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Research Article

Predictors of Risk and Success of Obesity Surgery

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Keywords

Excess weight loss · Comorbidities · Years of obesity · Age of onset of obesity · Risk of complications

Abstract

Background: Obesity surgery has proven successful for weight loss and the resolution of comorbidities. There is, however, little evidence on its success and the risk of complications when considering age of onset of obesity (AOO), years of obesity (YOO), preoperative body mass index (BMI), Edmonton obesity staging system (EOSS) score, and age as possible predictors of weight loss, the resolution of comorbidities, and the risk of complications. ***Methods:*** Patients who underwent Roux-en-Y gastric bypass (RYGB) and laparoscopic sleeve gastrectomy (LSG) from a prospective database were analyzed. Multiple regression analyses were used to predict comorbidities and their resolution, percentage excess weight loss (%EWL) and total weight loss (%TWL) 12 months after surgery, and the risk of complications using the predictors AOO, YOO, age, EOSS, and BMI. ***Results:*** 180 patients aged 46.8 ± 11.1 years with a preoperative BMI 49.5 ± 7.5 were included. The number of preoperative comorbidities was higher with older age ($\beta = 0.054$; $p = 0.023$) and a greater BMI ($\beta = 0.040$; $p = 0.036$) but was not related to AOO and YOO. Patients with AOO as a child or adolescent were more likely to have an EOSS score of ≥2. Greater preoperative BMI was negatively associated with %EWL ($\beta = -1.236$; $p < 0.001$) and older age was negatively associated with %TWL ($\beta = -0.344$; $p = 0.020$). Postoperative compli-

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cations were positively associated with EOSS score (odds ratio [OR] 1.147; *p* = 0.042) and BMI (OR 1.010; *p* = 0.020), but not with age. AOO and YOO were not related to postoperative outcome. ***Conclusion:*** Greater BMI was associated with a lower %EWL and age was associated with a low %TWL. YOO and AOO did not influence outcome. Age, BMI, and EOSS score were the most important predictors for risk and success after obesity surgery. Surgery should be performed early enough for optimal outcomes.

Introduction

Obesity is a worldwide epidemic disease [1] and a major risk for comorbidities such as diabetes mellitus type 2 (DM2), arterial hypertension, stroke, coronary heart disease, pulmonary disease, and >5 different cancers [2]. Treatment of obesity is a major concern for physicians [3]. The age of onset of obesity (AOO) varies greatly, and can occur in childhood, adolescence, or adulthood. Childhood obesity continues to be a major focus in public health [4]. Obese children may be at risk for short-term health consequences [5] and long-term tracking of obesity to adulthood [6]. Excess weight gain during adolescence often persists into adult life and is compounded during child-bearing years. Adolescence is a “high-risk period” for weight gain, characterized by critical changes in body composition, insulin sensitivity, eating and activity behaviors, and psychological adjustments [7].

Presently, obesity surgery is the only available treatment for morbid obesity that consistently achieves and maintains substantial weight loss and improves obesity-related comorbidity and quality of life [8–12]. Laparoscopic Roux-en-Y gastric bypass (RYGB) and laparoscopic sleeve gastrectomy (LSG) have been the most commonly performed obesity procedures in the last decade. The risk of complications is acceptable in most patients, but there can be considerable morbidity and even mortality [13, 14]. However, there is insufficient evidence on the risk factors for perioperative complications as opposed to the optimal timing of surgery. The aim of the Edmonton obesity staging system (EOSS) is to classify patients according to their current obesity-related complications [15]. Although the majority of patients achieve a successful degree of weight loss after surgery, typically defined as >50% excess weight loss (%EWL), there is an important minority of patients (15–20%) that fail to achieve this goal [16]. Failure to achieve successful weight loss after surgery is likely multifactorial, involving provider-level (e.g., technical factors and preoperative patient education) and patient-level characteristics [17–19].

Currently, there is limited evidence on the influence of AOO and the duration of obesity on the risks and success of obesity surgery. By knowing patients’ AOO, one can determine their years of obesity (YOO).

The aim of this study was to evaluate the role of AOO and YOO, together with other possible predictors such as age, body mass index (BMI), gender, and EOSS score, in the success of obesity surgery in terms of weight loss, the resolution of comorbidities, and the risk of complications.

