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ORIGINAL RESEARCH

The Therapeutic Effectiveness of Laparoscopic Sleeve Gastrectomy Among Individuals with Low BMI Obesity (30-35 Kg/m^2) and the Relationship of BMI to Weight Loss

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Purpose: Investigating the therapeutic efficacy of Laparoscopic Sleeve Gastrectomy (LSG) in low BMI (30–35 kg/m^2) patients with obesity, and exploring the correlation between patients' preoperative BMI and postoperative weight loss.

Methods: Comparing the weight loss, remission of comorbidities, occurrence of complications, and quality of life among the different BMI patients who underwent LSG. Analyzing the relationship between BMI and percentage of excess weight loss (%EWL) by using Spearman correlation analysis and linear regression analysis.

Results: The %EWL at 12 months after the surgical procedure was (104.26±16.41)%, (90.36±9.98)%, and (78.30±14.64)% for patients with Class I, II, and III obesity, respectively, P<0.05. Spearman correlation coefficients between %EWL and BMI at 1, 3, 6, and 12 months after surgery were R=−0.334 (P<0.001), R=−0.389 (P<0.001), and R=−0.442 (P<0.001), R=−0.641 (P<0.001), respectively. The remission of hypertension, diabetes and dyslipidaemia did not differ significantly between groups (P>0.05).

Conclusion: Individuals with obesity for varying BMI can experience favorable outcomes following LSG surgery. It is advisable to consider LSG treatment for patients with Class I obesity.

Keywords: laparoscopic sleeve gastrectomy, body mass index, percentage of excess weight loss

Introduction

Obesity presents a significant global challenge, characterized as a complex chronic condition resulting from abnormal or excessive fat accumulation.[1,2] By the year 2015, the global population witnessed an approximate count of 107.7 million children and 603.7 million adults who were afflicted by obesity.[3] Obesity is strongly associated with the onset and progression of numerous illnesses,[4–8] and it has become a serious threat to the health and lives of people in every country, imposing a substantial strain on public health systems across nations. Bariatric surgery frequently yields more favorable outcomes in addressing morbid obesity compared to conventional weight reduction approaches. According to a 2018 survey conducted by the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) across five branches worldwide, LSG is currently the most used form of bariatric surgery in the world, accounting for 55.4% of all bariatric procedures.[9] As the amount of LSG continues to increase, the suitability of patients with mild obesity for LSG treatment has become a major concern for bariatric surgeons.

In 1991, the patients with obesity of BMI ≥ 35 kg/m^2 as a criterion for bariatric surgery.[10] But in 2022, the criterion for bariatric surgery suggested revising the indication for to BMI >27.5 kg/m2 in Asian populations.[11] Differences in fat

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distribution, hormone regulation, nutrient absorption, and metabolism in individuals with obesity of various BMI,[12,13] which are associated with LSG efficacy.[14] More evidence is therefore needed to support the suitability of patients with low BMI for LSG treatment. The research conducted by Uri Kaplan demonstrated that patient's preoperative BMI was an independent influence on postoperative weight change.[15] Based on this premise, this study aimed to analyze patients with obesity treated with LSG in our center, to examine the effectiveness and safety of LSG in individuals with obesity who have varying BMI and the effectiveness of LSG as a treatment option for patients with a low BMI, to provide some help for future clinical work.

Methods

Study Design

This retrospective study was conducted at the Department of Gastrointestinal Surgery, The First Affiliated Hospital of Wannan Medical College. Patients who underwent LSG at our center from October 1, 2019, to May 31, 2022, were retrospectively analyzed. And follow-up deadline is May 31, 2023. Patients were classified into three groups based on their preoperative BMI, and the grouping criteria used the World Health Organization (WHO) obesity classification criteria,[16] Class I: 30 ≤ BMI ≤ 34.9kg/m^2; Class II: 35≤ BMI ≤ 39.9kg/m^2; Class III: BMI ≥ 40kg/m^2. This study was in accordance with the Declaration of Helsinki and approved by the Ethics Clerkship.

