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ORIGINAL CONTRIBUTIONS

# Early Weight Loss after Laparoscopic Sleeve Gastrectomy Predicts Sustained Weight Maintenance Among Chinese Individuals with a BMI < 35 kg/m$^2$

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## Abstract

**Objectives** This study assessed the efficacy and safety of laparoscopic sleeve gastrectomy (LSG) in Chinese individuals with a body mass index (BMI) under 35 kg/m$^2$ and to explore the association between early weight loss and sustained weight maintenance.

**Methods** Patients whose BMI < 35 kg/m$^2$ were recruited. Changes in BMI, total weight loss (%TWL), and excess weight loss (%EWL) were evaluated, with successful weight loss being a %EWL of > 50% and a %TWL of > 25%. Binary logistic regression was employed to assess relationships between %EWL and %TWL and to calculate a joint predictor. The association between early weight loss and sustained weight maintenance was assessed as a function of %EWL, %TWL, and this joint predictor, with receiver operating characteristic (ROC) curves being used for optimal cutoff threshold identification.

**Results** In total, 143 individuals with average preoperative weight and BMI values of 88 (82, 95) kg and 31.99 (29.41, 33.15) kg/m$^2$, respectively, were enrolled in present study. At 5 years, 48.00% of patients achieved successful weight loss. Both 3-month %EWL and %TWL were significantly related to sustained weight loss at 5 years ($P < 0.05$). ROC curves were used to identify %TWL of 19.54% at 3 months as the most reliable predictor of weight loss at a 5-year follow-up (sensitivity: 61.11%, specificity: 76.92%).

**Conclusion** LSG had long-term safety and efficacy, and %TWL at 3 months can predict sustained 5-year weight loss in Chinese individuals with BMI < 35 kg/m$^2$.

**Keywords** Laparoscopic sleeve gastrectomy · Obesity-related comorbidities · Early weight loss · Sustained weight maintenance · Chinese

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## Introduction

Obesity rates have risen rapidly throughout the world over recent decades, affecting all age groups and contributing to a higher incidence of serious comorbidities, thus representing a key public health threat [1–8]. Bariatric surgical approaches were initially pioneered in the 1950s and have been shown to be a safe and efficacious means of alleviating obesity and associated comorbidities in many patients [9–15]. Laparoscopic sleeve gastrectomy (LSG) is one such procedure performed with the highest frequency globally [10–12], with the rate of LSG in bariatric surgery ranging from 9.3 in 2010 to 58.2% in 2014 [11]. The recommendations of the National Institutes of Health are a primary guide for the global use of bariatric surgical approaches. However, these guidelines recommend restricting bariatric surgical interventions to severely obese individuals with a BMI > 40 kg/m$^2$ or to those that have

a BMI > 35 kg/m$^2$ and are suffering from serious obesity-related complications including type 2 diabetes mellitus (T2DM) [16]. While bariatric surgery is safe and efficacious in those that have a BMI > 35 kg/m$^2$ [17], evidence regarding their utility when BMI is < 35 kg/m$^2$ is less clear and is often contradictory, especially in a Chinese population [18–22]. At present, the efficacy and safety of LSG in Chinese individuals with a BMI < 35 kg/m$^2$ thus remain uncertain. Early weight loss has been utilized for predicting weight loss outcomes at 2–3 years after LSG in severely obese individuals [23–26]. The early detection of patients that are not likely to achieve long-term weight loss may aid earlier targeted medical, behavioral, and lifestyle interventions aimed at improving patient outcomes. As such, we herein sought to quantify the efficacy and safety of LSG as a means of achieving weight loss at 5 years post-surgery and the remission of obesity-associated comorbidities at 1-year post-surgery in Chinese individuals with a BMI < 35 kg/m$^2$. Furthermore, we explored the link between weight loss at early post-operative and long-term time points.

