Outcomes of Bariatric Surgery in Older Versus Younger Adolescents

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abstract

OBJECTIVES: In this report, we compare weight loss, comorbidity resolution, nutritional abnormalities, and quality of life between younger and older adolescents after metabolic and bariatric surgery.

METHODS: From March 2007 to December 2011, 242 adolescents (≤19 years of age) who underwent bariatric surgery at 5 clinical centers in the United States were enrolled in the prospective, multicenter, long-term outcome study Teen–Longitudinal Assessment of Bariatric Surgery. Outcome data from younger (13–15 years; $n = 66$) and older (16–19 years; $n = 162$) study participants were compared. Outcomes included percent BMI change, comorbidity outcomes (hypertension, dyslipidemia, and type 2 diabetes mellitus), nutritional abnormalities, and quality of life over 5 years post surgery.

RESULTS: Baseline characteristics, except for age, between the 2 cohorts were similar. No significant differences in frequency of remission of hypertension ($P = .84$) or dyslipidemia ($P = .74$) were observed between age groups. Remission of type 2 diabetes mellitus was high in both groups, although statistically higher in older adolescents (relative risk 0.86; $P = .046$). Weight loss and quality of life were similar in the 2 age groups. Younger adolescents were less likely to develop elevated transferrin (prevalence ratio 0.52; $P = .048$) and low vitamin D levels (prevalence ratio 0.8; $P = .034$).

CONCLUSIONS: The differences in outcome of metabolic and bariatric surgery between younger and older adolescents were few. These data suggest that younger adolescents with severe obesity should not be denied consideration for surgical therapy on the basis of age alone and that providers should consider adolescents of all ages for surgical therapy for obesity when clinically indicated.

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Dr Ogle conceptualized and designed the study, contributed to data interpretation, drafted the initial manuscript, and critically reviewed the manuscript for important intellectual content; Dr Dewberry conceptualized and designed the study and reviewed and revised the manuscript; Dr Jenkins designed the data collection instruments, collected data, conducted the analyses, contributed to data interpretation, and reviewed and revised the manuscript; Dr Inge conceptualized and designed the study, contributed to data interpretation, obtained funding for the study, and critically reviewed the manuscript for important intellectual content; Dr Kelsey contributed to data interpretation and critically reviewed the manuscript for important intellectual content; Dr Bruzoni conceptualized and designed the study, contributed to data interpretation, and reviewed and revised the manuscript; Dr Pratt conceptualized and designed the study, contributed to data interpretation, and critically reviewed the manuscript for important intellectual content; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

WHAT'S KNOWN ON THIS SUBJECT: Bariatric surgery is an effective, durable treatment of severe obesity in adolescents, with results generally similar to or surpassing those for adults. However, little is known about the relative merits and risks of these procedures in younger teenagers compared with older adolescents.

WHAT THIS STUDY ADDS: We found that younger and older adolescents had similar weight loss, resolution of hypertension and dyslipidemia, nutritional deficiencies, and improvement in quality of life after surgery. Age alone should not dissuade providers and patients from pursuing surgery when medically indicated.

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Over recent decades, the global health and economic burden of obesity has continued to rise rapidly in both developing and developed nations.[1,2] In the United States, obesity affects 13.7 million children, of whom 6% meet the definition of having severe obesity.[3,4] Obesity has been linked to numerous complications involving every body system.[5,6] The rise of childhood obesity has brought an emergence of chronic diseases once only present in adulthood (eg, hypertension, dyslipidemia, and type 2 diabetes mellitus) and associated with a decreased life expectancy of 5 to 20 years.[7,8] Intensive medical and lifestyle interventions for the treatment of obesity have demonstrated an average of 5% to 15% weight loss, with variable results in sustainability.[9–11] Alternatively, metabolic and bariatric surgery (MBS) has been shown to be an effective and durable treatment for obesity and complications of obesity in adolescents, with weight loss and health improvements far surpassing those achieved with nonsurgical treatments.[12–17] The most recent update of the pediatric American Society for Metabolic and Bariatric Surgery guidelines removed the recommendation of achieving adult height or pubertal maturity before pursuing MBS, thereby eliminating younger age restrictions.[12]

