

Long-Term Weight Loss Outcome of Laparoscopic Sleeve Gastrectomy Predicted by the Percentage of Excess Weight Loss at 6 Months in Chinese Patients with Body Mass Index ≥ 32.5 Kg/m²

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Purpose: To evaluate the predictive effect of the initial weight loss on the long-term weight loss in Chinese patients with a body mass index (BMI) ≥ 32.5 kg/m² who underwent LSG.

Patients and Methods: The follow-up was completed via phone or WeChat for outpatients and at the hospital for inpatients. We evaluated the BMI, percentage of excess weight loss (%EWL), and type 2 diabetes mellitus, hypertension, and hyperlipidemia statuses. Linear and logistic regression analyses were performed on the relationship between the initial and long-term weight loss. The optimal cut-off value was determined by receiver operating characteristic (ROC) curve analysis.

Results: We enrolled 307 patients, with a median preoperative BMI of 39.68 (35.68, 45.47) kg/m². %EWL $\geq 50\%$ was regarded as successful weight loss, and 76.55% of the patients lost their weight successfully. (Reviewer #1, comment #4) %EWL at 6 months and 5 years were positively correlated ($P < 0.001$). Further, the following linear equation could express the relationship: (%EWL_{5 years} = 29.193 + 0.526 × %EWL_{6 months}). %EWL $\geq 58.57\%$ at 6 months was the best predictor of successful weight loss at 5 years after LSG (Reviewer #1, comment #5) (sensitivity, 73.62%; specificity, 73.61%; AUC value, 0.780). Internal verification of the prediction model revealed satisfactory results in terms of discrimination and calibration.

Conclusion: In Chinese patients with BMI ≥ 32.5 kg/m² who underwent LSG, %EWL at 6 months and 5 years were correlated. %EWL $\geq 58.57\%$ at 6 months was a predictor of successful long-term weight loss.

Keywords: laparoscopic sleeve gastrectomy, obesity, weight loss, prognosis

Introduction

The global prevalence of obesity has doubled over the past 50 years. Approximately one-third of the world's population is currently obese or overweight.¹ In China, nearly half of the adults are overweight or obese.² Obesity can seriously damage physiological functions, be life-threatening, pose a significant threat to public health, and be a tremendous burden on national healthcare finances.^{3–6}

Laparoscopic sleeve gastrectomy (LSG) is currently the most widely performed bariatric procedure worldwide.⁷ Of all bariatric procedures, LSG increased in proportion from 9.3% in 2010 to 58.2% in 2014.^{7–9} In 2020, the annual report of the Greater China Metabolic and Bariatric Surgery Database showed that LSG accounted for 84.88% of all bariatric procedures.¹⁰ According to Western reports, the percentage of excess weight loss (%EWL) is 53.25% at 5 years after LSG. In Asia, however, the %EWL at 5 years after LSG ranges widely from 19.5% to 64.2%.^{11–13} Although these data suggest that LSG is effective, results from China may vary.

Preoperative variables affecting postoperative weight loss include stress, social support, age, sex, preoperative body mass index (BMI), and diabetes status.^{14–16} Early postoperative weight loss indicators, such as %EWL, are used to predict weight loss at 2–3 years.^{17–20} Our previous study reported long-term efficacy prediction of LSG for morbid obesity in the Chinese population.^{21,22} However, it did not verify the predictive effect of the model regarding weight loss success/failure or establish a linear prediction model for long-term %EWL. Chinese guidelines recommend LSG for patients with BMI ≥ 32.5 kg/m². Therefore, a large-scale study on weight loss prediction after LSG in these patients is warranted for the development of bariatric procedures in China. Early prediction of the failure to achieve the expected weight loss would help indicate more behavioral and medical interventions for maintaining weight loss over time and improving patient satisfaction with the procedure.

The aim of the present study was to evaluate the predictive effect of the initial weight loss on the long-term weight loss in Chinese patients with BMI ≥ 32.5 kg/m² who underwent LSG. This study explored the relationship between early weight loss indicators after LSG and cure rates of comorbidities associated with obesity. Further, a linear prediction model was established to predict %EWL after LSG, thus predicting the success and other outcomes of LSG.

Materials and Methods

Inclusion and Exclusion Criteria

In this retrospective study, (Reviewer #1, comment #3, 7; Reviewer #2, comment #4) we enrolled 307 patients who underwent LSG at our center from October 2006 to April 2017. Inclusion and exclusion criteria were selected from the 2019 Chinese Guidelines for Surgical Treatment of Obesity and Type 2 Diabetes Mellitus.²³ Inclusion criteria were: (1) treatment of obesity with LSG; (2) preoperative BMI ≥ 32.5 kg/m²; (3) Chinese residence. Exclusion criteria were: (1) lack of 5-year postoperative follow-up results; and (2) comorbidities, such as cancer and psychiatric disorders, during the 5-year follow-up period. The Ethics Review Board of Capital Medical University Affiliated Beijing Shijitan Hospital approved the study protocol (No. 2019-A24). All participants provided informed consent for participation in the study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments or comparable ethical standards (Ethical/Copyright Corrections).