## Materials and Methods

This was a retrospective study of individuals that had been enrolled in a prospective database of Chinese individuals undergoing consecutive LSG at Beijing Shijitan Hospital between June 2010 and June 2016. Individuals were eligible for LSG if they met at least one of the following criteria: BMI > 35 kg/m$^2$ or BMI > 27.5 kg/m$^2$ with refractory obesity-associated comorbidities including hypertension, impaired glucose tolerance (IGT), polycystic ovarian syndrome (PCOS), T2DM, hyperlipidemia, or obstructive sleep apnea (OSA) [27–29]. We excluded patients undergoing revisional LSG from our analyses and additionally excluded individuals with a history of abdominal surgery or a BMI ≥ 35 kg/m$^2$. All other individuals that had a BMI of 27.5–35 kg/m$^2$ were included in this study. LSG operations in these patients were conducted by three surgeons with experience conducting ≥ 800 laparoscopic bariatric procedures. Our hospital Institutional Review Board (IRB) approved this study (No. Z191100006619043).

A BMI of 23.0 kg/m$^2$ is considered to be ideal [26, 30–32], as this was a study of a Chinese patient cohort with a body composition distinct from that of European or American cohorts. Hypertension in these patients was defined as SBP ≥ 140 mmHg or DBP ≥90 mmHg, and remission was defined by blood pressure values below these thresholds without the use of antihypertensive medication at 1-year post-LSG. T2DM was defined by a hemoglobin A1c (HbA1c) level of ≥ 6.5%, with remission being defined by an HbA1c of < 6.0% without the use of insulin or oral hypoglycemic drugs at 1-year post-LSG. Patient fasting lipid profiles including total cholesterol, triglycerides, and cholesterol to high-density lipoprotein ratio were measured. Remission of hyperlipidemia was defined by these values having returned to levels within the corresponding reference ranges at one year after LSG without the use of any drugs designed to lower lipid levels. Chronic nausea and vomiting, cyclic vomiting, and cannabinoid hyperemesis syndromes were all assessed as possible vomiting/nausea-related disorders [33]. Functional dyspepsia was defined by post-prandial fullness, early satiation, epigastric pain, and/or epigastric burning not explained by routine clinical assessment. Two potentially overlapping categories of functional dyspepsia were assessed in these patients: post-prandial distress syndrome, which is only symptomatic after eating, and epigastric pain syndrome, which is not exclusively post-prandial [33]. A BMI < 18.5 kg/m$^2$ within 5 years post-LSG as a consequence of fat and/or muscle loss was used to define emaciation [34]. Alopecia was determined based upon the subjective feelings of individual patients. How post-LSG weight loss was linked to comorbidity alleviation was assessed using a definition of successful weight loss of excess weight loss (%EWL) > 50% and percent total body weight loss (%TWL) > 25% [26, 35–37]. Long-term weight loss was that which was achieved within 5 years following LSG.

### Surgical Approach

Three surgeons performed all LSG procedures in enrolled patients using a standardized approach. A Veress needle was used to create a pneumoperitoneum (15 mmHg) in the navel. Patients were then positioned in a Reverse Trendelenburg and left-side up position with their legs separated in an "A." Full dissociation of the greater curvature was conducted from ~3 cm above the pyloric ring to the angle of His. A 32 Fr. Bougie tube was then advanced from the patient's mouth into their stomach. 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 ~3 cm above the pylorus to the angle of His, with the entirety of the gastric fundus being excised. Roughly 1 cm of gastric tissue in the angle of His was preserved in an effort to decrease gastroesophageal reflux disease incidence. Drainage tubes and methylene blue tests were not routinely employed. Absorbable 2–0 sutures were used to close all fascial defects.

### Post-operative Follow-Up

Upper gastrointestinal contrast CT scans were performed on days 1–3 post-operatively in all patients. When no abnormalities were detected, patients were allowed to freely consume water and were given a liquid diet. When patients were able to drink and maintain this diet without significant discomfort or vomiting, they were discharged. Micronutrient and vitamin

supplements were administered to all patients. Follow-up was performed at 3, 6, 12, 36, and 60 months post-LSG to assess patient weight, height, abdominal circumference, BP, routine blood and urine analyses, fecal examinations, analyses of renal and liver function, and indicators of blood nutrition, lipid, and glucose metabolism.

### Statistical Analysis

We employed chi-squared or Fisher's exact tests when comparing categorical data. How early weight loss and successful weight loss at 5 years post-LSG were linked was assessed via binary logistic regression analyses, with optimal cutoff points associated with early weight loss being identified with receiver operator characteristic (ROC) curves using MedCalc (v.19.2.6; MedCalc, Inc., Mariakerke, Belgium). SPSS (v.20.0; IBM Corp, NY, USA) was utilized for all other statistical testing. $P < 0.05$ was the significance threshold for this study.