In a recent policy statement, the American Academy of Pediatrics advocates for increased use of and access to MBS for pediatric patients and acknowledges insufficient evidence to support age-based limitations for eligibility.[18,19] Evidence of the safety and effectiveness of MBS in young adolescents and children is increasing, but it is estimated that <1% of eligible pediatric patients undergo MBS for the treatment of severe obesity.[14,16–22] Hesitancy to refer due to concerns of safety, impact on growth, ethical concerns with patient assent, and compliance with postoperative instructions is a critical barrier to treatment of severe obesity, resulting in less than half of primary care physicians considering referral for pediatric patients.[23,24] Data on long-term outcomes after MBS in younger adolescent or preadolescent patients are limited, and outcomes in the youngest children have only been reported in case reports from outside the United States.[21,25–28] Comparative studies of adult and adolescent outcomes after MBS reveal similar weight loss and superior comorbidity resolution in the adolescent population. To explore potential age-related differences in MBS outcomes between older and younger adolescents, we divided the Teen–Longitudinal Assessment of Bariatric Surgery (Teen-LABS) study cohort into a younger and older group and compare weight loss, comorbidity change, nutritional deficiencies, and quality of life over 5 years.[13,29]

METHODS

Teen-LABS is a multicenter prospective observational study in which 242 adolescents (≤19 years of age) were enrolled between 2007 and 2011. Participants underwent MBS between 2007 and 2012. Study details, research methods, diagnostic criteria, and data collection have previously been described and are available at ClinicalTrials.gov (identifier NCT00474318).[17,30] Baseline data were collected within 30 days of MBS. Participants were then evaluated at 6 months, 12 months, and then annually, and outcomes were evaluated up to 5 years after surgery. During this time frame, 230 of the 242 (95%) participants remained as active study participants, completing 86% (1254 of 1452) of all postoperative research visits. Baseline demographic, anthropometric, and comorbidity data were obtained by trained study staff. Specifically, changes in 3 major comorbidities (hypertension, dyslipidemia, and type 2 diabetes), micronutrient status[31] (ferritin, folate, vitamin B_{12}, vitamin D, vitamin A, and parathyroid hormone), and quality-of-life metrics (Impact of Weight on Quality of Life [IWQOL] total score and 36-Item Short Form Health Survey (SF-36) physical and mental component scores) were evaluated. Because of the small number of participants who underwent laparoscopic adjustable gastric banding (*n* = 14), only those who underwent Roux-en-Y gastric bypass (RYGB) (*n* = 161) or vertical sleeve gastrectomy (*n* = 67) were analyzed.

The clinical care of participants was at the discretion of the clinicians at the centers where enrollment occurred and was not dictated by research protocol. Clinical care generally followed national guideline recommendations. Informed, written consent was obtained from caregivers and/or participants as appropriate on the basis of age at the time of enrollment. Reconsenting was done when each participant reached the age of 18. Study protocols, consents, and data and safety monitoring were approved by all institutional sites (Nationwide Children's Hospital in Columbus, OH; Cincinnati Children's Hospital Medical Center in Cincinnati, OH; Texas Children's Hospital in Houston, TX; University of Pittsburgh Medical Center in Pittsburgh, PA; and Children's of Alabama in Birmingham, AL) and an independent data and safety monitoring board before study initiation. Ongoing review of study performance and safety has been done by the data and safety monitoring board from 2007 to present day.

For this analysis, the Teen-LABS cohort was arbitrarily divided into 2 age groups: age 13 to 15 years and age 16 to 19 years at the time of surgery. Age group–specific categorical measures were presented as frequencies and percentages and were compared by using χ^2 tests. Continuous variables were summarized by using means and SDs, and *t* tests were used to compare by age group. Baseline BMI was calculated as kilograms divided by height (meters) squared. Linear mixed models were used to compare the following outcomes by age group: percentage weight change from baseline, IWQOL total score, SF-36 physical composite score, and SF-36 mental composite score. Poisson mixed modeling with robust error variance was used to compare comorbidity (type 2 diabetes, hypertension, and dyslipidemia) remission and prevalence of micronutrient abnormalities by study cohort. For all models, the following variables were considered for inclusion in the final model: age group, study visit, age group by visit interaction, sex, race, and baseline caregiver education. Percentage BMI change, quality-of-life metrics, and comorbidity prevalence were adjusted for BMI. Remission of hypertension was adjusted for percentage BMI change, baseline hypertension medications, and baseline blood pressure. Remission of dyslipidemia was adjusted for percentage BMI change, baseline lipid medications, and baseline lipid levels. Remission of type 2 diabetes was adjusted for percentage BMI change, baseline diabetes medications, baseline hemoglobin A1c levels, and duration of disease. For each outcome, modeled estimates and 95% confidence intervals (CIs) were calculated by age group and study visit. These models addressed missing values by maximum likelihood estimation under the data missing at random assumption. Weight values from peripartum female participants were omitted from analyses if obtained between the second trimester and 6 months post partum. All statistical analyses were conducted by using SAS version 9.4 (SAS Institute, Inc, Cary, NC); all reported *P* values were 2 sided and considered statistically significant when $<.05$. No adjustments were made for multiple comparisons.