BMI ≤ 23 kg/m² was considered normal BMI, based on the characteristics of the Chinese population.^{17,24–26} The diagnostic criteria and curative outcome were defined for comorbidities, including T2DM, hypertension, hyperlipidemia, nausea and vomiting, functional dyspepsia, emaciation, and alopecia, based on previous reports.^{21,22} Postoperative % EWL $\geq 50\%$ was regarded as successful weight loss which is the most widely used and recognized by many researchers.^{21,22} (Reviewer #2, comment #2) The long-term weight loss outcome was defined as the weight loss outcome at 5 years postoperatively.

Surgical Approach and Postoperative Follow-Up

The surgical approach and postoperative follow-up were described in our previous studies.^{21,22} Three surgeons performed all LSG procedures in enrolled patients using a standardized approach. Patients adopted a reverse Trendelenburg and left-side up position with their legs separated to form an “A” shape. The gastric greater curvature was fully dissociated from approximately 3 cm above the gastric pylorus to the His angle and a 32 Fr Bougie tube was placed into the stomach from the mouth. After this tip of the tube was across the pylorus, the placement of 60-mm endoscopic staples was conducted. The gastric antrum was incised using cartridges attached to the Bougie tube, and the gastric tissue was gradually separated from about 3 cm above the pylorus to the angle of His, with the entirety of the gastric fundus being excised. Approximately, 1 cm of stomach tissue was preserved in the His angle to reduce the incidence of gastroesophageal reflux disease. Drainage tube not routinely placed after surgery. Absorbable 2–0 sutures were used to close all fascial defects.

Upper gastrointestinal contrast studies were conducted postoperatively on day 1–3. When no abnormalities were detected, patients were allowed to freely consume water and were given a liquid diet. The patients can be discharged without any symptoms such as vomiting. All patients were given appropriate amounts of micronutrients and vitamin

supplements after surgery. (Reviewer #1, comment #8) The follow-up was completed via phone or WeChat for outpatients and at the hospital for inpatients. Follow-up at 3, 6, 12, 36 and 60 months after LSG to assess various physiological parameters of the patients (Reviewer #1, comment #1).

Statistical Analysis

Categorical variables were compared using the chi-square or Fisher's exact test, as applicable. The Kolmogorov–Smirnov test was performed for measurement data. Normally distributed data are expressed as mean \pm standard deviation, while non-normally distributed are expressed as median (interquartile range). The independent-samples *t*-test and the nonparametric test were performed for comparisons of normally and non-normally distributed data, respectively. The linear regression and binary logistic regression analysis were performed for the relationship between the initial and 5-year weight loss. The receiver operating characteristic (ROC) curve was used to determine the optimal cutoff values for the initial weight loss indicators. A two-sided *P*-value < 0.05 was set as statistical significance. ROC curves were drawn using MedCalc version 19.2.6 (MedCalc, Inc., Mariakerke, Belgium). Histograms were plotted using GraphPad Prism version 8.4.3 (GraphPad Software, San Diego, CA, USA). Calibration curve was drawn using the *pcmalplot* package of StataSE version 16 (64-bit) software. All other statistical analyses were performed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA).

Results

396 patients underwent LSG between October 2006 and April 2017. However, 89 patients lacked a 5-year follow-up and 307 patients met the inclusion criteria. Finally, the 307 patients were enrolled in this study, including (Reviewer #2, comment #3) 112 (36.48%) men and 195 (63.52%) women, with a median (Reviewer #2, comment #3) age of 31 (25, 37) years old. The preoperative BMI was 39.68 (35.68, 45.47) kg/m². [Table 1](#) presents the preoperative patient characteristics. [Table 2](#) shows the operation-related indicators.

None of the patients developed serious postoperative complications, such as death, fistula, stenosis, or bleeding. [Table 3](#) shows the above-mentioned complications and the incidences of postoperative nausea and vomiting, emaciation, hypoproteinemia, anemia, alopecia, functional dyspepsia, hypoglycemia, gallstones, hypotension, hypocalcemia, iron deficiency, hypomagnesemia, folic acid deficiency, vitamin B₁₂ (VitB₁₂) deficiency, and other rare complication. All complications subsided after symptomatic treatment, and none of them seriously impacted the patient's life.

The preoperative and 3- and 6-month and 1-, 2-, 3-, 4-, and 5-year postoperative BMIs were 39.68 (35.68, 45.47), 32.72 (29.04, 37.40), 29.00 (25.78, 33.28), 27.68 (24.74, 31.33), 28.18 (25.62, 31.99), 28.13 (25.86, 32.47), 28.58 (26.23, 32.70), and 29.05 (25.95, 33.14) kg/m², respectively. The %EWLs at 3 and 6 months and 1, 2, 3, 4, and 5 years were 41.11 (34.07, 54.14), 63.88 (51.97, 80.75), 69.37 (56.22, 87.91), 68.03 (53.27, 82.71), 66.46 (53.61, 81.91), 64.82 (53.14, 78.59), and 60.27 (50.79, 79.65), respectively. [Figure 1](#) illustrates the trends in the BMI and %EWL over time. Successful weight loss at 5 years was achieved in 235 (76.55%) patients. The weight loss per capita had gradually stabilized at 1 year. The body weight lost at 5 years was 33.09 (0–81) kg. Successful weight loss was not achieved in 72 (23.45%) patients. [Table 4](#) shows a comparison of the baseline data between weight loss success and failure groups. Preoperative BMI and PCOS prevalence significantly differed between the two groups. Considering that PCOS only affects women, it was not included as a independent variable in the logistic regression analysis. The binary logistic regression analysis showed that only %EWL at 6 months was a significant independent variable. [Table 5](#) shows the results of the predictive analysis performed for %EWL at 3 and 6 months.