## Results

In total, 384 patients were treated via LSG at Beijing Shijitan Hospital from June 2010 to June 2016. Of this overall patient population (143, 79, and 162 with respective BMI values of < 35, 35–40, and ≥ 40 kg/m$^2$), 143 patients (mean age, 39.59 years; median baseline BMI, 31.99 kg/m$^2$; 60.84% women; and 96.50% Han ethnicity) were included in the present study. Of these individuals, 141 (98.60%), 123 (86.01%), 105 (73.43%), 96 (67.13%), and 75 (52.45%) completed respective 3, 6, 12, 36, and 60-month follow-up analyses. T2DM was diagnosed in 91 of these patients, while 3 patients exhibited IGT. Preoperative characteristics of this patient cohort are compiled in Table 1.

All LSG procedures were successful, and no open surgery conversions were required. No instances of post-operative mortality, bleeding, or stenosis were observed. Fistulae, nausea and vomiting disorders, emaciation, hypoalbuminemia, anemia, alopecia, functional dyspepsia, hypoglycemia, cholecystolithiasis, hypotension, and other complications (micronutrient deficiencies, fatigue, and menstrual disorders) occurred in 1 (0.70%), 35 (51.47%), 3 (2.10%), 3 (4.35%), 4 (5.80%), 14 (20.59%), 19 (27.94%), 3 (4.41%), 4 (5.33%), 3 (4.00%), and 4 (5.33%) patients, respectively.

Mean BMI (kg/m$^2$) values in these patients were 31.44, 25.21, 24.03, 24.04, 24.57, and 24.79, respectively, at preoperative 3-, 6-, 12-, 36-, and 60-month time points. Patients' %TWL and %EWL trends are highlighted in Figs. 1 and 2, respectively. Post-operative mean respective %TWL was 19.68%, 23.49%, 24.51%, 23.14%, and 23.01% at 3, 6, 12, 36, and 60 months, respectively. Post-operative mean %EWL was 76.37%, 90.29%, 90.24%, 84.18%, and 81.59% at 3, 6, 12, 36, and 60 months, respectively. Patients achieved successful weight loss (> 50% EWL and > 25% TWL) in 46.67%, 48.96%, and 48.00% of cases at 12, 36, and 60 months post-LSG, respectively. After 12 months, average weight loss had stabilized at ~22.12 kg, but there was substantial individual variability in post-operative weight loss, which ranged from − 1 to 42 kg at 60 months post-LSG.

To explore the impact of weight loss at 3 months on long-term weight loss and comorbidity remission following LSG in Chinese individuals with a BMI < 35 kg/m$^2$, we excluded all patients without at least 12 months' worth of follow-up data. A binary logistic regression analysis of the remaining 105 patients revealed that %EWL and %TWL at 3 months were significantly correlated with long-term weight loss ($P < 0.05$), with respective OR values of 0.933 (95% confidence interval: 0.873–0.998) and 1.393 (95% confidence interval: 1.119–1.734), respectively. A joint predictor was then calculated using the following formula:

$$\text{Joint Predictor} = Y_{\%\text{EWL}} + Y_{\%\text{TWL}}{}^{*}B_{\%\text{TWL}}/B_{\%\text{EWL}}$$

This joint predictor was negatively correlated with long-term weight loss in these patients (OR: 0.933; 95% confidence interval: 0.900–0.969). ROC curves were then used to identify optimal 3-month %EWL, %TWL, and joint predictor cutoff values for assessing long-term weight loss. The AUCs of these three ROC curves for %EWL, %TWL, and joint predictor at 3 months were 0.637 (95% CO: 0.518 to 0.745), 0.737 (95% confidence interval: 0.623 to 0.832), and 0.790 (95% confidence interval: 0.680 to 0.875), respectively, suggesting that the predictive value of %TWL and joint predictor at 3 months had no significant difference ($P = 0.075$), while %EWL at 3 months had the lowest predictive value among these three indicators. This led us to select %TWL at 3 months as the most reliable predictor of sustained weight loss, given that it was associated with an ideal combination of sensitivity and specificity (Fig. 3). A %TWL of 19.54% at 3 months was able to most reliably predict weight loss at 5 years post-LSG (sensitivity: 61.11%, specificity: 76.92%). Changes in mean %TWL over time were compared between patients that did and did not achieve a > 19.54% TWL at 3 months post-LSG (Fig. 4).