RESULTS

Baseline Description of Participants

The overall cohort was predominantly female (75%) and white (72%) and had a mean baseline BMI of 52.6. Most participants underwent RYGB, as shown in Table 1. The younger cohort (n = 66) was 13 to 15 years of age at the time of surgery and had an average age of 15.1 ± 0.81 years and an average BMI of 53.1 ± 11. The older cohort (n = 162) was 16 to 19 years of age at the time of surgery and had an average age of 17.7 ± 1 years and an average BMI of 52.4 ± 9. In Table 1, we present baseline demographic and clinical characteristics by age grouping.

Percentage Weight Loss Over 5 Years After Surgery

BMI significantly declined from baseline until 1 year post surgery (group by time interaction, P = .60; Fig 1), remained stable between years 1 and 2 (P = .16), and then similarly, but significantly, increased in both groups thereafter ($P < .01$). Five years after surgery, the percentage BMI change from baseline was similar between younger (−22.2%; 95% CI: −26.2% to −18.2%) and older (−24.6%; 95% CI: −27.7% to −22.5%) adolescents (P = .59).

Hypertension

Baseline prevalence of hypertension was 27% (n = 18) in younger adolescents and 37% (n = 59) in older adolescents (P = .16). At 5 years, remission of hypertension was achieved by 77% (95% CI: 57.1% to 100.0%) of younger adolescents and 67% (95% CI: 54.5% to 81.5%) of older adolescents (Fig 1). After adjustment, postoperative hypertension remission was similar by age group (P = .84). Five years after surgery, the incidence of hypertension in the younger group

TABLE 1 Baseline Characteristics by Age at Surgery

	Ages 13–15 y (n = 66)	Ages 16–19 y (n = 162)	P
Age at surgery, mean (SD), y	15.1 (0.81)	17.7 (1.04)	<.001
Female sex, % (n)	72.7 (48)	75.9 (123)	.61
White, % (n)	72.7 (48)	71.6 (116)	.86
Non-Hispanic, % (n)	97.0 (64)	91.4 (148)	.16
Surgical procedure, % (n)			.14
RYGB	63.6 (42)	73.5 (119)	—
VSG	36.4 (24)	26.5 (43)	—
Household income, % (n)			.31
<$25 000	34.4 (22)	39.6 (61)	—
$25 000–$74 999	34.4 (22)	39.0 (60)	—
$75 000+	31.3 (20)	21.4 (33)	—
Caregiver education attained			.98
Less than high school	10.8% (7)	10.3% (16)	—
High school graduate	30.8% (20)	30.8% (48)	—
Some college	41.5% (27)	39.7% (62)	—
College graduate or higher	16.9% (11)	19.2% (30)	—
Wt, mean (SD), kg	148.6 (31.88)	148.9 (31.05)	.95
BMI, mean (SD)	53.1 (10.75)	52.4 (8.79)	.66
Systolic BP, mean (SD), mm Hg	121.5 (12.53)	126.8 (13.31)	.007
Diastolic BP, mean (SD), mm Hg	71.2 (8.96)	75.4 (10.27)	.004
Type 2 diabetes, % (n)	10.6 (7)	13.6 (22)	.54
Hypertension, % (n)	27.3 (18)	37.1 (59)	.16
Dyslipidemia, % (n)	73.4 (47)	77.0 (124)	.57
IWQOL total score, mean (SD)	64.1 (17.75)	61.7 (18.16)	.37
SF-36 physical composite score, mean (SD)	44.8 (9.47)	43.9 (8.12)	.49
SF-36 mental composite score, mean (SD)	50.0 (10.33)	49.2 (10.34)	.59

Baseline demographics, anthropometrics, comorbidity status, and quality-of-life metrics for both age groups were similar, with the exception of age and BP, which were significantly different at $P < .05$. BP, blood pressure; VSG, vertical sleeve gastrectomy; —, not applicable.