The linear regression model developed using %EWL at 5 years as the dependent variable and %EWL at 6 months as the independent variable showed a significant positive correlation between %EWL at 5 years and 6 months ($P < 0.001$; $r^2 = 0.247$). [Figure 2](#) shows the histograms and probability–probability plots of standardized residuals. The following linear equation explained the relationship between the long-term postoperative weight loss and %EWL at 6 months:

$$\%EWL_{5 \text{ years}} = 29.193 + 0.526 \times \%EWL_{6 \text{ months}}$$

Table 1 The Preoperative Patients' Characteristics

Variable	Value
Age (years)	31 (25, 37) ^a
Gender	
Female (%)	112 (36.48%) ^b
Male (%)	195 (63.52%)
The ethnic	
Han (%)	274 (89.25%)
Other ethnics (%)	33 (10.75%)
Residence	
Urban (%)	237 (77.20%)
Rural (%)	70 (22.80%)
North & South	
North (%)	29 (9.45%)
South (%)	278 (90.55%)
Preoperative BMI (kg/m ²)	39.68 (35.68, 45.47)
T2DM (%)	147 (47.88%)
Hypertension (%)	94 (30.62%)
Hyperlipidemia (%)	177 (57.65%)
Hyperuricemia (%)	242 (78.83%)
Fatty liver (%)	296 (96.42%)
OSA (%)	301 (98.05%)
PCOS (%)	79 (40.51%)

Notes: ^aMedian (upper and lower quartiles). ^bNo.(%).

Abbreviations: BMI, body mass index; T2DM, type 2 diabetes mellitus; OSA, obstructive sleep apnea; PCOS, polycystic ovary syndrome.

Table 2 Operation-Related Indicators

Variable	Value
Operation time (min)	80 (60, 100) ^a
Intraoperative bleeding volume (mL)	20 (10, 50)
Hospital stay (day)	3 (2, 4)
Expense (¥)	68,725.28 ± 17,583.21 ^b
Time to first liquid intake (day)	2 (2, 2)

Notes: ^aMedian (upper and lower quartiles). ^bMean ± SD. ¥ is Chinese currency symbol.

Table 3 The Incidence of Postoperative Complications

Variable	Value
Mortality	0 (0.00) ^a
Anastomotic fistula	0 (0.00)
Hemorrhage	0 (0.00)
Anastomotic stenosis	0 (0.00)
Nausea and vomiting	92 (29.97%)
Emaciation	2 (0.65%)
Hypoproteinemia	15 (4.89%)
Anemia	6 (1.95%)
Alopecia	107 (34.85%)
Functional dyspepsia	29 (9.45%)
Hypoglycemia	12 (3.91%)
Gallstones	29 (9.45%)
Hypotension	7 (2.23%)
Hypocalcemia	15 (4.89%)
Iron deficiency	13 (4.23%)
Hypomagnesemia	0 (0.00)
Folic acid deficiency	11 (3.58%)
VitB ₁₂ deficiency	5 (1.67%)
Other rare complications	10 (3.26%)

Note: ^aNo.(%).

Weight loss success at 5 years was the categorical variable, and %EWL at 6 months was the variable used to plot the ROC curves. **Figure 3** shows the result. The optimal cutoff %EWL at 6 months for predicting the weight loss outcome at 5 years was 58.57% (area under the ROC curve, 0.780 (95% confidence interval: 0.730~0.825); sensitivity, 73.62%; specificity, 73.61%; $P < 0.001$).

At 3 years, the ROC curve analysis revealed that the optimal cutoff %EWL at 6 months for predicting the weight loss outcome was 58.57%. The sensitivity was 74.09%, specificity was 85.00% and the AUC value was 0.829. At 4 years, the ROC curve analysis revealed that the optimal cutoff %EWL at 6 months for predicting the weight loss outcome was 58.57%. The sensitivity was 73.14%, specificity was 76.92% and the AUC value was 0.766 (Reviewer #1, comment #17).

Among patients with %EWL $\geq 58.57\%$ at 6 months, the mean %EWLs at 3 and 6 months and 1, 2, 3, 4, and 5 years were 51.80%, 78.42%, 82.96%, 77.60%, 75.94%, 73.29%, and 71.93%, respectively. Among patients with %EWL $< 58.57\%$ at 6 months, the mean %EWLs at 3 and 6 months and 1, 2, 3, 4, and 5 years were 32.98%, 47.03%, 55.16%, 53.24%, 54.45%, 53.50%, and 51.42%, respectively. **Figure 4** shows the trends of %EWL over time in the two groups.

