Long-Term Outcome of Bariatric Surgery in Morbidly Obese Adolescents

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ORIGINAL CONTRIBUTIONS

Long-Term Outcome of Bariatric Surgery in Morbidly Obese Adolescents: a Systematic Review and Meta-Analysis of 950 Patients with a Minimum of 3 years Follow-Up

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Abstract
Background Obesity in pediatric and adolescent population has reached a universal pandemic. This study aimed to summarize the literature on the longest available outcome of bariatric surgery in morbidly obese adolescents.
Methods A systematic review was conducted to pool available data on the longest available (>3 years) weight loss and comorbidity resolution outcome in adolescent bariatric surgery.
Results A total of 14 studies reporting the result of bariatric surgery after 3 years in 950 morbidly obese adolescents were included. Preoperative age and BMI ranged from 12 to 19 years and from 26 to 91 kg/m^2, respectively. Females were the predominant gender (72.8%). Laparoscopic roux-en-Y gastric bypass (n = 453) and adjustable gastric banding (n = 265) were the most common bariatric procedure performed. The number of patients at the latest follow-up was 677 (range from 2 to 23 years). On average, patients lost 13.3 kg/m^2 of their BMI. Among comorbidities, only diabetes mellitus resolved or improved dramatically. Of 108 readmissions, 91 led to reoperation. There was a weight regain < 5 kg/m^2 between 5 and 6 years of follow-up. Removal, exchange, or conversion of the previous band constituted the majority of the revisional procedures. Three deaths were reported. No long-term data was obtainable on nutritional deficiency or growth status of adolescents who underwent a bariatric procedure.
Conclusion Although bariatric surgery is a safe and effective procedure in the treatment of adolescent morbid obesity, long-term data is scarce regarding its nutritional and developmental complication in this growing population of patients.

Keywords Adolescent · Pediatric · Obesity · Morbidly obese · Bariatric surgery · Mid-term · Systematic review · Meta-analysis

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Introduction

In parallel with the global pandemic of morbid obesity in adult population, pediatric and adolescent obesity has also reached a warning level [1, 2]. Despite the global increase in the prevalence of obesity in childhood and adolescence [3, 4], the national utilization of bariatric surgery has reached a plateau in this population [5]. One reason for this underutilization of adolescent bariatric surgery (ABS) can be the heterogeneous analysis of obesity prevalence among adolescents within different socioeconomic status (SES). A recent systematic review of 30 studies revealed that over half of the studies are indicative of an increasing obesity prevalence in low SES compared to only one third of the studies on adolescents of high SES [4].

Another explanation for the underutilization of ABS includes poor access to the health care resources [6].

Regardless of the underlying reason for such an inadequate surgical treatment, adolescent morbid obesity can turn into the adulthood comorbid conditions such as established hypertension (HTN), limited mobility, diabetes mellitus, renal failure, adult-onset asthma, and obstructive sleep apnea (OSA) [7]. To prevent the transmission of adolescent obesity into an adulthood compromised health status and to encourage appropriate utilization of bariatric surgery among adolescent population, a long-term assessment of the successfulness of ABS is warranted.

Although there is four systematic reviews regarding bariatric surgery in adolescents [8–11], there is no study to exclusively pool available data in the literature on the long-term outcome of weight loss surgery in this young group of morbidly obese patients. Our systematic review aimed to investigate the outcome of bariatric surgery in morbidly obese adolescents after a minimum of 3 years follow-up. The result of this meta-analysis can encourage proportional utilization of ABS in selected candidates.

Methods and Materials

Study Design

A comprehensive literature review was conducted through January 2017 to identify studies reporting the longest outcome of bariatric surgery in morbidly obese adolescents. Our systematic review strictly followed the instructions provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [12].

Search Strategy

We performed an electronic database search on PubMed/Medline, ISI Web of Science, and Scopus. The following search terms were used: ("long term" OR "long-term" OR "mid-term" OR "mid term" OR "years" OR "year") AND ("adolescents" OR "adolescent" OR "pediatrics" OR "pediatric" OR "children" OR "childhood" OR "teenagers" OR "teens" OR "young" OR "youth") AND ("bariatric surgery" OR "sleeve gastrectomy" OR "gastric bypass" OR "Roux-en-Y" OR "RYGB" OR "LSG" OR "biliopancreatic diversion" OR "duodeno-ileal switch" OR "duodenoileal switch" OR "duodeno-ileal bypass" OR "duodenoileal bypass" OR "ileal bypass" OR "adjustable gastric band" OR "gastric banding" OR "LAGB" OR "AGB").