Out of the remaining 105 patients who had 1-year post-operative follow-up, 66, 39, and 56 patients were preoperatively diagnosed with diabetes, hypertension, and hyperlipidemia, respectively. Twenty-four (36.36%), 17 (43.59%), and 22 (39.29%) patients received blood glucose, blood pressure, and blood lipid reexaminations one year after surgery, respectively. In these patients, overall comorbidity remission rates were 75.00%, 76.47%, and 90.91% for T2DM, hypertension,

**Table 1** Patient demographics

| Parameter ($n = 143$) | Value |
|---|---|
| Age (yr) (mean ± standard deviation) | 39.59 ± 12.34 |
| Gender, *n* (%) | |
| Male | 56 (39.16%) |
| Female | 87 (60.84%) |
| Race, *n* (%) | |
| Han | 138 (96.50%) |
| Mongolia | 2 (1.40%) |
| Manchu | 1 (0.70%) |
| Tibetan | 1 (0.70%) |
| Lahu | 1 (0.70%) |
| Median preoperative weight (kg) (upper and lower quartile) | 88 (82,95) |
| Median preoperative BMI (kg/m$^2$) (upper and lower quartile) | 31.99 (29.41,33.15) |
| IGT, *n* (%) | 3 (2.10%) |
| T2DM, *n* (%) | 91 (63.64%) |
| Hypertension, *n* (%) | 50 (34.97%) |
| Hyperlipidemia, *n* (%) | 78 (54.55%) |
| PCOS, *n* (%) | 21 (87.50%) |
| Hyperuricemia, *n* (%) | 60 (41.96%) |
| Fatty liver, *n* (%) | 98 (68.53%) |
| OSA, *n* (%) | 49 (52.13%) |

*OSA* obstructive sleep apnea, *PCOS* polycystic ovary syndrome

and hyperlipidemia, respectively. Out of the above 24, 17, and 22 patients, 15, 12, and 11 patients achieved > 19.54% TWL at 3 months, respectively. Subgroup analyses did not reveal any significant differences in the remission rates of T2DM