Patients

Inclusion criteria: (1) 18≤ Age≤ 60 years; (2) BMI≥30 kg/m^2; (3) Type 2 diabetes (T2DM) patients still have some insulin secretion function.

Exclusion criteria: (1) BMI>60 kg/m^2 or BMI<30 kg/m^2; (2) severe mental or eating disorders, alcohol or drug abuse; (3) those who cannot control their own behaviour; (4) patients who are physically unable to tolerate the procedure; (5) special types of diabetes (gestational diabetes, type 1 diabetes, islet-deficient diabetes, etc.); (6) previous other bariatric surgery; (7) gastroscopy suggesting the presence of gastric ulcers; (8) patients with gastroesophageal reflux disease (GERD).

Treatment

In this study, all patients underwent LSG by the same surgical team, following the standardized LSG protocol (see Appendix Content 1). Patients fasted from water for 24 hours after surgery, with routine intravenous drips of glucose and saline during the fast, and the rest of the treatment was individualized according to the patient's postoperative condition. If the patient does not experience severe discomfort within 24 hours following the surgery, it is recommended that they begin consuming a small quantity of water. After observing the patient for 6 hours following water intake, if there are no adverse reactions, the drainage tube will be removed and the patient will be discharged. When a patient is discharged from hospital, he is given a post-operative management guide, which details post-operative diet, exercise and review considerations. The patients were asked to undergo follow-up surveys at 1, 3, 6, and 12 months after surgery.

Outcome Measurements

General clinical indicators such as weight (kg), BMI (kg/m^2), blood pressure (mmHg) and quality of life score (QOL score) were measured 1 day before surgery and at 1, 3, 6, and 12 months after surgery. The postoperative weight change expressed as the percentage of excess weight loss (%EWL) which was calculated from the postoperative follow-up data, %EWL = (initial weight - follow-up weight)/(initial weight - 25 × height^2) × 100%.[17] The patients' QOL was scored using the Moorehead-Ardelt QOL II scale (scores: −3 to +3), higher scores mean better QOL.[18] The standards for remission of comorbidities refer to the American Society for Metabolic and Bariatric Surgery (ASMBS).[17]

The blood samples used for the examination are all venous blood drawn on a fasting basis. Blood samples were used to measure fasting insulin (FINS), fasting blood glucose (FBG), total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-c), and high-density lipoprotein cholesterol (HDL-c). FBG, TC, TG, LDL-c, and HDL-c were measured using an automated biochemical analyzer. Serum concentrations of FINS were measured using an ELISA immunoassay (Sigma-Aldrich).

The primary endpoint of this study was to determine if there were variations in weight loss after surgery among patients with obesity who had different BMI and to evaluate the effectiveness of surgery in patients with Class I obesity. The secondary endpoint was the correlation between patients' preoperative BMI and %EWL.

Statistics

The statistical analysis for this study utilized SPSS 22.0 and R (version 3.6.3). P<0.05 was employed to establish statistically significant distinctions, and all tests were conducted with two-sided analysis. Data that followed a normal distribution were presented as mean ± SD, One-Way ANOVA was employed to compare the three groups, and the Least-Significant Difference (LSD) test was used to compare the two groups. Data that did not conform to a normal distribution were expressed as M(P25, P75), and the Kruskal–Wallis *H*-test was used for comparison between the three groups. Utilized the chi-square test to analyze and compare the count data of the different groups. The relationship between % EWL and BMI was explored using Spearman correlation analysis and linear regression analysis.

Results

Patient Characteristics

During the study period, 153 patients underwent LSG. A total of 19 patients were excluded from this study as they did not meet the inclusion criteria. Among them, 2 patients became pregnant after surgery, 1 patient was using antidepressant medication, 4 patients underwent cholecystectomy during the surgery, and 12 patients had incomplete follow-up data. Ultimately, this study included a total of 134 patients, Figure 1 shows the detailed flow chart of this study. There were 61 patients in Class I, 44 patients in Class II and 29 patients in Class III. The average weight of the patients who took part in this study was (98.62 ± 15.00) kg, their average age was (28.53±6.69) years, and their average BMI was (36.53±4.53) kg/m^2. There were no statistically significant differences in the remaining baseline characteristics (P>0.05). Table 1 details the relevant preoperative data for each group and compares them.