Eligibility Criteria

Original studies in English language with a minimum follow-up of 3 years after bariatric surgery in adolescent or pediatric population (age at surgery <18 years) were eligible. Only studies regarding primary bariatric surgery for adolescents' idiopathic morbid obesity including at least 10 patients were eligible. Review articles, case reports, editorials, and commentaries were excluded.

Outcome Definition

According to the executive summary of the American Society for Metabolic and Bariatric Surgery (ASMBS) on the outcome reporting standards [13], the mid-term and long-term follow-up are defined as >3 and <5 years and >5 years, respectively. At each follow-up, weight loss outcome and comorbidity resolution were investigated as the primary endpoint of this review article. The second endpoints were any postoperative complication, nutritional deficiency, or other adverse events attributable to the weight loss procedure.

Data Extraction and Analysis

For each included article, primary characteristics of the study, demographics and preoperative features of the participants, and perioperative variables were extracted. Data were pooled according to the availability of the variables of interest. The pooled estimations are expressed as mean ± SD, minimum and maximum range, or the number (%) whenever appropriate. No other quantitative synthesis was sought in this systematic review.

Results

A total of 3193 records were identified through the initial database search. After exclusion of the duplicates, title/abstract of the remaining 1832 papers were screened of which 45 articles were relevant. Reviewing the full text of the relevant papers yielded 16 eligible articles for quality assessment. Finally, 2 articles were excluded during data extraction and 14 papers were included into qualitative synthesis (Fig. 1).

Primary Characteristics of the Included Studies

Fourteen studies encompassed 950 morbidly obese adolescents who were followed at least 3 years after their bariatric surgery [7, 14–25]. Publication timeframe of the included studies ranged from 2003 [26] to 2016 [7, 15–17]. Of these, 8 studies were retrospective chart review (301 patients, 31.7%) [14, 16, 17, 19, 21, 23, 25, 26], 4 were prospective observational studies (621 patients, 65.4%), and 2 were case

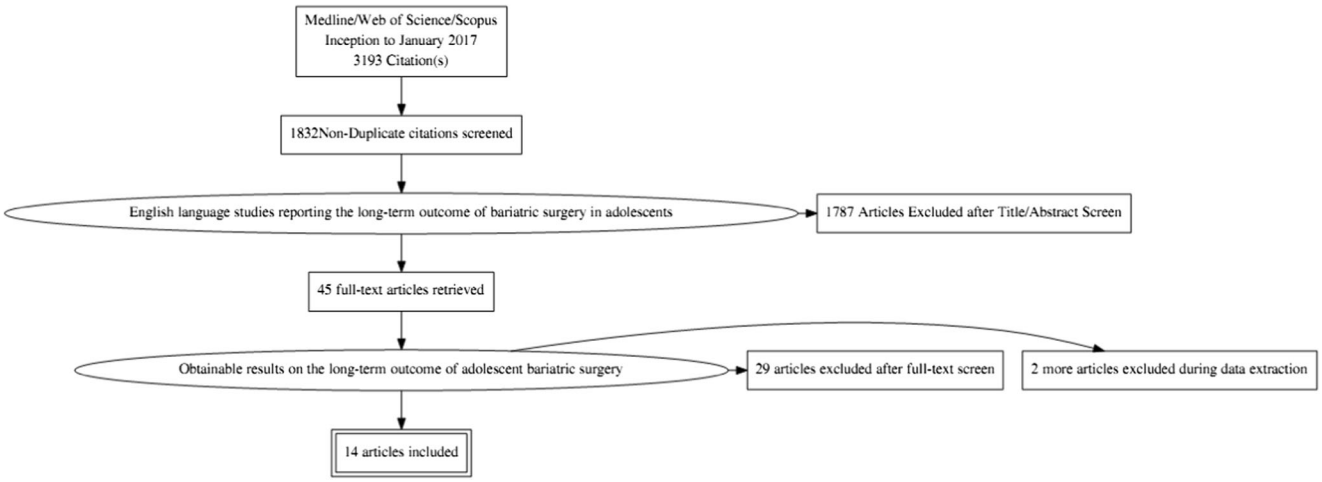

Fig. 1 PRISMA flowchart describing our strategy for electronic database searching

series (28 patients, 2.9%) [22, 24]. Follow-up after bariatric surgery ranged from 2 to 23 years [25] with an average greater than 3 years (Table 1).