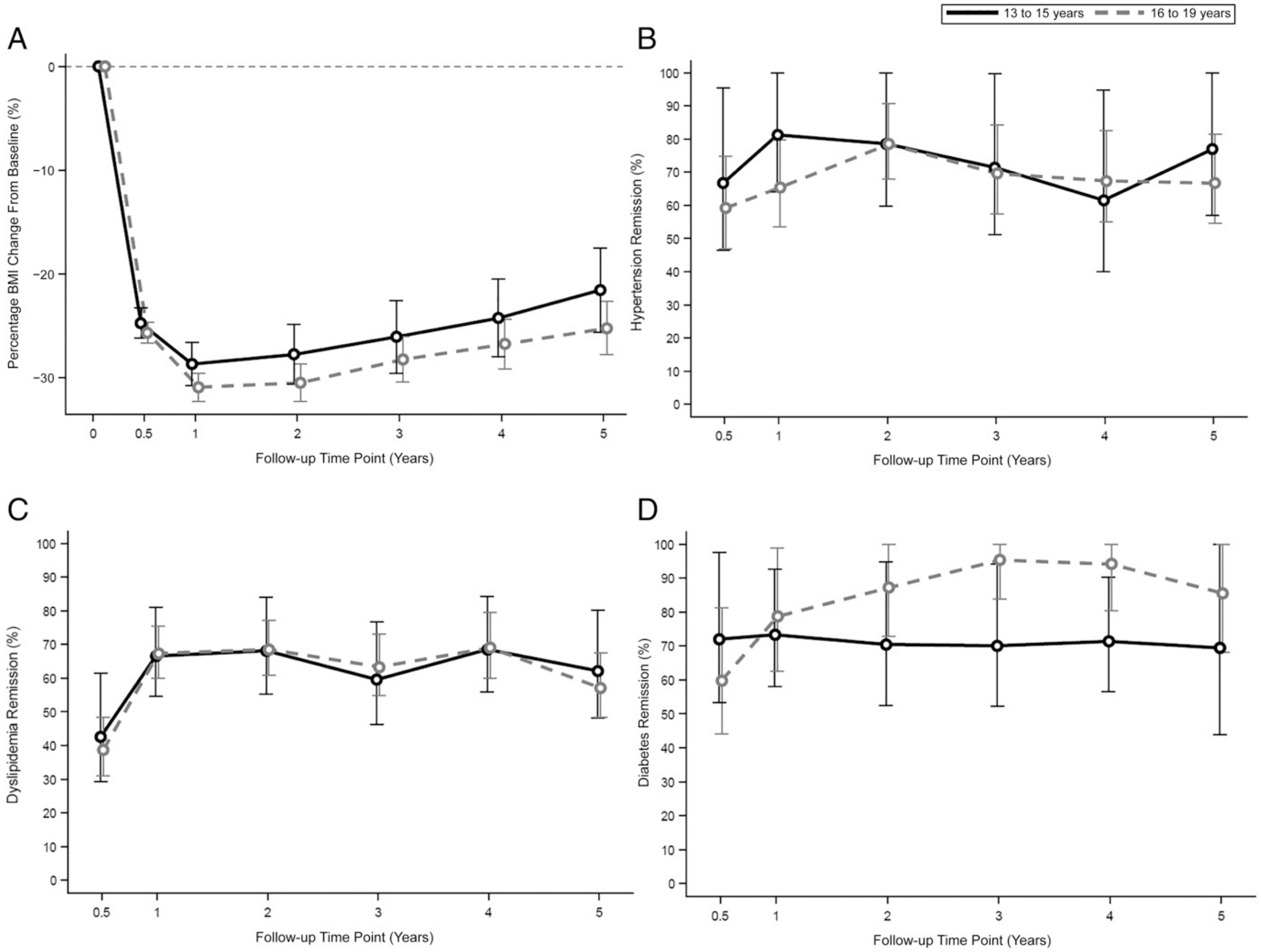

FIGURE 1

Percentage BMI change and comorbidity resolution over 5 years after MBS. A, Percentage BMI change from baseline. B, Remission of hypertension. C, Remission of dyslipidemia. D, Remission of type 2 diabetes mellitus. Younger adolescents were less likely to achieve remission of diabetes (*P* = .046). Error bars indicate 95% CIs.

was 8% (*n* = 5), compared with 2% (*n* = 4) in the older group.