Post-operative weight change and comparison between three groups

At 12 months postoperatively, the mean %EWL for Class I, Class II and Class III obesity were (104.26±16.41)%, (90.36±9.98)%, and (78.30±14.64)%, respectively, with statistically significant differences between the groups (P<0.001). The mean %TWL were (24.10 ± 4.02)%, (29.92 ± 3.20)%, and (32.89 ± 7.33)%, P<0.001, as shown in Content 2: Table S1. When comparing the two groups, the mean %EWL for Class II obesity was lower than Class

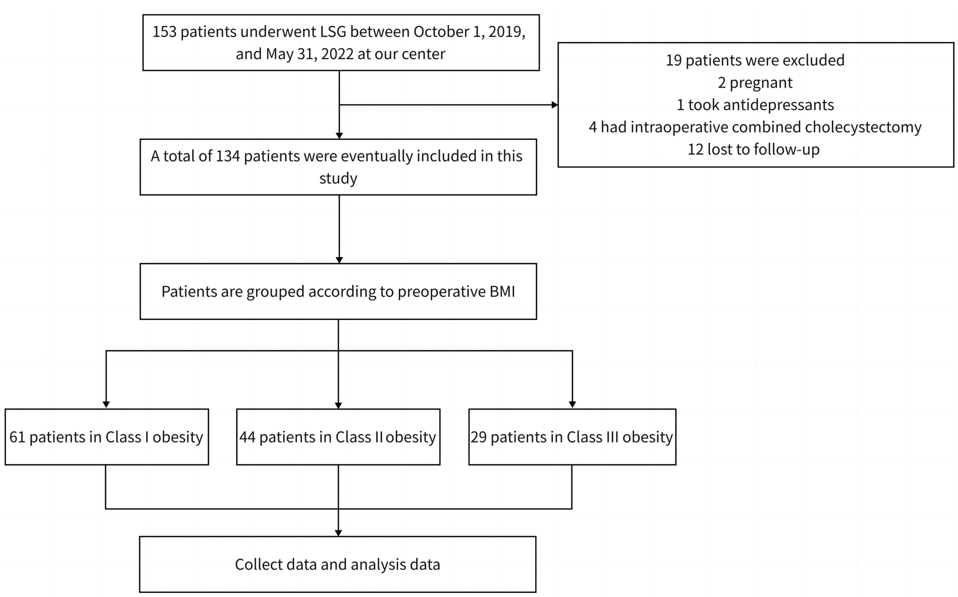

Figure 1 Study flow diagram.

Table 1 Baseline Characteristics of the Three Groups

Variables	Class I (*n*=61)	Class II (*n*=44)	Class III (*n*=29)	P value
Age (year)	28.75 ± 6.56	28.98 ± 7.69	27.38 ± 5.29	0.574
Men/Women	6/55	5/39	5/24	0.580
QOL score	0.30 (0.10, 0.90)	0.20 (0.00, 0.40)	0.20 (−0.10, 0.40)	0.193
SBP (mmHg)	129.87 ± 14.27	131.32 ± 12.63	137.48 ± 17.49	0.066
DBP (mmHg)	78.79 ± 9.55	80.14 ± 9.34	83.38 ± 11.89	0.131
TC (mmol/L)	4.75 ± 0.93	4.69 ± 0.85	4.82 ± 1.22	0.846
TG (mmol/L)	2.02 ± 0.88	1.94 ± 0.97	2.44 ± 1.21	0.196
HDL-c (mmol/L)	1.27 (1.19, 1.39)	1.25 (1.18, 1.38)	1.23 (1.12, 1.34)	0.410
LDL-c (mmol/L)	2.87 ± 0.69	2.97 ± 0.73	3.24 ± 1.23	0.161
FBG (mmol/L)	5.82 ± 1.48	6.19 ± 1.78	6.80 ± 2.94	0.092
Hypertension, No.(%)	21, 34.42%	17, 38.64%	11, 37.93%	0.894
Diabetes, No.(%)	8, 13.11%	11, 25.00%	6, 20.69%	0.289
Dyslipidmeia, No.(%)	19, 31.14%	16, 36.36%	12, 41.38%	0.621

Notes: Data are mean ± SD, % or median (P25, P75).
Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, glycosylated hemoglobin; TC, total cholesterol; TG, triglyceride; HDL-c, high-density lipoprotein cholesterol; LDL-c, low-density lipoprotein cholesterol; FBG, fasting blood glucose.