The patients with successful weight loss at 5 years had higher %EWL at 6 months than those with fail weight loss (67.64 [57.65, 84.54] vs 51.32 [43.67, 60.88], $P < 0.001$). Compared with the patients whose %EWL $< 58.57\%$ at 6 months, the patients with %EWL $\geq 58.57\%$ at 6 months had lower preoperative BMI (37.64 [34.87, 42.65] vs 44.09 [39.39, 51.31], $P < 0.001$) and BMI at 1 year (25.69 [23.30, 28.10] vs 32.31 [28.94, 36.77], $P < 0.001$) (Reviewer #1, comment #17).

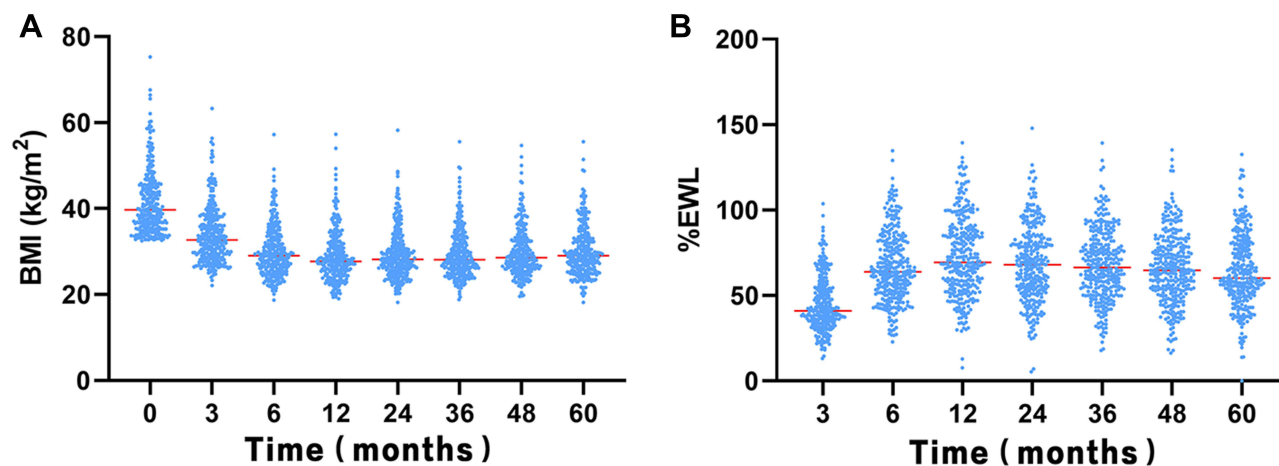


Figure 1 The trends in the BMI (A) and %EWL (B) over time.

Note: Each point in the figure represents a patient, and the red horizontal line represents the median.

Table 6 shows the remission rates of T2DM, hypertension, and hyperlipidemia at 1 year in patients with %EWL \geq 58.57% at 6 months and those with %EWL $<$ 58.57% at 6 months. The cure rate of hyperlipidemia differed significantly between the two groups ($P < 0.001$). Figure 5 shows the model's calibration curve drawn to further verify the reliability of the %EWL model at 6 months for predicting the weight loss outcome at 5 years. When the predicted probability was below 0.6, the model overestimated the weight loss success rate. In contrast, when the predicted probability was at least 0.6, the model correctly estimated the weight loss success rate. Considering that the predicted probability exceeded 0.6 in most patients, the prediction model was considered to be well-calibrated. The model showed an area under the ROC curve of 0.780, consistent with the statistical analysis results. Thus, the prediction model was well-discriminative.

Discussion

Currently, LSG is the most widely performed bariatric procedure worldwide.^{7–9} It is effective and safe in the treatment of obesity and its comorbidities.^{27–29} However, there are no studies that predict long-term weight loss using early postoperative weight loss as an indicator after LSG in Chinese population with BMI \geq 32.5 kg/m². (Reviewer #1, comment #21) In this study, %EWL at 6 months and 5 years showed a clear positive relationship. Further, %EWL \geq 58.57% at 6 months correlated with %EWL \geq 50% at 5 years. Thus, %EWL at 6 months could be used to predict the long-term weight loss success after LSG (sensitivity, 73.62%; specificity, 73.61%).

In our study, %EWL at 5 years was 60.27%, which was significantly higher than the %EWL of 19.5%–64.2% reported in other related studies from Asia.^{11–13} None of the patients developed severe complications, such as death, anastomotic leakage, bleeding, or anastomotic stenosis. However, the incidences of postoperative alopecia (34.85%) and nausea and vomiting (29.97%) were high. The follow-up examinations revealed that alopecia was transient, with onset at 3–4 months and recovery at 6–10 months without treatment. Alopecia might have resulted from rapid reduction in subcutaneous fat, dramatically changing the environment of the hair roots, which gradually adapted to the change after the weight stabilized.^{30–33} Severe nausea and vomiting were routinely treated and relieved significantly after 1–3 months of treatment. The incidences of postoperative serum albumin, calcium, iron, magnesium, folic acid, and VitB₁₂ deficiencies were low. Patients with nutrient deficiencies were effectively treated with supplementation of the deficient nutrient.^{34–37} In addition, the incidences of gallstones and functional dyspepsia were high (9.45%). Therefore, currently, we routinely perform gallbladder ultrasound before LSG at our hospital. For symptomatic gallstones, laparoscopic cholecystectomy and sleeve gastrectomy are recommended.^{38,39}