Dyslipidemia

Baseline prevalence of dyslipidemia was 73% (*n* = 47) in younger adolescents and 77% (*n* = 124) in older adolescents (*P* = .57). Five-year dyslipidemia remission was 61% (95% CI: 46.3% to 81.1%) among younger adolescents and 58% (95% CI: 48.0% to 68.9%) among older adolescents (Fig 1). Over the 5-year postoperative period, there was no significant difference in remission between age groups (*P* = .74). Incidence of dyslipidemia at 5 years occurred in 2% (*n* = 1) of younger adolescents and 4% (*n* = 6) of older adolescents.

Type 2 Diabetes Mellitus

Baseline prevalence of type 2 diabetes was 11% (*n* = 7) in younger adolescents and 14% (*n* = 22) in older adolescents (*P* = .54). Remission of type 2 diabetes was achieved by 83% (*n* = 6) of young adolescents and 87% (*n* = 15) of older adolescents by 5 years. Adjusted analyses revealed that over the 5-year postoperative period, younger adolescents were less likely to achieve remission compared with older adolescents (relative risk 0.86 [95% CI: 0.74 to 0.99]; *P* = .046). Five years after surgery, incidence type 2 diabetes was rare and present in 4.5% (*n* = 1) of older adolescents and 0% (*n* = 0) of younger adolescents.

Nutritional Abnormalities

Compared with baseline, prevalence of abnormal ferritin, transferrin, vitamin B_{12}, and vitamin A levels significantly increased by 5 years post surgery. However, over 5 years post surgery, only prevalence of elevated transferrin levels and vitamin D deficiency was significantly different by age group (Fig 2). Specifically, younger adolescents were less likely to have elevated transferrin levels (prevalence ratio [PR] 0.52 [95% CI

0.27 to 0.99]; $P = .048$) and low vitamin D levels (PR 0.80 [95% CI 0.65 to 0.98]; $P = .034$) compared with older adolescents.

Quality of Life

Quality-of-life measures evaluated in this study included the IWQOL total score by visit, the SF-36 physical composite score by visit, and the SF-36 mental composite score by visit (Supplemental Figs 3–5). For each measure, values significantly improved by 6 months (each $P < .05$) and remained similar thereafter. The trajectory of change for each measure did not differ by age group, nor were there any group differences observed.

DISCUSSION

In this analysis, we identified similar improvement to percentage BMI loss, resolution of hypertension and dyslipidemia, and quality of life over 5 years after MBS between younger and older adolescents. We found a lower likelihood of nutritional deficiencies in younger adolescents. Diabetes remission was slightly higher, although statistically significant, in older youth. These results appear promising for the treatment of severe obesity in young patients; however, further controlled studies are needed to fully evaluate the timing of surgery and extended long-term durability.[32] Alqahtani et al[21] retrospectively reviewed MBS outcomes at a single center in patients aged >14 and ≤14 years and noted that although the older cohort had superior weight loss at 1 year after surgery, there were no significant differences at years 2 to 5 after surgery, and the groups had similar rates of comorbidity resolution, complications, and mortality. Therefore, this analysis confirms similar findings, in a slightly older age range, to those by Alqahtani et al[21] within a multicenter prospective observational data set.

In this study, differences in percentage BMI loss were not identified between the older and younger groups. The average BMI in each cohort was 53, indicating late referral in both age groups. Alqahtani et al[21] also had similar percentage BMI loss; however participants had a lower baseline BMI. Ability to achieve a normal BMI after MBS is related to baseline BMI; therefore, what may be more important for postoperative success is intervening at a lower BMI rather than a specific age.[33,34] Surgical intervention at a lower BMI is particularly important because current medical treatments have limited success in resulting in weight loss or stabilization in youth with severe obesity.[35] Increased duration of obesity is linked to increased mortality, cardiovascular risk, and risk of type 2 diabetes; therefore, the BMI requirements for pediatric patients with complications of obesity have been reduced to 120% of the 95th percentile for age, allowing for earlier intervention before surgery alone may become ineffective.[36–39]