I obesity, and this difference was statistically significant (P<0.001). Similarly, the mean %EWL for Class III obesity was also lower than Class I obesity (P<0.001), and Class III obesity was also lower than Class II obesity (P=0.001). However, %TWL was higher in Class III and Class II obesity than in Class I obesity (P<0.001 for all). Detailed data on %EWL and %TWL over the postoperative follow-up time for the three groups are presented in Table 2 and Content 2: Table S1, respectively. Figure 2 and Content 3: Figure S1 show a comparison of %EWL and %TWL at various postoperative time points for each group.

Association of %EWL and BMI

There was a negative correlation between preoperative BMI and %EWL at 1, 3, 6, and 12 months postoperatively (R= −0.344, P<0.001; R= −0.389, P<0.001; R= −0.442, P<0.001; R= −0.641, P<0.001), see Figure 3. The results of the linear regression analysis between preoperative BMI and %EWL at 1, 3, 6, and 12 months postoperatively are shown in Table 3, showing that preoperative BMI affects %EWL.

The ROC curve results indicated that utilizing the patient's preoperative BMI to predict the return to normal BMI at 12 months after LSG had some clinical application value, and the model's accuracy was satisfactory (AUC=0.791, CI: 0710–0.872), refer to Table 4 and Figure 4.

Table 2 Comparison of the Percentage of Excess Weight Loss (%EWL) in the Three Groups After Surgery

Groups	1 Month	3 Months	6 Months	12 Months
Class I (*n*=61)	45.53±15.61	71.41±19.33	92.12±22.13	104.26±16.41
Class II (*n*=44)	37.20±10.72	61.63±12.75	80.78±12.57	90.36±9.98
Class III (*n*=29)	34.22±10.48	56.02±12.80	72.90±15.46	78.30±14.64
P value	<0.001	<0.001	<0.001	<0.001
$P_{1\text{-}2}$ value	0.002	0.003	0.002	<0.001
$P_{1\text{-}3}$ value	<0.001	<0.001	<0.001	<0.001
$P_{2–3}$ value	0.345	0.147	0.071	0.001

Note: Data are mean ± SD.
Abbreviations: $P_{1\text{-}2}$ value are P values after comparison of %EWL for Class I and Class II obesity at postoperative follow-up time; $P_{1\text{-}3}$ value are P values after comparison of %EWL for Class I and Class III obesity at postoperative follow-up time; $P_{2–3}$ value are P values after comparison of %EWL for Class II and Class III obesity at postoperative follow-up time.

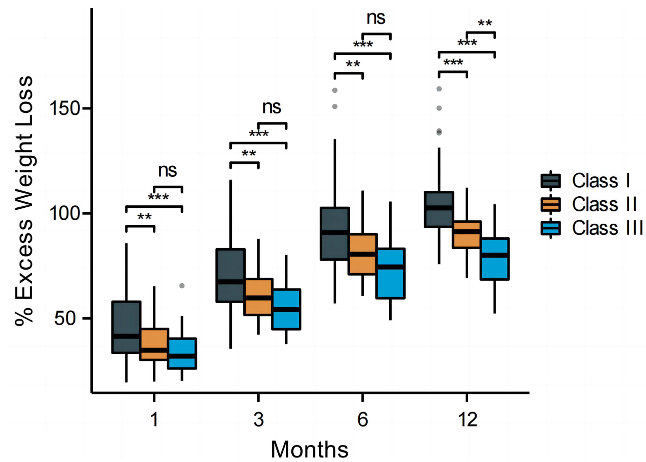

Figure 2 Comparison of postoperative % Excess Weight Loss between the three groups at 1, 3, 6, and 12 months postoperatively. ns, P > 0.05; **P < 0.01; ***P < 0.001.