Materials and Methods

A retrospective analysis of a prospectively collected database from the Department of General, Visceral and Transplant Surgery of the Heidelberg University Hospital was conducted. We included all patients who underwent RYGB or LSG between January 2006 and November

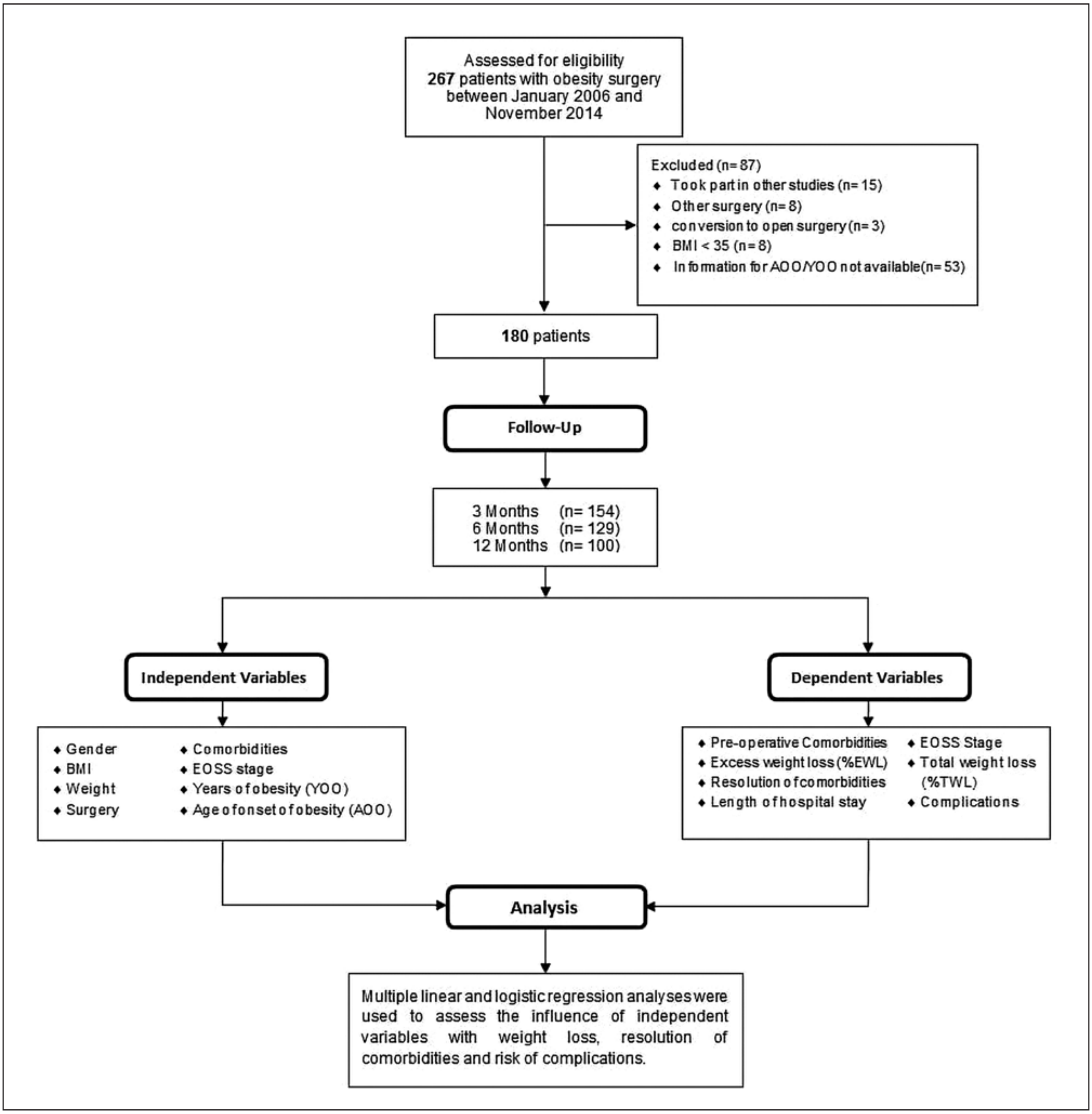

Fig. 1. Study flow chart. BMI, body mass index; EOSS, Edmonton obesity staging system.

