not reported among the major surgical series, although recruitment difficulties were not highlighted as problematic (26, 131). Furthermore, in Sweden, almost one in every 1000 citizens undergoes bariatric surgery each year, a rate twice as high as that of the US (132). Public understanding and acceptance of bariatric surgery is high in Sweden as a result, perhaps more so than in many other countries. This may contribute to a greater acceptance of adolescent bariatric surgery as a viable therapeutic option, and perhaps goes some way to explaining the local difficulty described in Germany within the case against, where surgery is almost ten times less common (132). However, other nations with roughly half the rate of bariatric surgery of Sweden, such as the United States and Saudi Arabia, have recruited sizable adolescent series (22, 107).

The case against accurately alludes to the wealth of randomized trials evaluating the effects of lifestyle interventions and concluding their superiority to standard care or self-help at 6 and 12 months. It is also acknowledged that, within the mature literature base, comprising more than 70 randomized trials and at least seven meta-analyses in the past decade, reports of outcomes of non-surgical interventions beyond 12–24 months are rare (43, 44, 82, 133, 134, 135, 136, 137). This is suggestive of significant publication bias toward short-term reports. The efficacy of such interventions in terms BMI/weight measures, although often significant, is consistently modest at best. Of the few studies reporting outcomes at five years or more, only one followed up more than 100 patients (51). Furthermore, very few studies have focused on severe obesity (83), and adolescents with severe obesity in these programs are more likely to fail to lose weight or regain weight within two to three years (13, 14, 46).

It has been proven possible to achieve good rates of follow-up (>75%) to two or more years in adolescent

bariatric surgical programs (22, 86). However, follow-up does present a major challenge, particularly in relation to individuals whose outcome is favorable and who no longer feel reliant upon health services. Reliable follow-up strategies are sorely needed across all interventions for obesity. Technological solutions may play a part in this.

Compliance with the necessary multiple daily supplements is another such issue, as adolescents are disinclined to take prescribed medication after bariatric surgery (27). However, the advent of compounds, containing all standard supplements in a single tablet, may increase the palatability of supplements to adolescents (138).

Despite the immaturity of the literature base describing bariatric surgical outcomes in adolescents with severe obesity, with robust five-year outcomes imminently emerging from Europe (139) and the United States (140), it is rapidly catching up with the long-term evidence on non-surgical interventions.

In the context of marked limitations in the effectiveness of non-surgical approaches to adolescent severe obesity, further research into bariatric surgery is of extreme urgency and importance. More important than specifically identifying those who benefit most from surgery, we must focus resources on identifying those who experience difficulty or suboptimal outcomes after surgery to ensure they are fully supported, to find solutions to their difficulties and to optimize outcomes in future candidates.

Conclusions

The authors of the case for and the case against bariatric surgery in adolescents are in agreement that bariatric surgery offers superior therapeutic outcomes, in terms of weight loss and resolution of comorbid disease states, over other existing treatments for severe obesity in adolescence. However, we also agree regarding a number of important considerations within adolescent bariatric surgery.

Firstly, the evidence currently underpinning surgical treatments is from studies of adolescents whose obesity is severe and whose growth is near complete. As such, we cannot currently recommend consideration of bariatric surgery for non-severe obesity ($\text{BMI} < 35 \text{ kg/m}^2$) or the very young, except under the exceptional circumstances of life-threatening obesity-related conditions. When BMI is $< 35 \text{ kg/m}^2$, less invasive treatments, which are proven to offer significant benefit, should be considered instead.

Second, the effect of lifestyle interventions and/or medications is only moderate in adolescents with severe obesity ($\text{BMI} \geq 35 \text{ kg/m}^2$), and these patients should be offered bariatric surgery. This should be exclusively within formal programs, delivered by specialist multidisciplinary child/adolescent obesity teams, within specialist centers. Patients and their family/careers must be educated regarding the benefits and risks, including the irreversibility of the procedure where applicable, potential side effects, expected changes in eating behavior and the lifelong requirement for regular medical follow-up after surgery. In cases of syndromes, genetic mutations or injury affecting satiety regulation, bariatric surgery should be discussed by the multidisciplinary team on an individual-case basis to assess the potential for deterioration in quality of life after surgery. Before initiating bariatric surgery in adolescents with severe obesity, compliance to treatment should be demonstrated to minimize the risk of nutritional deficiencies and associated potential complications.

Third, as an emerging research field, the follow-up evidence in the adolescent population largely refers to short- and medium-term outcomes at present. Robust long-term evidence, although emerging, is currently limited. Such evidence will be crucial to answer questions and concerns regarding the long-term effects, both positive and negative, of bariatric surgery, as treated adolescents progress into adulthood. Similarly, although the risks of non-surgical interventions appear fewer in the short term, their long-term effectiveness also requires formal evaluation.

Finally, as invasive and often irreversible procedures, with varying outcomes for individuals, conscious efforts must be made to identify factors associated with successful and suboptimal outcomes, both physical and psychological, optimizing patient selection criteria and outcomes.

Therefore, when other treatments for adolescent severe obesity are unsuccessful, it is appropriate to consider the use of bariatric surgery, within the context of existing guidance.

Declaration of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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