Comparison of Hypertension Relief in Three Groups

A total of 49 (36.57%) patients with obesity had preoperative combined hypertension and 31 (63.27%) patients achieved remission criteria at 12 months after surgery. As listed in Table 5, the number of hypertension remission in each group of Class I, II, and III obesity was 15 (71.43%), 9 (52.94%), and 7 (63.64%), with no statistically significant difference between groups (P>0.05, Table 5).

Comparison of Diabetes Remission in Three Groups

At 12 months postoperatively, 19 patients (76.00%) met the criteria for diabetes remission. As shown in Table 5, the number of patients with diabetes remission in each group for Class I, II, and III obesity was 6 (75.00%), 8 (72.73%) and 5 (83.33%), P>0.05.

Comparison of Remission of Dyslipidemia in Three Groups

As listed in Table 5, 32 patients (82.35%) reached remission of dyslipidemia at 12 months postoperatively. The number of patients with remission of dyslipidemia in each of the Class I, II, and III obesity groups [13 (68.42%) vs 11 (68.75%) vs 8 (66.67%)] with no statistically significant difference between groups (P>0.05).

Comparison of Quality of Life in the Three Groups After Surgery

The QOL scores for Class I, II, and III obesity at 12 months postoperatively were 1.30 (0.80, 1.80), 0.90 (0.70, 1.23), and 0.90 (0.70, 1.50) respectively, P<0.05, as listed in Table 6.

Comparison of Post-Operative Complications Between the Three Groups

Out of the total number of patients, 7 patients (5.22%) developed incision infection, 73 patients (54.48%) experienced postoperative nausea and vomiting (PONV), 18 patients (13.43%) developed gastroesophageal reflux disease (GERD), and 1 patient experienced gastric leakage. There was no notable variation in the frequency of complications among the groups (P>0.05), the data presented in Table 6.

Discussion

Obesity and its related health issues have emerged as a major public health concern in numerous countries worldwide.[19] According to the 2018 data, approximately 51.2% of Chinese adults were categorized as overweight or obese, and it is estimated that this percentage could rise to 70.5% by the year 2030.[20] LSG is an exceptionally effective method for treating obesity, and it is currently the most extensively used surgical procedure for bariatric surgery on a global scale.[21] Previous studies[22–25] have mostly focused on evaluating the efficacy as well as the safety of LSG, and there is a limited