In this study, after LSG, weight loss occurred within 1 year, followed by slow weight gain, consistent with other studies.^{17–20} %EWL at 6 months as an initial weight loss indicator could predict long-term weight loss. %EWL or the percentage of total weight loss at 1–6 months could be used as an early weight loss indicator.^{17,40,41} The prediction model

Table 4 The Comparison of the Baseline Data Between Successful and Fail Weight Loss Groups at 5 Years (Reviewer #1, Comment #11)

	Successful Weight Loss Group (n=235)	Failed Weight Loss Group (n=72)	χ^2/z	P value
Age (years)	31 (25, 38) ^a	31 (26, 36)	-0.466	0.641
Gender				
Male (%)	84 (35.74%) ^b	28 (38.89%)	0.235	0.628
Female (%)	151 (64.26%)	44 (61.11%)		
The ethnic				
Han (%)	210 (89.36%)	64 (88.89%)	0.013	0.910
Other ethnics (%)	25 (10.64%)	8 (11.11%)		
Residence				
Urban (%)	185 (78.72%)	52 (72.22%)	1.323	0.250
Rural (%)	50 (21.28%)	20 (27.78%)		
North & South				
North (%)	25 (10.64%)	4 (5.56%)	1.665	0.197
South (%)	210 (89.36%)	68 (94.44%)		
Preoperative BMI (kg/m ²)	38.51 (35.26, 44.10)	43.64 (38.69, 51.24)	-4.515	0.001
T2DM (%)	115 (48.94%)	32 (44.44%)	0.446	0.504
Hypertension (%)	71 (30.21%)	23 (31.94%)	0.078	0.780
Hyperlipidemia (%)	138 (58.72%)	39 (54.17%)	0.469	0.494
Hyperuricemia (%)	182 (77.45%)	60 (83.33%)	1.144	0.285
Fatty liver (%)	225 (95.74%)	71 (98.61%)	-	0.468
OSA (%)	229 (97.45%)	72 (100%)	-	0.342
PCOS (%)	52 (34.44%)	27 (61.36%)	10.25	0.001

Notes: ^aMedian (upper and lower quartiles). ^bNo.(%). χ^2/z is represented the result of the chi-square test, the larger the value, the smaller the p-value, the better the significance. Significant differences in preoperative BMI and PCOS between successful and fail weight loss groups.

Table 5 Logistic Regression Analysis of Factors for Successful Weight Loss (Reviewer #1, Comment # 15, 16)

	OR (95% CI)	P value
Preoperative BMI (kg/m ²)	0.982 (0.941, 1.024) ^a	0.397
%EWL at 3 months	1.022 (0.985, 1.060)	0.243
%EWL at 6 months	1.051 (1.022, 1.081)	0.001

Notes: ^aMedian (upper and lower quartiles). %EWL at 6 months used to predict the long-term weight loss was significantly different from preoperative BMI and %EWL at 3 months.

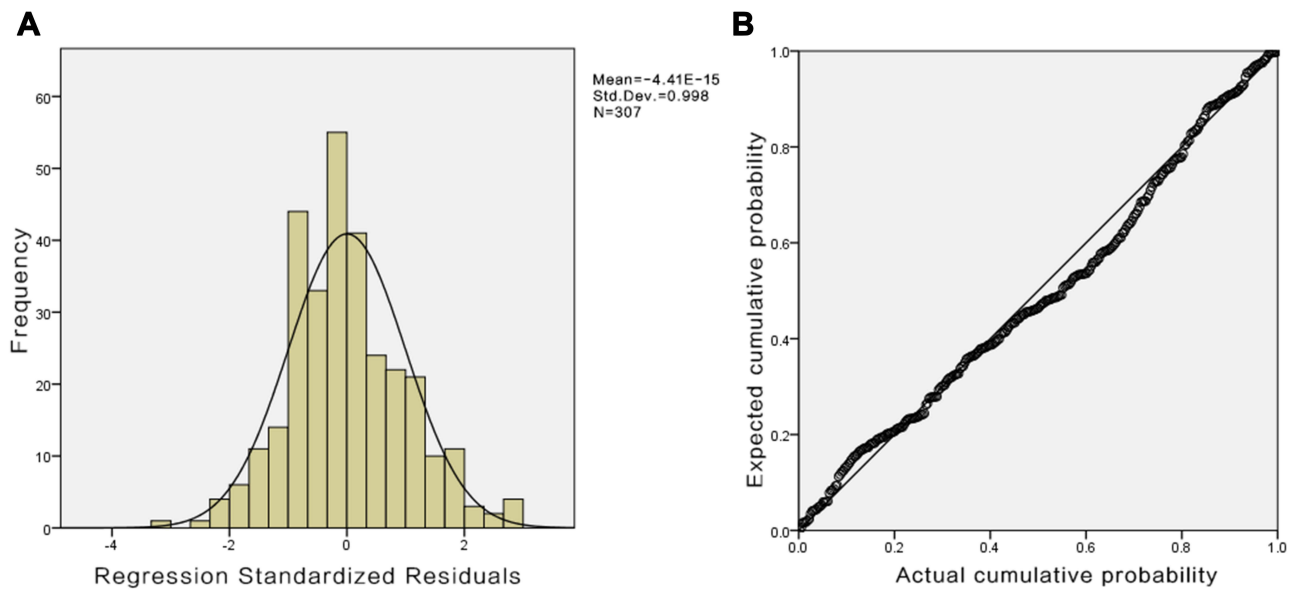


Figure 2 The histograms (A) and probability–probability plots (B) of standardized residuals for %EWL at 5 years.