2014, with indication for obesity surgery according to SAGES, ASMBS, IFSO, and the German S3 guidelines [20–22], and a BMI ≥40 or 35–40 with major obesity-associated comorbidities. Selection between surgical procedures was conducted through shared decision-making. We excluded all patients who had surgeries other than RYGB or LSG, re-do surgery, or open surgery, or who were participating in concurring studies, and those with insufficient information on follow-up, AOO, and YOO. Patients with a BMI <35 were also excluded (Fig. 1).

Ethical approval was obtained from the local ethics committee at Heidelberg University (S-181/2009, S-618/2011, S-500/2012 and S-629/2013). Patients' gender, age, type of

Table 1. Demographic data and baseline characteristics of patients

	RYGB (*n* = 48)	LSG (*n* = 132)	*p* value
Age at baseline, years			
Mean ± SD	49.7±10.9	45.8±11.0	0.038
Range	27–70	21–72	
Gender			
Male	15 (31.2)	50 (37.8)	0.520
Female	33 (68.7)	82 (62.1)	
Preoperative BMI			
Mean ± SD	47.1±7.4	50.4±7.3	0.012
Range	36.1–73.1	36.6–74.0	
Comorbidities			
DM2	29 (60.4)	69 (52.2)	0.423
Arterial hypertension	33 (68.7)	91 (68.9)	1
Joint pain	23 (47.9)	77 (58.3)	0.283
Reflux	16 (33.3)	18 (13.6)	0.005
Sleep apnea	13 (27.0)	48 (36.6)	0.325
AOO			0.011
Child	10 (20.8)	60 (45.4)	
Adolescent	12 (25.0)	20 (15.1)	
Adult	20 (41.6)	39 (29.5)	
No information	6 (12.5)	13 (9.8)	
YOO			
Mean ± SD	27.0±11.3	26.2±11.4	0.698
Range	8–56	5–51	

Values express *n* (%), unless otherwise indicated. BMI, body mass index; DM2, diabetes mellitus type 2; AOO, age of onset of obesity; YOO, years of obesity; RYGB, Roux-en-Y gastric bypass; LSG, laparoscopic sleeve gastrectomy.

surgery, preoperative weight and BMI, comorbidities, EOSS, YOO, and AOO were recorded. For AOO, we used 3 different classifications: childhood AOO (6–11 years), AOO as an adolescent (12–18 years), and adult AOO (>18 years). To determine patients' YOO, we calculated their current age minus AOO. The influence of these parameters on %EWL (initial weight minus actual weight, divided by initial weight minus ideal weight × 100) and % total weight loss (%TWL; operative weight minus follow-up weight, divided by operative weight × 100) at 3, 6, and 12 months after surgery, preoperative comorbidities, the resolution of comorbidities, the risk of complications, and the length of hospitalization were investigated. The results were divided into preoperative and postoperative groups.

Statistical Analysis

Quantitative data were presented as mean ± standard deviation for selected variables. Categorical variables were expressed as absolute and relative frequencies. Multiple linear and logistic regression analyses were used to assess the influence of several independent variables. The single coefficients (β) in the linear regression model were used to describe the effects of the respective independent variables on the dependent variable adjusted for all other variables in the model. Single coefficients were represented as slopes in the regression models comparing independent variables; the higher the single coefficient, the higher the association. A negative β implied that the corresponding independent variable was negatively

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Table 2. Logistic regression analysis of DM2 and predictor variables before obesity surgery

	Estimate, *β*	SE	OR	*p*
Intercept	–0.189	0.324	0.828	0.562
Age	0.019	0.007	1.019	0.004
Sex (reference: male)				
Female	–0.026	0.080	0.974	0.741
BMI	0.002	0.005	1.002	0.717
AOO (reference: childhood)				
Adolescence	–0.058	0.118	0.943	0.621
Adulthood	–0.017	0.159	0.983	0.915
YOO	–0.008	0.007	0.992	0.251

β describes the effects of the respective independent variables on the dependent variable. SE, standard error; OR, odds ratio; BMI, body mass index; DM2, diabetes mellitus type 2; AOO, age of onset of obesity; YOO, years of obesity.