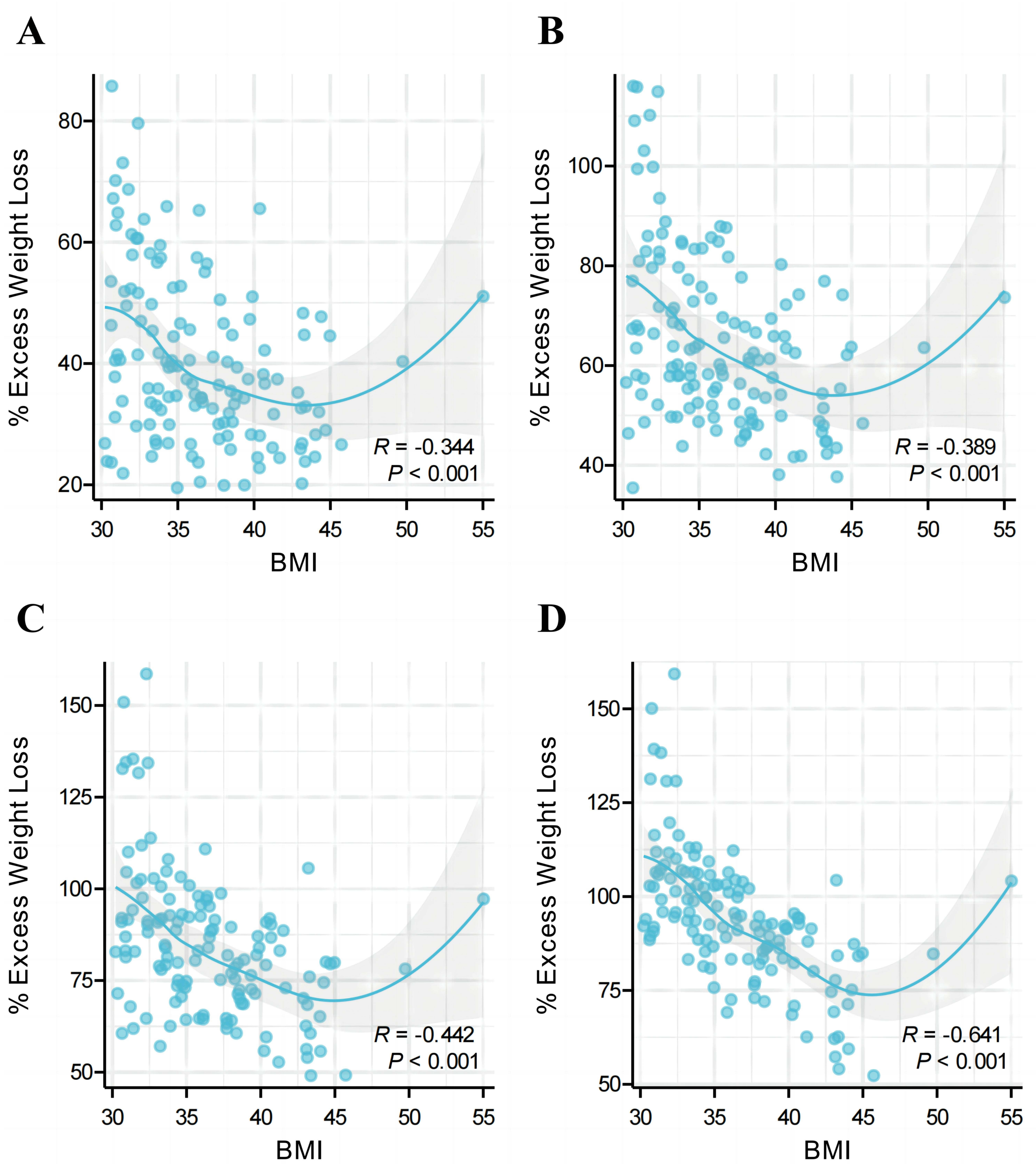

Figure 3 Correlaion analysis of %Excess Weight Loss and BMI. (**A**) Correlation between preoperative BMI and postoperative % Excess Weight Loss of patients at 1 month postoperatively; (**B**) Correlation between preoperative BMI and postoperative % Excess Weight Loss of patients at 3 months postoperatively; (**C**) Correlation between preoperative BMI and postoperative % Excess Weight Loss of patients at 6 months postoperatively; (**D**) Correlation between preoperative BMI and postoperative % Excess Weight Loss of patients at 12 months postoperatively.

amount of research available on whether the effectiveness of LSG treatment varies among patients with different BMI obesity and whether LSG treatment is recommended for patients with low BMI. Various academics have contrasting opinions regarding the appropriateness of using LSG as a treatment for patients with low BMI obesity.

Table 3 Linear Regression Analysis of Preoperative BMI and %EWL at 1, 3, 6, and 12 Months Postoperatively

Modle	Independent Variable	β	SE	β'	t	P
1 Month	Constants	77.305	9.293		8.391	<0.001
	Preoperative BMI	−1.012	0.252	−0.329	−4.007	<0.001
3 Months	Constants	117.825	11.231		10.491	<0.001
	Preoperative BMI	−1.449	0.305	−0.382	−4.751	<0.001
6 Months	Constants	150.690	12.537		12.020	<0.001
	Pre operative BMI	−1.819	0.341	−0.422	−5.341	<0.001
12 Months	Constants	176.756	9.989		17.694	<0.001
	Pre operative BMI	−2.263	0.271	−0.587	−8.339	<0.001

Table 4 ROC Curve Analysis Results

	AUC	95% CI	Cut-off value	Sensitivity	Specificity
BMI	0.791	0.710–0.872	37.499	0.956	0.562

Abbreviations: Balanced sensitivity and specificity at the cut-off yielding the largest Youden index value; AUC, area under the receiver operating characteristic curve.