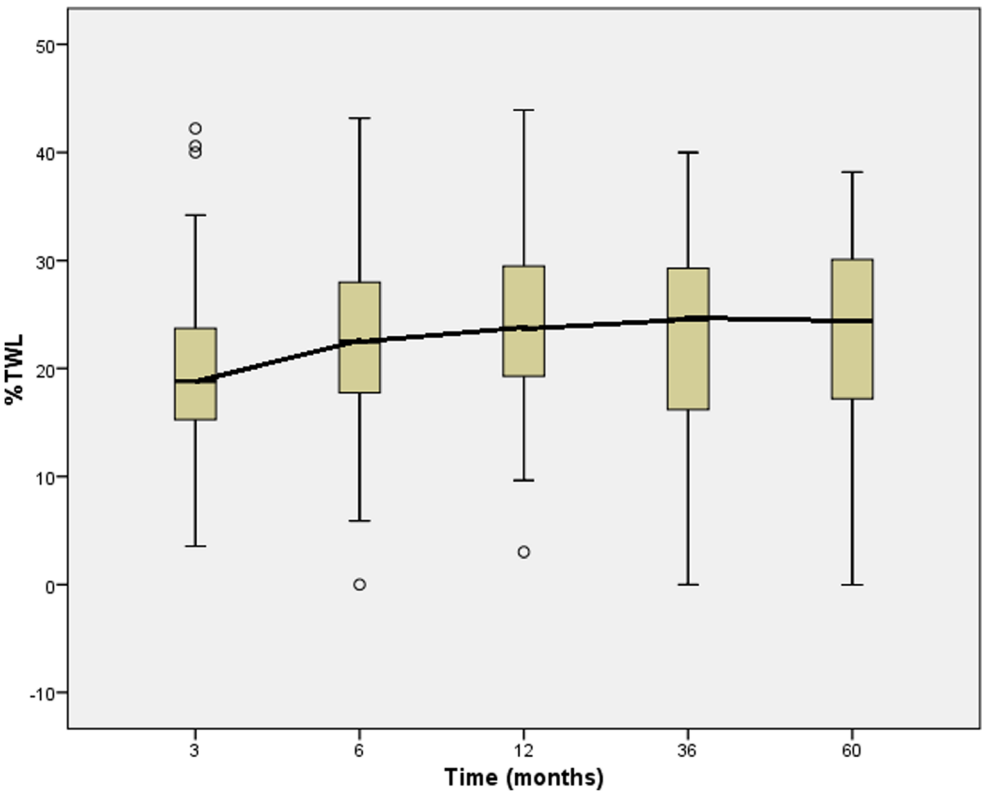


**Fig. 1** Trends of %TWL dynamics up to 60 months post-LSG

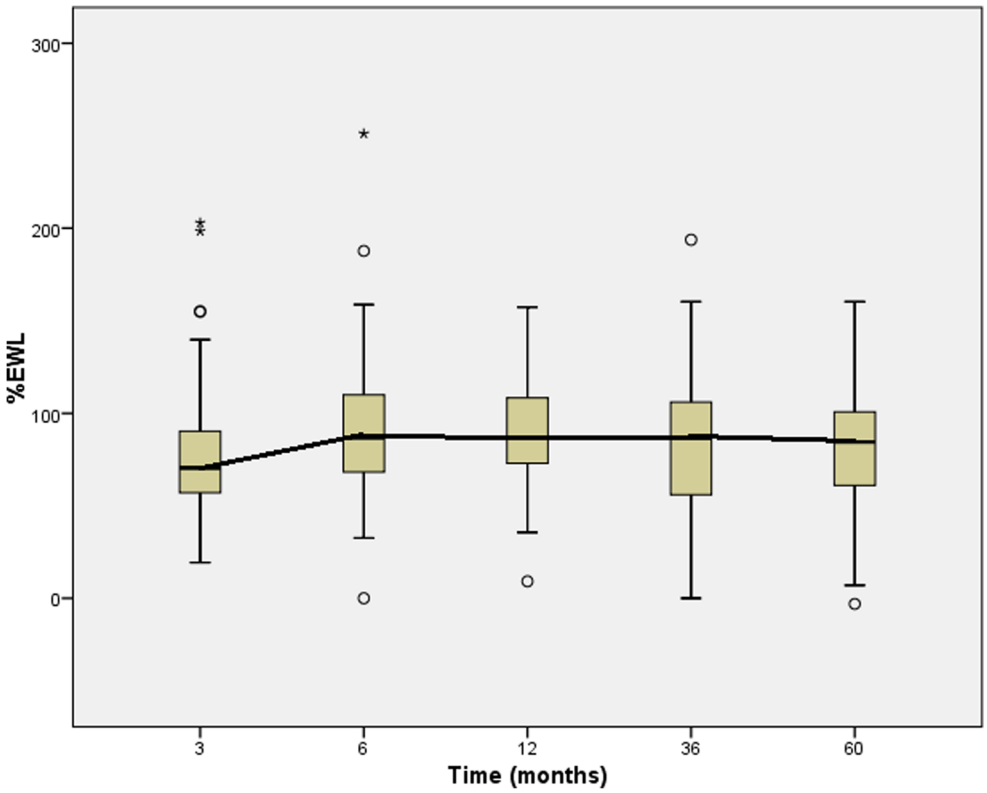


**Fig. 2** Trends of %EWL dynamics up to 60 months post-LSG

(73.33% vs. 77.78%, $P = 1.000$), hypertension (75.00% vs. 80.00%, $P = 1.000$), or hyperlipidemia (100% vs. 81.82%, $P = 0.476$) at 1-year post-LSG when comparing patients that did and did not achieve > 19.54% TWL at 3 months.