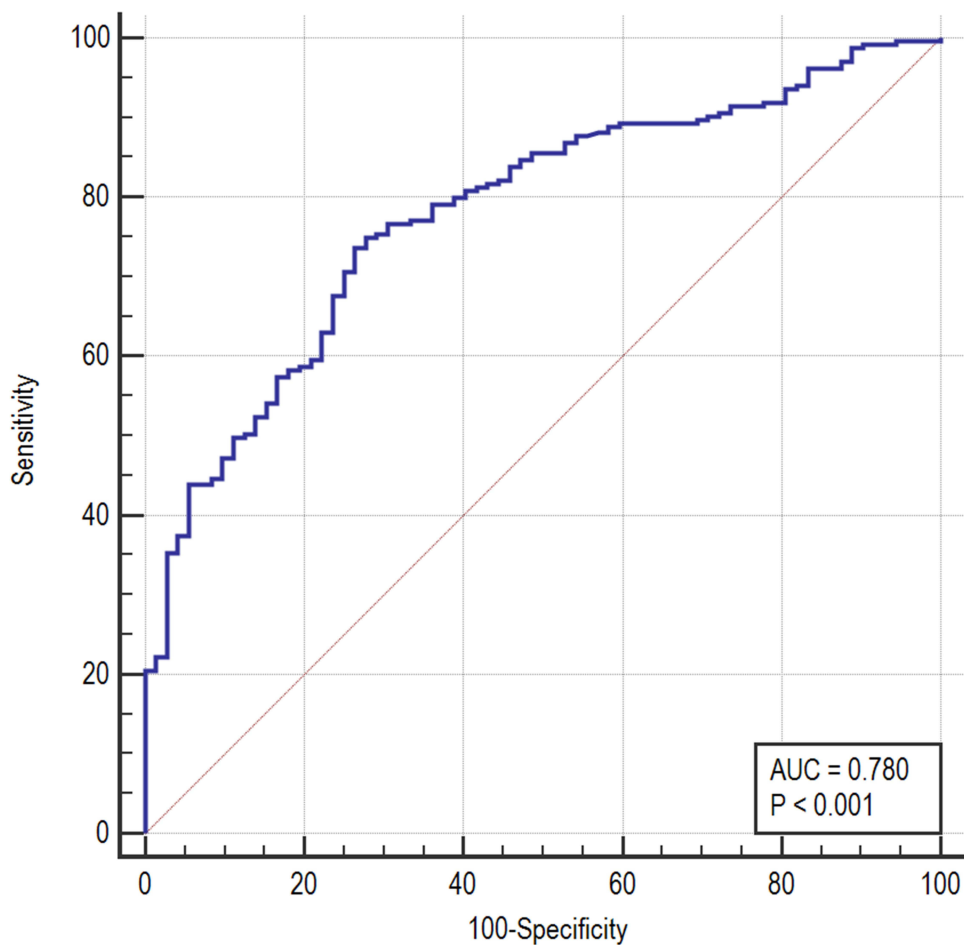


Figure 3 ROC curve of %EWL at 6 months among patients with successful %EWL at 5 years after LSG.

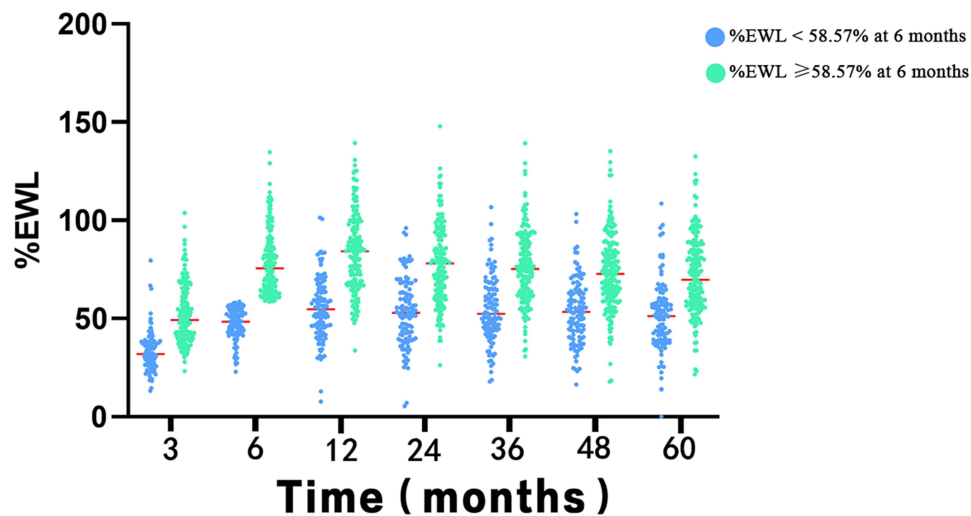


Figure 4 Change in the mean %EWL among patients who achieved 58.57% EWL at 6 months compared to patients who did not.

was more time-efficient when %EWL at 3 months was used to predict the long-term weight loss outcome. %EWL at 3 months was not a significant independent variable in the logistic regression analysis of risk factors for weight loss failure. In addition, %EWL at 3 months and 5 years were positively correlated ($r^2 = 0.165$, $P < 0.001$). However, the coefficient of determination of the linear regression model was low. We finally selected %EWL at 6 months as an early weight loss indicator and used it to predict the long-term weight loss outcome.