Preoperative Characteristics of Adolescents Undergoing Bariatric Surgery

Gender distribution was reported in 12 studies (875 patients, 92.1%) [7, 14–20, 22–26]. Of these, most patients were female (637 patients, 72.8%) and 224 were male (27.2%). Patients' age and preoperative BMI ranged from 12 to 19 years and from 26 to 91 kg/m^2, respectively.

Preoperative comorbidity was reported by 11 studies (844 patients, 88.8%) [7, 14–21, 25, 26]. Of these, dyslipidemia was the most prevalent comorbidity (497 patients, 58.8%), followed by hypertension (305 patients, 36.1%), dyspnea (134 patients, 15.9%), and insulin resistance (93 patients, 11%). The majority of patients underwent Roux-en-Y gastric bypass (453 patients, 47.7%), adjustable gastric banding (265 patients, 27.9%), and then sleeve gastrectomy (148 patients, 15.6%). Only one study (68 patients, 7.1%) reported their patients to undergo biliopancreatic diversion [25]. Moreover, one study (33 patients, 3.5%) had their patients undergo standard RYGB, distal gastric bypass (D-GBP), long-limb gastric bypass (LL-GBP), horizontal gastroplasty, and vertical gastroplasty [26].

Outcome of Morbidly Obese Adolescents after Bariatric Surgery

After a minimum follow-up of 3 years, data of 677 patients (71.3%) was available for analysis (attrition rate of 28.7%) (Table 2). The weight loss outcome based on BMI ranged from 11.3 to 33 kg/m^2. Two studies (43 patients) reported weight regain at the last follow-up for 6 patient (13.9%) [9, 26]. Additionally, comorbidities at the last follow-up were reported by 11 studies (645 patients, 67.9%) [7, 14–21, 25, 26]. Of these, dyslipidemia (213 patients, 33%) was the most common persistent comorbidity followed by hypertension (118 patients, 18.3%), dyspnea (63 patients, 9.8%), and diabetes/insulin resistance (28 patients, 4.3%). On the other hand, comorbidity resolution rate was 57.1% for dyslipidemia (284 resolved out of 497), 61.6% for hypertension (188 resolved out of 305), 53% for dyspnea (71 resolved out of 134), and 69.9% for diabetes mellitus/insulin resistance (65 resolved out of 93).

During the postoperative follow-up, there were 108 readmissions (11.4%) and 91 reoperations (9.6%). Three deaths were reported (0.3%), 1 due to a hypoglycemic event after gastric bypass [7] and 2 unrelated to the bariatric procedure [26]. In a meta-analysis of 8 studies (746 patients, 78.5%) for which the mean ± SD weight loss was obtainable [7, 9, 15, 17, 18, 21, 22, 26], adolescents demonstrated a pooled BMI loss of 13.3 kg/m^2 (95% confidence interval [95%CI], 11.9–14.7) at the last available follow-up (Fig. 2). A small amount of weight gain was observed between 5 and 6 years after bariatric surgery (Fig. 3). Moreover, the fate of bariatric surgery after a minimum of 3 years follow-up was reported in 7 studies (224 patients, 23.6%) [16, 18, 21, 22, 24–26]. Of a total of 53 revisional surgeries performed in adolescents, conversion of LAG to RYGB (31 patients, 58.5%), band removal (15 patients, 28.3%), band exchange or band to BPD (each in 2 patients, 3.8%), LSG to RYGB (1 patient, 1.9%), and D-GBP to GBP and GBP to a LL-GBP (each in 1 patient, 1.9%) constituted the fate of the failed primary bariatric procedures (Fig. 4).