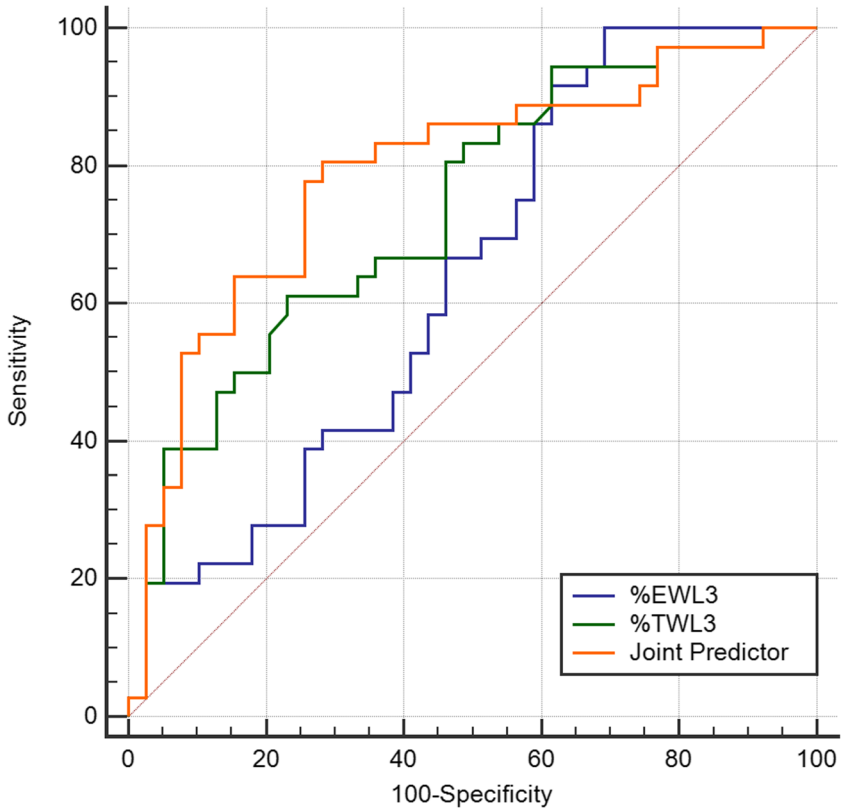


**Fig. 3** ROC curves pertaining to %EWL, %TWL, and joint predictors at 3 months in patients that achieved successful weight maintenance at 5 years post-LSG