Table 3. Logistic regression analysis between preoperative arterial hypertension and predictor variables

	Estimate, *β*	SE	OR	*p*
Intercept	0.101	0.306	1.106	0.742
Age	0.016	0.006	1.017	0.009
Sex (reference: male)				
Female	–0.051	0.075	0.950	0.495
BMI	0.002	0.005	1.002	0.723
AOO (reference: childhood)				
Adolescence	–0.068	0.111	0.934	0.540
Adulthood	–0.132	0.150	0.876	0.379
YOO	–0.006	0.007	0.994	0.360

β describes the effects of the respective independent variables on the dependent variable. SE, standard error; OR, odds ratio; BMI, body mass index; AOO, age of onset of obesity; YOO, years of obesity.

associated with the dependent variable, and a positive β implied a positive association. $p < 0.05$ was considered statistically significant. Due to the exploratory nature of the study, no adjustment for multiplicity was performed.

Results

Out of 267 patients available during the study period, 180 fulfilled the inclusion criteria. There were 65 (36.1%) male and 115 (63.9%) female patients with a mean age of 46.8 ± 11.1 years, a preoperative weight of 145.5 ± 26.8 kg, and a preoperative BMI of 49.5 ± 7.5 (Table 1). Data on AOO was available for 161 patients and on YOO for 160 patients out of these 180. 85.5% of patients were available at the 3-month postoperative follow-up. For the 6- and 12-month follow-up, 71.6 and 55.5% of patients were available, respectively. There were 87 patients that matched the exclusion criteria. Fifteen patients were taking part in a concurring study, 8 had a surgery other than RYGB and LSG, and 3 had a conversion to open surgery. There were 8 patients with a preoperative BMI ≤35 and 53 with insufficient information regarding follow-up, AOO, and YOO.

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Table 4. Logistic regression analysis between sleep apnea and predictor variables before obesity surgery

	Estimate, *β*	SE	OR	*p*
Intercept	−0.005	0.317	0.995	0.987
Age	0.011	0.006	1.011	0.093
Sex (reference: male)				
Female	−0.265	0.078	0.767	0.001
BMI	0.004	0.005	1.005	0.385
AOO (reference: childhood)				
Adolescence	−0.131	0.115	0.878	0.258
Adulthood	−0.110	0.155	0.896	0.480
YOO	−0.005	0.007	0.995	0.446

β describes the effects of the respective independent variables on the dependent variable. SE, standard error; OR, odds ratio; BMI, body mass index; AOO, age of onset of obesity; YOO, years of obesity.

Table 5. Logistic regression analysis between preoperative reflux and predictor variables

	Estimate, *β*	SE	OR	*p*
Intercept	0.641	0.264	1.898	0.016
Age	0.002	0.005	1.002	0.692
Sex (reference: male)				
Female	0.051	0.065	1.052	0.436
BMI	−0.009	0.004	0.991	0.037
AOO (reference: childhood)				
Adolescence	−0.098	0.096	0.906	0.306
Adulthood	−0.098	0.129	0.907	0.451
YOO	−0.003	0.006	0.997	0.554

β describes the effects of the respective independent variables on the dependent variable. SE, standard error; OR, odds ratio; BMI, body mass index; AOO, age of onset of obesity; YOO, years of obesity.

Preoperative Results

Patients had a mean 3.5 ± 1.7 comorbidities. Linear regression showed that older age (β = 0.054, $p = 0.023$) and greater BMI (β = 0.04, $p = 0.036$) were the only predictors associated with a higher number of preoperative comorbidities. This means that patients had 1 more comorbidity with every 18.5 years of age and with every 25 BMI points.

Logistic regression analysis of the 5 most common comorbidities showed possible predictors for comorbidity. For DM2 (Table 2) and arterial hypertension (Table 3), the only significant predictor was older age. With every 10 years of age, a patient's risk of developing DM2 grew by 21% (odds ratio [OR] 1.019), and for hypertension the risk grew by 10% (OR .017). For sleep apnea, the covariate sex was predictive, with female patients at a lower risk (OR 0.767) (Table 4). Patients with greater BMI were less likely to have reflux than those with a low BMI (Table 5). AOO and YOO were not predictive of these comorbidities. No variable showed any influence on joint pain preoperatively. In the logistic regression analysis, patients who had AOO as an adult were 25.5% less likely to have an EOSS score ≥2 than those with childhood AOO (OR 0.745, $p = 0.043$). Patients who were 1 year older (OR 1.022, $p < 0.001$) were 2% more likely to have an EOSS score ≥2. This means that every 10 years the risk of having an EOSS score of at least 2 grew by 25%.