Discussion

Bariatric surgery has been established as an effective treatment for severe adolescent obesity [11, 19]. Initially, most morbidly obese adolescents were conservatively selected for

Table 1 Primary characteristics of the studies on primary bariatric surgery in adolescents

Author/year	Study type	Sample size	Mean ± SD age (years)	Gender (M:F)	Preop BMI (kg/m^2)	Preop comorbidity					Type of BS		
						DM/ InsI	HTN	Dyslip	OSA/ Dysp	Other	RYGB	SG	AGB
Nehus/2016 [15]	POS	242	17.1	59:183	50.5	30	104	179	N/A	39	161	67	14
Inge/2016 [7]	POS	228	17 ± 1.6	57:171	53 (51–54)	29	96	171	N/A	36	161	67	0
Paulus/2016 [16]	ROS	10	16.5 (14.9–18.5)	4:6	43 (37–51)	0	2	0	7	0	0	0	10
Vilallonga/2016 [17]	ROS	19	15.5 (13–17)	4:15	38.9 (35–44)	3	1	5	1	N/A	0	0	19
Zitsman/2015 [18]	POS	137	16 ± 1.2	42:95	48.3 ± 8.2	2	30	104	93	N/A	0	0	137
Cozacov/2014 [19]	ROS	18	17.5	5:13	47.2	1	2	1	7	N/A	8	10	0
Nijhawan/2012 [14]	ROS	25	14–18	N/A	45.7	3	3	10	10	N/A	25	0	0
Osorio/2011 [20]	POS	14	16	4:10	46.1 ± 3.14	13	11	12	6	N/A	0	0	14
Silberhumer/2011 [21]	ROS	50	17.1 ± 2.2	N/A	45.2 ± 7.6	5	12	4	3	19	0	0	50
Widhalm/2011 [22]	CS	18	17.7 ± 2.6	12:6	51.7 ± 8.0	N/A	N/A	N/A	N/A	N/A	9	1	8
de la Cruz-Muñoz/ 2010 [23]	ROS	78	17.8 (12–19)	18:60	45.8 ± 5.6	N/A	N/A	N/A	N/A	N/A	71	1	6
Widhalm/2008 [24]	CS	10	17.3 ± 3	7:3	49.1 ± 6.8	N/A	N/A	N/A	N/A	N/A	1	2	7
Papadia/2007 [25]	ROS	68	16.8 (14–18)	12:56	46 (26–71)	5	33	11	N/A	N/A	BPD	0	0
Sugerman/2003 [26]	ROS	33	16 ± 1	14:19	52 ± 11 (38–91)	2	11	N/A	7	22	17	GP: 3	LL:10 D: 3
Total		950	12–19	238:637	26–91	93	305	497	134	116	453	148	265

M:F male to female ratio, *Preop* Preoperative, *BMI* body mass index, *DM* diabetes mellitus, *InsI* insulin intolerance, *HTN* hypertension, *Dyslip* dyslipidemia, *OSA* obstructive sleep apnea, *Dysp* dyspnea, *AKF* abnormal kidney function, *N/A* not available, *RYGB* Roux-en-Y gastric bypass, *SG* sleeve bypass, *AGB* adjustable gastric banding, *BS* bariatric surgery, *POS* prospective observational study, *ROS* retrospective observational study, *CS* case series, *BPD* biliopancreatic diversion, *GP* gastroplasty, *LL* long-limb gastric bypass, *D* distal gastric bypass

Table 2 Postoperative outcome of primary bariatric surgery in adolescents

Author/year	Longest FU	No. of pts. at the last FU	BMI loss (kg/m^2)	Comorbidity at the last FU					Complications		
				DM	HTN	Dyslip	Dysp	Other	Admission	Reoperation	Death
Nehus/2016 [15]	3 yrs	206	14.2	1	29	54	N/A	28	N/A	N/A	N/A
Inge/2016 [7]	3 yrs	183	15 (13–16)	19	56	84	N/A	22	28	27	1
Paulus/2016 [16]	64 (52–84) mo	10	10.7 (−0.9–12.9)	0	0	0	0	N/A	4	4	0
Vilallonga/2016 [17]	7.2 yrs (2.4–10.2)	19	11.4	0	0	0	0	N/A	3	0	0
Zitsman/2015 [18]	36 mo	68	9 ± 0.2	1	21	71	62	N/A	36	30	0
Cozacov/2014 [19]	55.2 mo	15	30.1	0	0	0	N/A	N/A	N/A	N/A	0
Nijhawan/2012 [14]	5–10 yrs	25	17.1	0	0	0	0	N/A	4	1	0
Osorio/2011 [20]	45.5 ± 27.3 mo	1	11.3	2	4	4	1	N/A	N/A	N/A	0
Silberhumer/2011 [21]	85.9 ± 17.7 mo (63.3–138.3	45	17	5	1	0	0	2	6	6	0
Widhalm/2011 [22]	42 mo	8	11.3	N/A	N/A	N/A	N/A	N/A	0	0	0
de la Cruz-Muñoz/ 2010 [23]	4 yrs	16	16.15–18.56	N/A	N/A	N/A	N/A	N/A	2	0	0
Widhalm/2008 [24]	4 yrs	8	10.33 ± 6.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Papadia/2007 [25]	11 yrs (2–23)	67	78% EWL	0	6	0	N/A	N/A	15	14	0
Sugerman/2003 [26]	14 yrs	6	14 kg/m^2 33 ± 68% %EWL	0	1	0	0	2	12	9	2
Total	2–23 yrs	677	11.3–33	28	118	213	63	52	108	91	3