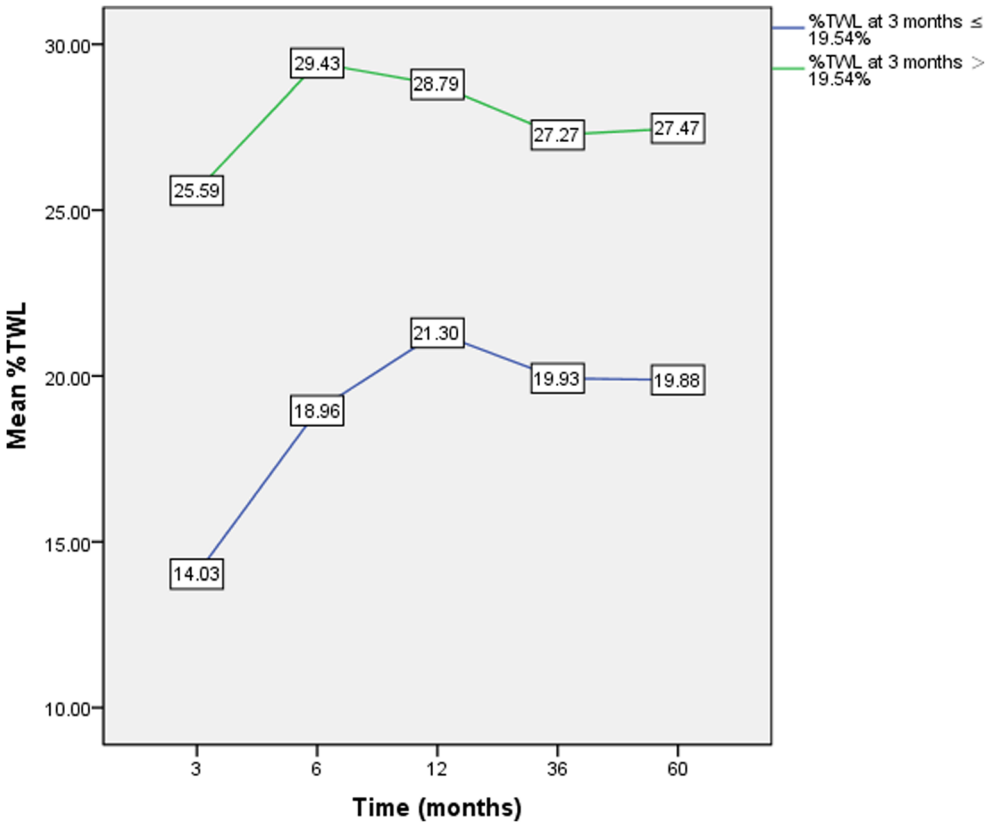


**Fig. 4** Changes in mean %TWL in patients that achieved 19.54% TWL at 3 months relative to those that did not

## Discussion

LSG is an increasingly popular surgical strategy, and long-term analyses have shown that it is a safe and efficacious approach to achieving weight loss and remission of obesity-related comorbidities [38–40]. The degree to which this approach is safe and efficacious in Chinese patients that have a BMI < 35 kg/m$^2$, however, remains uncertain. In addition, no prior studies have evaluated approaches to predicting long-term weight loss outcomes in these patients.

Herein, we found that %TWL at 3 months predicted 5-year weight loss such that good weight loss was more likely to be achieved in individuals with a %TWL at 3 months of > 19.54% (sensitivity: 61.11%, specificity: 76.92%). At 5 years, the mean BMI, %TWL, and %EWL for these patients were 24.79 kg/m$^2$, 23.01%, and 81.59%, respectively. Overall, patients in this study exhibited satisfactory weight loss outcomes. Relative to randomized controlled trials (RCTs) [14, 15], however, we detected slightly higher rates of surgical complications even though no bleeding, stenosis, or mortality was detected. Nausea and vomiting-related conditions were the most common adverse events (51.47%) and were treated with esomeprazole (40 mg) for 3 months. Of these patients, 14 (20.59%) experienced alopecia (1 male, 13 females) and were cured spontaneously at 1-year post-LSG. Additionally, 19 individuals (27.94%) experienced symptoms of functional dyspepsia including diarrhea, constipation, and abdominal distension. Relative to prior analyses conducted in Asian populations [38–40], we utilized a smaller Bougie tube (32 Fr. vs. 36–45 Fr.) in all patients, given that larger Bougie size is negatively correlated with sustained weight maintenance [40]. Additionally, in all patients, the stomach antrum was preserved at 3 cm from the pyloric ring, as opposed to the 4–6 cm employed in prior studies [38–40]. This choice was made because shorter distance has been shown to be positively correlated with sustained weight maintenance [13, 40]. The higher rates of complications in our study may thus be attributable to the smaller Bougie tube size and the decreased reserved distance to the pyloric ring [40]. However, symptomatic treatment was largely sufficient to alleviate patient symptoms in this study. Overall, our data suggest that LSG can be safely and efficiently used to treat patients with a BMI < 35 kg/m$^2$. We also detected no differences in rates of remission for comorbidities including T2DM, hypertension, and hyperlipidemia when comparing patients that had a BMI of 35–40 kg/m$^2$ and those that had a BMI of < 35 kg/m$^2$. This suggests that LSG may offer value to patients even when they have not achieved a BMI > 35 kg/m$^2$.

The majority of weight loss in patients within the present study cohort primarily occurred within 1 year following LSG. After that time, BMI tended to rise slowly, in line with prior results [23–26]. There is a close relationship between post-

operative weight loss and maximal achieved weight loss [41]. Definitions of early weight loss tend to vary among studies, corresponding to periods of 1–6 months post-LSG [26, 41, 42]. Herein, we identified %TWL at 3 months as a factor that can predict sustained maintenance of weight loss. Identifying an optimal predictive post-operative time point is of value, as it provides a means of more reliably identifying individuals who require further intensive therapy. Our study results suggest that patients that are unlikely to achieve sustained weight loss can be reliably identified as early as 3 months post-LSG. Actually, we also performed a binary logistic regression between %EWL and %TWL at 6 months and long-term weight loss outcome. Only %TWL at 6 months was significantly linked to long-term weight maintenance ($P < 0.001$), and its OR value was 1.173 (95% confidence interval: 1.081 to 1.272). %TWL of 24.14% at 6 months was the factor best able to predict 5-year weight loss (sensitivity: 80.56%, specificity: 79.49%). Even with a higher Youden index compared with %TWL at 3 months (0.60 vs. 0.38), we still preferred %TWL at 3 months as an optimal predictor because of its earlier predictive value.