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Table 6. Linear regression analysis investigating the association of %EWL 12 months after obesity surgery and predictor variables

	Estimate, *β*	SE	*p*
Intercept	137.972	14.949	<0.001
Age	–0.799	0.284	0.006
Sex (reference: male)			
Female	4.188	3.480	0.232
RYGB (reference: LSG)	4.950	3.989	0.218
BMI	–1.236	0.235	<0.001
AOO (reference: childhood)			
Adolescence	9.755	5.312	0.070
Adulthood	13.113	7.095	0.068
YOO	0.555	0.294	0.063

β describes the effects of the respective independent variables on the dependent variable. SE, standard error; %EWL, percentage excess weight loss; BMI, body mass index; AOO, age of onset of obesity; YOO, years of obesity; RYGB, Roux-en-Y gastric bypass; LSG, laparoscopic sleeve gastrectomy.

Table 7. Logistic regression analysis between DM2 resolution 12 months after obesity surgery and predictor variables

	Estimate, *β*	SE	OR	*p*
Intercept	0.483	0.516	1.622	0.352
Age	–0.005	0.010	0.995	0.619
Sex (reference: male)				
Female	0.237	0.122	1.267	0.057
BMI	0.001	0.008	1.001	0.855
AOO (reference: childhood)				
Adolescence	0.009	0.180	1.009	0.960
Adulthood	0.030	0.236	1.031	0.899
YOO	0.007	0.010	1.007	0.499

β describes the effects of the respective independent variables on the dependent variable. SE, standard error; OR, odds ratio; DM2, diabetes mellitus type 2; BMI, body mass index; AOO, age of onset of obesity; YOO, years of obesity.

Postoperative Results

In the linear regression analysis, preoperative BMI had an impact on %EWL at 3, 6, and 12 months, but no impact on %TWL. Age was related to %EWL and %TWL at 12 months, with older patients showing a lower %EWL ($\beta = -0.799$, $p = 0.006$) (Table 6) and %TWL ($\beta = -0.344$, $p = 0.020$). %TWL at 3 and 6 months after surgery had no statistically significant relation with any predictor.

Regarding possible predictors of resolution of comorbidities 12 months after surgery, the odds of having a DM2 resolution were 26% more likely for females (OR 1.267, $p = 0.057$) (Table 7). Patients with adolescent AOO were 31% less likely to have joint pain resolution than patients with AOO in childhood (OR 0.697, $p = 0.019$) (Table 8).

Multiple logistic regression showed that BMI (OR 1.01, $p = 0.020$) and EOSS (OR 1.147, $p = 0.042$) were significant predictors of the risk of postoperative complications. Patients with an EOSS score >1 were 14% more likely to have postoperative complications (Table 9). With every 10 BMI points, the risk of postoperative complications grew by 10.5%. The median length of hospital stay after obesity surgery was 6 days. Patients who underwent RYGB had

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Table 8. Logistic regression analysis between resolution of joint pain 12 months after obesity surgery and predictor variables

	Estimate, *β*	SE	OR	*p*
Intercept	0.602	0.426	1.825	0.162
Age	0.004	0.008	1.004	0.630
Sex (reference: male)				
Female	–0.091	0.109	0.913	0.406
BMI	0.009	0.007	1.009	0.210
AOO (reference: childhood)				
Adolescence	–0.362	0.151	0.697	0.019
Adulthood	–0.281	0.196	0.755	0.156
YOO	–0.011	0.009	0.989	0.242

β describes the effects of the respective independent variables on the dependent variable. BMI, body mass index; AOO, age of onset of obesity; YOO, years of obesity.