Using MBS for the purpose of resolving or improving complications of obesity carries significant positive health benefits. This study revealed remission rates for hypertension and dyslipidemia in younger and older adolescents similar to those found by Alqahtani et al.[21] Michalsky et al[40] previously explored cardiovascular risk prevalence and reduction after MBS in the Teen-LABS cohort. Comparative studies between adults and adolescent patients reveal higher rates of comorbidity resolution after surgery in adolescents, likely due to shorter duration of disease.[13,41–43] Resolution of cardiac risk factors with MBS is compelling because authors of previous studies have warned that childhood hypertension generally persists in adulthood and leads to a significant increase in cardiovascular disease.[36,44,45]

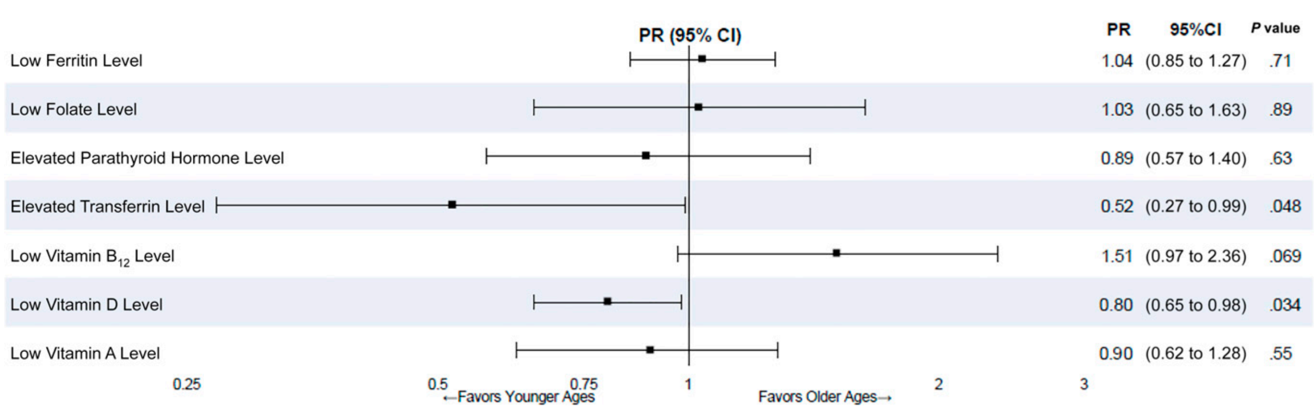

FIGURE 2
Micronutrient status over 5 years after MBS and age group associations with micronutrient abnormalities. Micronutrient status was similar over 5 years after surgery. Younger adolescents were less likely to have elevated transferrin ($P = .048$) or low vitamin D ($P = .034$) levels compared with older adolescents. Bars represent 95% CIs. Box symbols represent PRs.

Extended long-term studies are needed to evaluate the full potential benefit of early cardiovascular risk reduction with MBS in pediatric patients; however, in adult studies, researchers estimate a near 50% risk reduction of myocardial infarction, 33% to 50% risk reduction of stroke, and >50% risk reduction of death after a cardiovascular event.[46–48]

The difference in remission of type 2 diabetes in younger and older adolescents was small, and with a sample size of only 7 individuals in the younger adolescent group, it would not be appropriate to provide any recommendation on the basis of these preliminary data. Patients with type 2 diabetes in the Teen-LABS study had an overall remission rate of 86% (95% CI: 85 to 100), comparable to similar MBS studies in adolescents.[17,20,21,42,49] In a similar-sized group, Alqahtani et al[21] found a higher baseline prevalence but similar rates of remission of type 2 diabetes in older adolescents compared with younger adolescents. The average age at type 2 diabetes diagnosis is 13.6 years in pediatric patients, presenting a significant long-term health burden and risk of early mortality.[50,51] Despite more rapidly progressive β-cell failure in youth with type 2 diabetes, youth with type 2 diabetes have higher remission rates after MBS than adult patients undergoing bariatric surgery or those receiving maximum medical therapy.[13,15,38,41,43,52,53] Improvement in glycemic control and insulin sensitivity after MBS leads to the reversal or stabilization of many diabetes complications.[53] Patients with obesity and type 1 diabetes also benefit from MBS by reducing insulin requirements and improving complications of diabetes; however, glycemic control remains challenging in these individuals. Furthermore, MBS appears to prevent incident type 2 diabetes.[54,55] As such, the authors do not feel that the minor statistical differences in this analysis warrant hesitation to pursue MBS in adolescents for the treatment of type 2 diabetes.