FU follow-up, *No.* number, *BMI* body mass index, *DM* diabetes mellitus, *HTN* hypertension, *Dyslip* dyslipidemia, *Dysp* dyspnea, *AKF* abnormal kidney function, *N/A* not available, *Yrs* years, *Mo* months

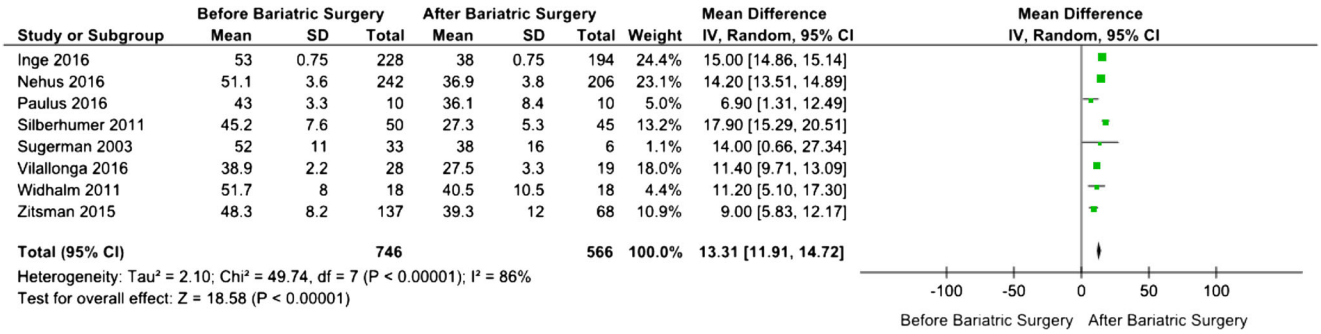

Fig. 2 Meta-analysis of the adolescents' weight loss outcome based on BMI at the last follow-up

a less aggressive weight loss surgery such as adjustable gastric banding (AGB) [27]. Later on, academic centers began to consider other procedures such as sleeve gastrectomy [28] and gastric bypass (RYGB) for those who were a candidate for ABS [26]. According to an analysis of the University Health System Consortium (UHC) database between 2008 and 2011, out of 329 ABS, 136 procedures were LAGB, 47 were LSG, and 146 were LRYGB [29]. This analysis compared to a similar one for ABS data between 2002 and 2009 [27] showed a decreased use of AGB and an increased use of LSG in morbidly obese adolescents. This trend is in the same direction as the one recently reported for adult population of morbidly obese patients [28]. Nevertheless, the outcome of bariatric surgery in adolescents has been rarely described beyond 1–3 years. On the other hand, since most studies on ABS present data on AGB [27], the majority of data on the long-term outcome of ABS are related to this weight loss procedure.

Weight Loss

Our study demonstrated the maintenance of an average BMI loss of 13.3 kg/m^2, 3 years after ABS. This pooled estimate is similar to that reported by previous meta-analyses [9, 11]. In a systematic review of 23 studies (637 morbidly obese adolescents), Black et al. showed a significant BMI loss of 13.5 kg m^2 (95%CI, −14.1 to −11.9) at 1 year after bariatric surgery [11]. Furthermore, the authors showed the superiority of RYGB (−17.2 kg/m^2) to LSG (−14.5 kg/m^2) and AGB (−10.5 kg/m^2) in terms of adolescent weight loss. Another meta-analysis of 37 studies similarly showed a BMI loss of 11.6 kg/m^2 for AGB, 16.6 kg/m^2 for RYGB, and 14.1 kg/m^2 for LSG [9]. Interestingly, this review commented that no significant association was observed between the length of follow-up and the amount of weight loss after 1 year. This finding is in the same direction as our analysis pointing the possible plateaued weight loss of morbidly obese adolescents after 1–3 years. Moreover, while these reviews did not aim to evaluate the long-term outcome of bariatric surgery in adolescents, they demonstrated the superiority of RYGB over the other two procedures [9, 11]. Unfortunately, there were insufficient studies on the long-term weight loss of ABS to be included in a sub-analysis based on the procedure type. Nevertheless, with increasing preference of LSG and RYGB over the AGB, a changing pattern of weight loss might be expected when more studies with long-term follow-up are available on these two globally accepted weight loss procedures in adolescent population.