The ROC curve analysis revealed that the optimal cutoff %EWL at 6 months for predicting the weight loss outcome at 5 years was 58.57%, with a sensitivity and a specificity of 73.62% and 73.61%, respectively. %EWL at 6 months was significantly higher in patients with successful weight loss at 5 years than in those without (67.64 [57.65, 84.54] vs 51.32 [43.67, 60.88], $P < 0.001$). The reliability of the optimal cutoff %EWL at 6 months of 58.57% was supported by the value being between the medians of the two groups in addition to the high sensitivity and specificity in the ROC curve. The patients were divided into two groups based on %EWL at 6 months: $\geq 58.57\%$ and $< 58.57\%$ groups. The preoperative BMI was compared between the two groups. We found that the preoperative BMI in patients with %EWL $\geq 58.57\%$ at 6 months was significantly lower than in those with %EWL $< 58.57\%$ at 6 months (37.64 [34.87, 42.65] vs 44.09 [39.39, 51.31], $P < 0.001$), in line with the significant difference in preoperative BMI between the long-term weight loss success and failure groups.

Patients seek bariatric surgeries to not only lose weight but also cure comorbidities associated with obesity, such as T2DM, hypertension, hyperlipidemia, and hyperuricemia. In this study, the early postoperative weight loss outcome was positively correlated with the cure rate of hyperlipidemia but not of T2DM or hypertension, unlike previous report.¹⁷ (Reviewer #1, comment #22). The outcomes of T2DM and hypertension were inconsistent with other studies and the reasons are listed as follows. First, patients undergoing LSG are subjected to diet restrictions that do not allow an oral glucose tolerance test to be performed after LSG. Therefore, in this and previous studies, HbA1c $\geq 6.0\%$ was set as the

Table 6 Cure Rates of Major Comorbidities in Patients with %EWL $\geq 58.57\%$ and $< 58.57\%$ at 6 Months

	T2DM (n=147)		Hypertension (n=94)		Hyperlipidemia (n=177)	
	Cured	Not Cured	Cured	Not Cured	Cured	Not Cured
%EWL $< 58.57\%$ at 6 months	38 (90.48%) ^a	4 (9.52%)	35 (83.33%)	7 (16.67%)	35 (53.03%)	31 (46.97%)
%EWL $\geq 58.57\%$ at 6 months	56 (90.32%)	6 (9.68%)	47 (90.38%)	5 (11.90%)	86 (77.48%)	25 (22.52%)
P	1.000		0.308		0.001	

Notes: ^aNo.(%). There was a significant difference in cure rates for hyperlipidemia in patients with %EWL $\geq 58.57\%$ and $< 58.57\%$ at 6 months.