Table 9. Logistic regression analysis investigating the association of risk of complications and predictor variables after obesity surgery

	Estimate, *β*	SE	OR	*p*
Intercept	–0.537	0.257	0.585	0.038
Number of preoperative comorbidities	–0.008	0.021	0.992	0.703
RYGB (reference: LSG)	0.082	0.068	1.085	0.229
AOO (reference: childhood)				
Adolescence	0.032	0.090	1.033	0.722
Adulthood	0.029	0.121	1.029	0.813
EOSS score	0.137	0.067	1.147	0.042
Age	0.001	0.005	1.001	0.890
Sex (reference: male)				
Female	0.054	0.060	1.055	0.369
BMI	0.010	0.004	1.010	0.020
YOO	–0.004	0.005	0.996	0.465

β describes the effects of the respective independent variables on the dependent variable. SE, standard error; OR, odds ratio; RYGB, Roux-en-Y gastric bypass; LSG, laparoscopic sleeve gastrectomy; BMI, body mass index; AOO age of onset of obesity; YOO, years of obesity; EOSS, Edmonton obesity staging system.

66% lower odds of staying at least 7 days after surgery than those who underwent LSG (OR 0.660, $p < 0.001$). Patients with a higher EOSS score (OR 1.175, $p = 0.022$) had an 18% higher risk of a longer hospital stay, while older patients (OR 1.016, $p = 0.019$) had a greater probability of a longer hospital stay by 2% when age increased by 1 year.

Discussion

Age and BMI were found to be major predictors of %EWL 12 months after obesity surgery. Patients with older age and greater BMI had a higher number of preoperative comorbidities and a higher risk of having an EOSS score ≥2. A greater BMI and higher EOSS score were positive predictors of postoperative complications. High BMI patients had a lower %EWL at 3, 6, and 12 months after obesity surgery. Older patients had a lower %TWL than younger patients 12 months after surgery. Patients with AOO before adulthood were more likely to have an EOSS score ≥2 and patients with AOO in adolescence were less likely to have joint pain resolution. YOO had no influence on patients' outcomes after obesity surgery.

Older age and greater BMI were also major predictors of preoperative comorbidities and %EWL at 3, 6, and 12 months after surgery. Age was a predictor of %TWL at 12 months after surgery. Other studies also found that patients with BMI >50 had greater weight loss [23, 24]. Although a high BMI normally correlates with higher %EWL reduction, some studies have found older age and greater BMI to be negative predictors of %EWL [25–28]. Findings on the influence of gender on weight loss are controversial. Some studies have found greater weight loss in women [26–28], others in men [29], and others found no gender differences [24, 25]. This study indicated that women had lower weight loss than men during the first 6 months after surgery. Patients with a low BMI had more reflux than those with a greater BMI. A study by Lagergren et al. [30] showed that those with overweight or obesity had an adjusted OR of 0.99 for reflux and they found no association between obesity and reflux. In contrast, other studies found reflux to be persistent in patients with a BMI >35, concluding that overweight and obesity are directly associated to the risk of reflux [31, 32].

There is limited evidence on the influence of the onset and/or duration of obesity [33–35]. Some studies have found that an early onset and long duration of obesity attribute to a higher risk of obesity-related diseases. Stenholm et al. [33] reported an increased risk of walking limitation associated with an increased duration of self-reported recalled obesity after adjusting for education, smoking, alcohol, and chronic diseases. Sakurai et al. [35] found the duration of obesity, either ordinary or extreme, was associated with a significantly higher risk of non-insulin-dependent diabetes mellitus compared with no obesity, independent of other factors. In our study, there was no influence of AOO or YOO on the success and risks of obesity surgery. This means that obesity surgery can be successfully performed independently of the duration or onset of obesity.

Recent evidence suggests that obesity-related comorbidities, such as DM2, may be reversible with an EOSS score ≤2. The EOSS may be an important tool to redefine indications for obesity surgery [36]. Stroud et al. [37] concluded that, while not every adolescent will benefit from obesity surgery, their model indicates that RYGB performed in adolescence improves quality-adjusted life expectancy compared with delayed surgery. As our patients with an earlier onset of obesity had a higher EOSS score, adequate treatment in the form of obesity surgery was not to be delayed. Outcome variables such as quality of life and comorbidities are encompassed in the EOSS tool and provide an overview of pre- and postoperative condition. A correlation between early onset of obesity and high EOSS score was found in this study. Due to its importance as a tool, EOSS should be taken into account, not only in the selection of patients and operative planning for bariatric surgery but also when analyzing the efficacy of the surgery.