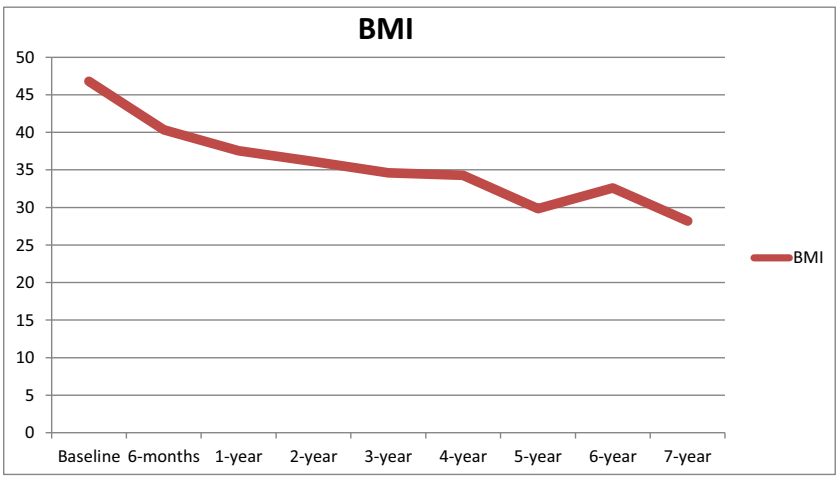

Fig. 3 Weigh loss pattern in adolescents after bariatric surgery

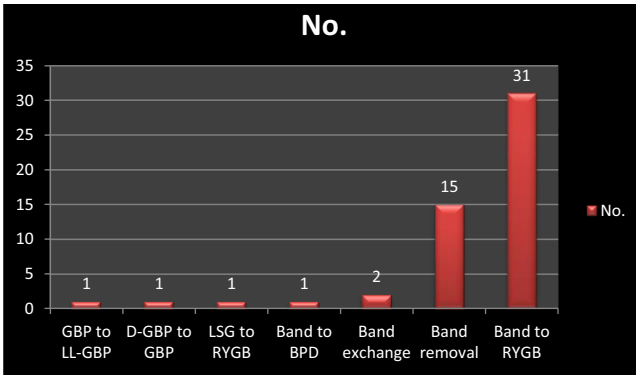

Fig. 4 Fate of bariatric surgery in adolescents determined at the last follow-up

Resolution of Comorbidities

Data on comorbidity resolution were of a very poor quality due to the inconsistency outcome measure definition, variable focus of different studies on numerous types of comorbidities, and lack of sufficient evaluation at the latest follow-up. Our meta-analysis revealed that one third of the adolescents with dyslipidemia still suffer the condition. Although the observed effect of bariatric surgery on resolution or improvement of morbidly obese associated conditions are well above that of the medical management, it is not clear if those patients would still require treatment the resolved/improved comorbidities. The meta-analysis of Black et al. has commented that the resolution rates in the studies with a larger sample size are moderate in comparison to the larger rate by smaller studies, probably due to the inflated variation of the observed effect across the studies [11]. The other meta-analysis on ABS by Paulus et al. also points out to a lower resolution rate for dyslipidemia compared to other comorbidities such as DM, HTN, and dyspnea. This provokes the concept of the possibly different metabolic responses after bariatric surgery between adolescent and adult morbidly obese individuals and potentially more strict diet modification and consideration of the medical treatment in high-risk individuals.

Complications, Reoperation, and Mortality

Overall there was a 11.4% readmission rate among adolescents after bariatric surgery. However, postoperative complications were poorly defined and very sparsely reported by the included studies. Previous systematic reviews have also mentioned the inadequate focus of studies on defining the cutoff and presenting of post-bariatric complications. This lack of data is mainly realized in studies reporting the long-term outcome of ABS. In case of AGB, gastrointestinal symptoms such as nausea, vomiting, gastroesopageal reflux, epigastric discomfort, port malfunction, and band slippage/erosion were reported. For RYGB and LSG, postoperative complications mostly included postoperative bleeding, leak, stenosis, infection, hernia, and vitamin deficiencies.