In addition to the medical complications of obesity, obesity also has detrimental effects on quality of life. In the current study, we identified a significant improvement in quality of life in both age groups after MBS. Long-term potential learning, earnings, and opportunity can be impacted by obesity bias, obesity-related cognitive or mental health impairments, and absenteeism secondary to chronic obesity-related health problems.[56–63] Although no extended long-term studies decades after MBS in the pediatric populations exist to evaluate the impact of increased quality of life on school performance, occupational opportunity, earnings, and overall psychosocial health, it could be theorized that early intervention may limit the exposure risk of obesity and provide early referral to trained pediatric psychologists integrated into pediatric MBS programs and access to long-term mental health follow-up.[64]

As MBS has become recognized as the safest and most effective treatment of severe obesity in adults, it initially was recommended that surgery be delayed until patients could reach physical maturity, were of an age to consent to lifelong altering procedures, and to avoid the risk of a surgery or potential nutritional deficiencies. Here we demonstrate lower rates of the 2 most common nutritional deficiencies (vitamin D and iron) in younger adolescents and no differences in other nutritional deficiencies between groups. Thus, the risk of nutritional deficiency is not a reason to delay surgery in young adolescents. More recent studies have refuted common concerns regarding the safety of MBS in pediatric patients and have revealed increased linear growth after MBS.[11,12,21,29,65,66] Arguably, the youngest patients are unable to fully understand the risks, benefits, and lifelong lifestyle changes that come with MBS. However, the alternative of delaying MBS and managing severe obesity with less effective therapies, exposing pediatric patients to insufficiently studied medications for obesity and to comorbidities, and increasing the exposure risk of obesity to the child's health may provide an even greater ethical challenge.[64,67] The morbidity and mortality of MBS has improved with time and is now comparable to that of a laparoscopic cholecystectomy.[11] Early comparisons between adult and adolescent patients initially revealed a potentially higher complication rate in adolescents that may have been attributed to surgeon experience, case volume, or increased use of RYGB rather than patient age.[13,43] However, more recent adolescent studies reveal lower rates of complications in comparison with adults and comparable complication rates in both younger and older pediatric patients.[21,25,41,42] Family involvement is more common and necessary in the youngest patients to ensure compliance with supplements and access to healthy foods. Older adolescents are at risk for noncompliance as they transition to adulthood and self-independence, emphasizing the need for long-term follow-up for this unique population.[31,68] It is possible that earlier initiation of postoperative habits and increased supervision in the younger cohort lead to the pattern of nutritional deficiencies seen in this study and may support a role for earlier intervention.

Limitations of this study include the observational nature of the study, lack of randomization, and potentially subtle differences in care or technique across the 5 participating institutions, although center effect was accounted for in the statistical models. However, Teen-LABS data were collected prospectively by using rigorous data collection methods.

Some analyses were based on small sample sizes (eg, type 2 diabetes), and results should be interpreted with caution. Additionally, many studies of MBS, including this one, have a greater percentage of white and female patients, which limits the generalizability. Furthermore, lack of extended longitudinal studies decades after MBS in this population limits our current ability for fully assess the long-term risk/benefit ratio.

CONCLUSIONS

Obesity and duration of obesity are significant risk factors for early mortality, type 2 diabetes, cardiovascular events, multiple cancers, end-stage renal disease, end-stage liver disease, and decreased quality of life.[5–8,46,69] MBS currently represents the most effective and durable, yet underused, treatment of severe obesity and complications of obesity in thoughtfully selected children.[12,22,65,70] The findings in this study support the use of early intervention based on clinical indication rather than age alone, thereby providing the patient with the best opportunity to reach a normal BMI after surgery, promoting resolution of complications of obesity, and reducing the number of obese years in a child's lifetime.

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ABBREVIATIONS

CI: confidence interval
IWQOL: Impact of Weight on Quality of Life
MBS: metabolic and bariatric surgery
PR: prevalence ratio
RYGB: Roux-en-Y gastric bypass
SF-36: 36-Item Short Form Health Survey
Teen-LABS: Teen–Longitudinal Assessment of Bariatric Surgery

Deidentified individual participant data (including data dictionaries) are available via the National Institute of Diabetes and Digestive and Kidney Diseases Central Repository (https://repository.niddk.nih.gov/home).

This trial has been registered at www.clinicaltrials.gov (identifier NCT00474318).

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