As other publications state, RYGB and LSG are safe and effective surgeries for the treatment of obesity [38–41]. In our study, RYGB and LSG were both found to be safe and effective, with a notable %EWL 12 months postoperatively (%EWL: 69.5 for RYGB and 62 for LSG) and resolution of comorbidities. Patients who underwent RYGB had a higher mean %EWL 12 months after surgery than those who underwent LSG. However, this is limited evidence as this was not a randomized trial. Results available in the literature show a wide range of %EWL 12 months after surgery, i.e., 45–86%, according to different study designs and inclusion criteria [38–41]. Multicenter randomized trials such as the ongoing BariSurg trial will result in better evidence for the comparison of LSG and RYGB [42].

Sugerman et al. [43] reported that hypertension and DM2 are associated with age in severely obese patients, stating that RYGB is an effective surgery for DM2 and hypertension resolution. The patients in their study that had an adequate %EWL were more likely to have remission of obesity-related comorbidities. Iacobellis et al. [44] found no significant gender differences but concluded that age is the most significant preoperative predictor of DM2 remission. Hamza et al. [45] found %EWL and younger age to be predictors of DM2 resolution after bariatric surgery. They stated that each additional 12 years of age lower the probability of DM2 remission by 20% after RYGB. We found a better DM2 resolution 12 months after surgery in women than in men, but age was not a significant preoperative predictor of DM2 resolution. Benaiges et al. [46] and Flores et al. [47] agreed that the only independent predictor of hypertension resolution after obesity surgery is the number of antihypertensive drugs used preoperatively. In our study, there was no significant influence of any variable for the resolution of hypertension. We showed that there was a significant reduction of joint pain 12 months after obesity surgery, mainly in patients with AOO as an adolescent. In other studies [48], 12 months after obesity surgery, joint pain was resolved in >65% of patients, no matter which surgery was performed, although the duration and onset of obesity were not evaluated. Vincent et al. [49] concluded that obesity procedures show a promising relief of joint pain.

Numerous studies have shown that complications in obesity surgery are associated with a variety of factors: older age [50–54], surgical-team experience [55–57], greater BMI [54–58] and body weight [57], insufficient preoperative weight loss [59, 60], and obesity-related comorbidities [52, 54, 55]. Chiappetta et al. [61] prospectively analyzed patients' preoperative EOSS score to predict if EOSS is useful for obesity surgery outcomes and concluded that patients with a score ≥3 have a higher risk of postoperative complications. In our series, only 2 factors were independent predictors of complications after surgery. Patients with a greater BMI and a higher EOSS score had a higher risk of complications. Older age was not independently associated with the risk of complications. With a median hospital stay of 6 days, RYGB patients had a shorter stay than patients with LSG. However, it must be stated this could have been an effect caused by the learning curve of the surgical team in the early LSGs performed, and involved complications associated with a prolonged hospital stay and involved a more cautious discharge policy [62].

In conclusion, our study demonstrated the importance of BMI and age as predictors of weight loss after obesity surgery. Furthermore, a higher EOSS score and greater BMI were predictive of a risk of complications. Success and risks of obesity surgery were independent of the duration of obesity and AOO, but AOO in adolescence had an influence on joint pain resolution and an EOSS score ≥2 had an association with the risk of complications. Therefore, obesity surgery should be performed as early as possible, to avoid the risk of unnecessary complications which increases along with higher EOSS score and greater BMI. Earlier surgery also provides the best option for weight loss and the resolution of comorbidities.

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Statement of Ethics

Ethical approval was obtained from the local ethics committee at Heidelberg University (S-181/2009, S-618/2011, S-500/2012 and S-629/2013).

Disclosure Statement

The authors have no conflicts of interest to declare.

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Author Contributions

All of the authors contributed according to the ICMJE criteria for authorship, i.e., substantial contributions to the conception, acquisition, analysis, and interpretation of data; drafting the work and revising it critically for important intellectual content; final approval of the version to be published; and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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