Reoperation after the initial bariatric procedure took place for two main reasons, postoperative complication and weight loss failure. That said, 7.9% of the adolescents underwent reoperation due to a procedure-related complication. Although this rate is not far above the reoperation rate in adult bariatric surgery, which ranges from 9% [30] to more than 20% [31], considering the number of years remained ahead of the adolescents who undergo a bariatric procedure, it adds to the possibility of encountering a reoperation incident. Previous reviews also reported a numerous of reinterventions including band repositioning, replacement, or removal, and port revision for AGB, endoscopic balloon dilation of anastomotic stricture, and reoperation for GI obstruction, leak, or fistula, and reoperation for leak in terms of sleeve gastrectomy [9, 11].

Our systematic review detected only 1 death after RYGB due to a hypoglycemic event [7] and 2 deaths after gastric bypass unrelated to the procedure [26]. Similarly, 2 deaths were reported after RYGB in both Paulus et al. [9] and Black et al. review article [11], which seemed unrelated to the procedure. Although the overall mortality of ABS is comparable to that of adult surgery [32], an age-specific analysis of mortality after RYGB revealed that patients younger than 35 years old especially women are at a higher risk of mortality due to external cause of death such as accident, suicide, and hypoglycemic attacks [33].

Fate of Bariatric Surgery in Adolescents

Due to the relative simplicity of the laparoscopic placement of an adjustable silicon band around the stomach, 1–2 cm below the gastroesophageal junction, AGB has been widely offered to the morbidly obese pediatric and adolescent patients [11]. Furthermore, an analysis of the national trend data from the Healthcare Cost and Utilization Project Kids' Inpatient Database 2000–2009 revealed that the predominant procedure has changed to minimally invasive techniques, such as laparoscopic AGB and RYGB [6]. Thus, it is not unexpected that after analysis of the long-term data, band removal or exchange and conversion to RYGB or BPD constitute the majority of revisional bariatric surgeries in adolescent population. Although AGB is becoming of less interest in adult population [28], it has been commonly performed initially in adolescent population.

Importance of Long-Term Follow-Up in Adolescent Bariatric Surgery

Although the current picture of weight loss and comorbidity resolution is still meaningful after ABS, the amount of weight gain (< 5 kg/m^2) observed between 5 and 6 years after the surgery (Fig. 3), as well as the countable proportion of adolescents

with persisting comorbidities may question the greater potential of the adolescents to benefit from bariatric surgery [7]. Although this diluted benefit of bariatric surgery in the long-term may result from the combined analysis of different procedures, it undoubtedly highlights the importance of a long-term follow-up to ensure the adequate adherence of the adolescents to the lifestyle modification programs and identify those who would benefit the medical treatment for residual or recurred comorbidities after bariatric surgery. Another benefit of a more robust long-term follow-up in adolescent population is the possibility of nutritional evaluation for identification of deficiencies and appropriate provision of supplements to prevent metabolic and physiologic consequences.

Limitations

Despite the worsening childhood obesity epidemic, bariatric surgery utilization has plateaued over the last years [5, 6]. The decreasing interest in adolescent bariatric surgery might be considered a cause for inconsistency in reporting data regarding the long-term follow-up. This inherent drawback of the literature is responsible for the lack of evidence regarding the long-term sustainability of the improved metabolic status or worsening nutritional reservoir of morbidly obese adolescents who underwent bariatric surgery. Hence, although our pooled analysis of the literature data suggest the short-term safety and long-term efficacy of bariatric surgery in achieving a substantial weight loss among adolescents with morbid obesity, it was unable to comment on the ultimate safety profile of this treatment option in terms of nutritional sufficiency and appropriate thrive.

Conclusion

Bariatric surgery is the only stand-alone treatment option for morbidly obese adolescents with sustainable weight loss outcome. However, a considerable proportion of patients later require reoperation due to weight loss failure or technical complications. Additionally, many patients still suffer those conditions associated with their morbid obesity such as dyslipidemia, HTN, and dyspnea. Further data is required on the long-term results of bariatric surgery in adolescent population in terms of nutritional deficiency, metabolic condition, and weight loss failure.

Compliance with Ethical Standards

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

Statement of Informed Consent Not relevant.

Statement of Human and Animal Rights Not relevant.

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