ROC curve analyses enabled us to suggest a %TWL at 3 months of 19.54% as a cutoff value for predicting 5-year weight loss (sensitivity: 61.11%, specificity: 76.92%). When comparing patients that did and did not achieve successful 5-year weight loss, the mean %TWL at 3 months was 22.17% and 15.89%, respectively. These results support the use of a %TWL at 3 months cutoff of 19.54% for the stratification of patients based on their likelihood of achieving sustained weight loss. Using this cutoff value, we therefore compared characteristics and outcomes between these two patient groups. This approach revealed that patients who achieved a suboptimal %TWL at 3 months had significantly higher baseline BMI values (32.82 vs. 31.21 kg/m$^2$, $P < 0.001$), although in a binary logistic regression analysis baseline BMI was unrelated to better outcomes at 3 months. There was also no relationship between optimal %TWL at 3 months and patient age, sex, race, or comorbidities. This lack of significance may be attributable to the wide range of BMI values among patients and to the relatively limited sample sizes in these two groups.

Bariatric surgeries aim to alleviate obesity-related comorbidities and to enable patients' sustained weight loss. However, we detected no significant relationship between initial weight loss and hypertension, hyperlipidemia, or T2DM remission at 1-year post-LSG, in contrast with prior research [26]. This may be attributable to the smaller sample size in our study or to missing data pertaining to OGTT and blood biochemical tests. Our criteria for successful weight loss (%EWL > 50% and TWL% > 25%) were also relatively high, resulting in certain patients with positive outcomes having been excluded, thus potentially impacting our result validity.

In total, 52% of patients in this study did not achieve target weight loss at 5 years post-LSG. Additional interventional strategies are therefore necessary to facilitate weight loss in these patients. Approaches to reliably identifying patients that are less likely to achieve target weight loss are essential in order to guide bariatric treatment efforts, but additional large-scale RCTs will be necessary to identify these patients. Our findings indicate that in those patients with a %TWL at 3 months of ≤ 19.54%, more conservative methods are warranted to facilitate weight loss. Patients should be made aware of the possibility that they may not achieve weight loss following LSG, as weight maintenance is influenced by many lifestyle factors including exercise, stress, diet, and social/financial support [43–47]. For patients with a %TWL at 3 months ≤ 19.54%, long-term weight loss may be dependent upon further changes in dietary or exercise habits. Additional studies of the factors that contribute to sustained obesity in patients with a %TWL at 3 months ≤ 19.54% are warranted.

There are a few limitations to the present study. For one, this was a retrospective study and it is thus vulnerable to selection or recall bias. However, the prospective collection of these data was performed in an effort to minimize the potential for bias, and all patients that met the study inclusion criteria were enrolled in this analysis. Second, comorbidity remission was only evaluated at 1-year post-LSG, without any assessment of patients achieving remission or exhibiting relapse of these comorbidities after this time point. Moreover, the post-operative 1-year reexamination rates for obesity-related comorbidities were too low to draw convincing conclusions. The long-term follow-up rate for this study, however, was relatively high, with 75 out of 143 patients (52.45%) completing follow-up at 5 years post-LSG. Finally, we had to admit that all the conclusions of this study were based on a Chinese population who would develop medical problems of obesity at a lower BMI when compared to Caucasian [30, 32], so it is likely that these conclusions cannot directly translate to other populations such as a Caucasian population.

## Conclusion

These data indicate that LSG is safe and effective and that early weight loss following LSG is strongly associated with sustained weight maintenance in Chinese individuals with a BMI < 35 kg/m$^2$. A %TWL of > 19.54% at 3 months post-LSG may predict successful weight maintenance for up to 5 years in these patients.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s11695-020-05173-0.

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## Compliance with Ethical Standards

**Conflict of Interest** All authors declare no conflict of interest.

**Ethical Approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed Consent** Informed consent was obtained from individual participants included in this study.

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