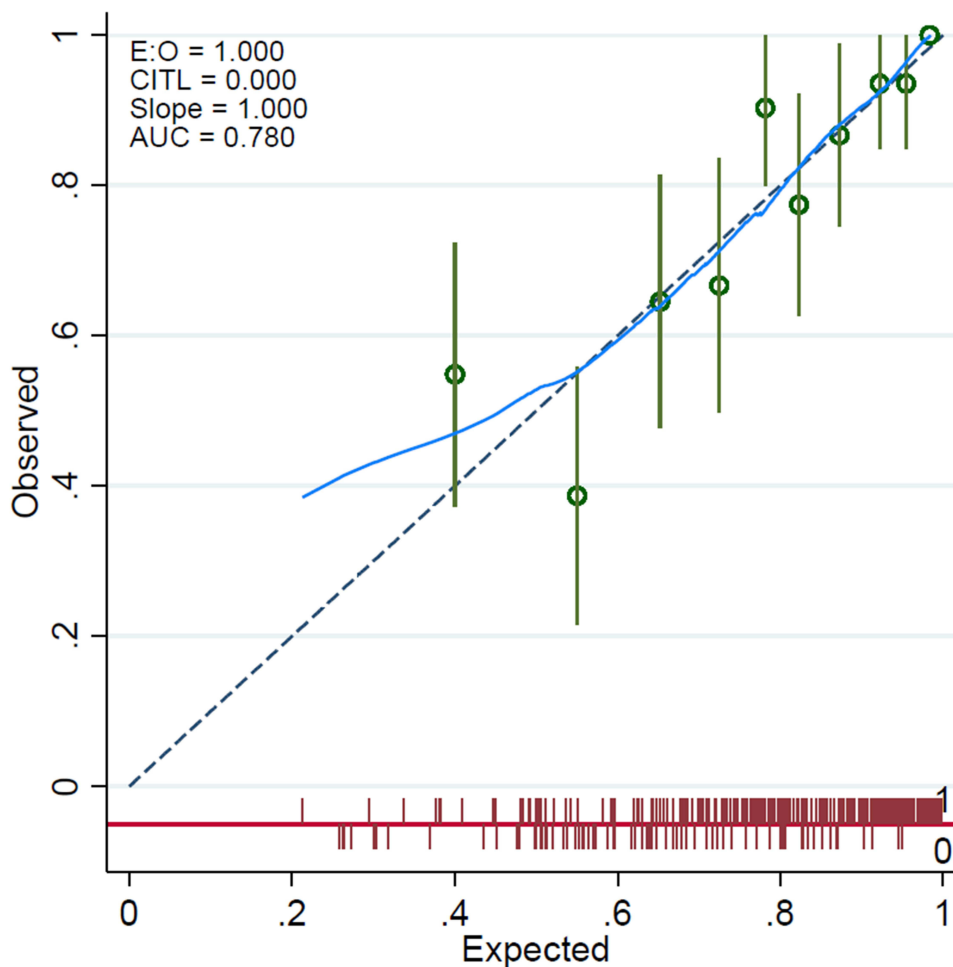


Figure 5 Calibration curve for %EWL at 6 months to predict weight loss at 5 years.

diagnostic criterion for T2DM assessed after LSG.¹⁷ However, HbA1c does not reflect the actual T2DM status. Second, in this study, patients with preoperative T2DM had a follow-up completion rate of 70.75% for T2DM-related indicators at 1 year after LSG, thus reducing the reliability of the results. Third, T2DM is more difficult to cure in patients with low preoperative BMI, who tend to lose more weight in the early postoperative period.^{42,43} Therefore, the conclusions of previous studies may need further verification. Finally, although patients with preoperative hypertension completed the follow-up via telephone or WeChat, self-reports may not yield accurate results. The cure rate of hypertension was higher in patients with %EWL \geq 58.57% at 6 months than in those with %EWL $<$ 58.57%, although without statistical significance (90.38% vs 80.33%, $P = 0.308$). This result may be attributable to the small sample size. Consistent with previous studies, the cure rate of hyperlipidemia was associated with the early postoperative weight loss outcome. BMI at 1 year was significantly lower in patients with %EWL \geq 58.57% at 6 months than in those with %EWL $<$ 58.57% at 6 months (25.69 [23.30, 28.10] vs 32.31 [28.94, 36.77], $P < 0.001$). This result may underlie association between the weight loss outcome at 6 months and the cure rate of hyperlipidemia at 1 year. Taken together, the early postoperative weight loss outcome might be associated with the cure rate of hyperlipidemia, but its association with the cure rates of T2DM and hypertension requires further investigations.

In this study, 23.45% of patients showed weight loss failure 5 years after LSG. These patients should actively seek other weight loss methods, such as Chinese medicine, acupuncture and so on. Early detection of patients who might fail long-term weight loss was of great significance to bariatric surgeons and patients. According to the results of this study, %EWL $<$ 58.57% at 6 months was predictive of unsatisfactory long-term weight loss after LSG. Therefore, it was

necessary to recommend that patients changed their expectations and actively sought other weight loss methods, which was of great significance for increasing their satisfaction with operation. In fact, factors influencing the weight loss outcome after LSG include lifestyle, dietary habits, exercise, stress, social situation, and financial support.^{14–16,44–47} Therefore, patients who could not achieve the desired early postoperative weight loss outcome, should make appropriate exercise, diet, and lifestyle changes to maintain the weight loss achieved by LSG in the long term. In addition, surgeons should pay more attention to these patients and help them eliminate factors not conducive to postoperative weight loss, including inappropriate postoperative diet and exercise habits. This will maximize the long-term weight loss success rates.

This study has some limitations. First, this was a retrospective study, making it prone to recall bias. (Reviewer #1, comment #7) Second, when evaluating the relationship between early postoperative weight loss indicators and the cure rate of comorbidities associated with obesity, although we included T2DM, hypertension, and hyperlipidemia statuses at 1 year, other common comorbidities that patients seek LSG for, including PCOS, OSA, or hyperuricemia, were excluded because of the difficulty in accurate follow-ups of these comorbidities. Future research should clarify the relationship between the early postoperative weight loss outcome and the long-term postoperative cure rate of various comorbidities associated with obesity. In our study, the patients' body weight reached the lowest measurement at 1 year and tended to stabilize or increase slightly thereafter. Therefore, we can speculate that comorbidities associated with obesity also stabilized at 1 year. Finally, this study lacked external validation of large randomised controlled trials. In order to make up for the defects, we performed internal verification. Internal verification of the prediction model revealed satisfactory results in terms of discrimination and calibration. The sample size for this study included 307 patients, who underwent a complete 5-year follow-up. This sample size and follow-up duration will be sufficient for the Chinese population because bariatric procedures are still new, and the credibility of the findings is also relatively high.

Conclusion

In this study involving Chinese patients with BMI ≥ 32.5 kg/m² who underwent LSG, %EWL at 6 months and 5 years were positively correlated. %EWL $\geq 58.57\%$ at 6 months was a predictor of weight loss success at 5 years, with a sensitivity and a specificity of 73.62% and 73.61%, respectively. High preoperative BMI was a risk factor for long-term postoperative weight loss failure.

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Disclosure

The authors declare that they have no conflicts of interest.

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