Based on our research, we propose that individuals with Class I obesity should receive more assertive recommendations for LSG treatment. In our 12 months study following surgery, we observed patients with different BMI showed varying degrees of postoperative weight loss. Specifically, we discovered that patients in Class I obesity experienced a significantly higher of %EWL at 1, 3, 6, and 12 months after surgery compared to the other two groups ($P < 0.05$). As the postoperative period increased, it was seen that the difference in the %EWL between the Class I patients with obesity and the other two groups became more pronounced. In contrast, %TWL presented significantly higher in patients with Class II and III obesity than in those with Class I ($P < 0.05$). Both %EWL and %TWL are indicators used to assess postoperative weight loss, but we think that %EWL provides a more comprehensive assessment of post-surgical weight modifications, due to the %EWL provides a more intuitive assessment of the loss of the excess weight of patients, while

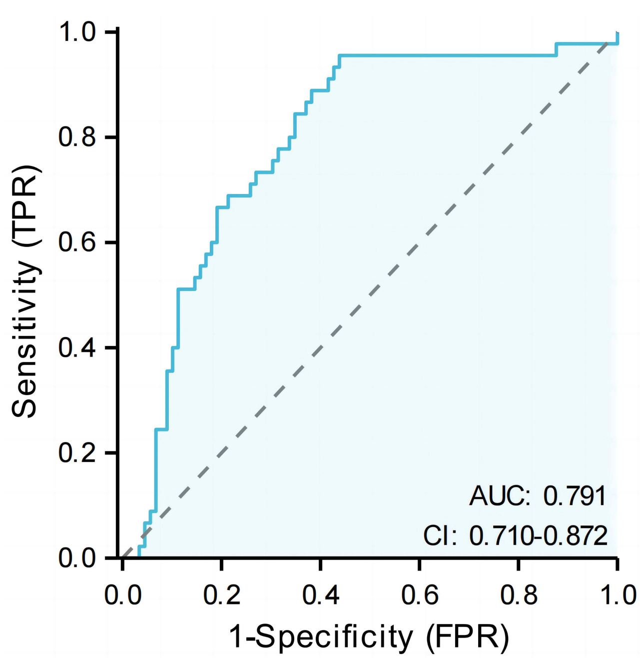

Figure 4 The ROC curve for predicting patients reaching normal BMI at 12 months post-operatively by using preoperative BMI.

Table 5 Comparison of Remission Rates of Relevant Comorbidities in the Three Groups of Patients After Surgery

	Class I	Class II	Class III	P value
Hypertension remission, No.(%)	15, 71.4%	9, 52.9%	7, 63.6%	0.513
Diabetes remission, No.(%)	6, 75.0%	8, 72.7%	5, 83.3%	1.000
Dsylipidaemia remission, No.(%)	13, 68.4%	11, 68.8%	8, 66.7%	1.000

Table 6 Comparison of 12-Months Postoperative Complications and Quality of Life Scores Among the Three Groups of Patients

	Class I	Class II	Class III	P value
Incision infection, No.(%)	2, 3.28%	2, 4.55%	3, 10.34%	0.369
PONV, No.(%)	32, 52.16%	23, 52.27%	18, 62.07%	0.650
GERD, No.(%)	10, 16.39%	3, 6.82%	5, 17.24%	0.290
Gastric leakage, No.(%)	1, 1.64%	0, 0%	0, 0%	1.000
QOL scores, No.(%)	1.30 (0.80, 1.80)	0.90 (0.70, 1.23	0.90 (0.70, 1.50)	0.041

Abbreviations: PONV, postoperative nausea and vomiting; GERD, gastroesophageal reflux disease; QOL, quality of life.

%TWL is closely associated with baseline weight. In a 3-year study by Park et al,[26] postoperative %EWL was found to be higher in patients in the low BMI (30–35 kg/m^2) group than in patients in the high BMI (>35 kg/m^2) group. The timing of undergoing bariatric surgery is similar to that of cancer surgery. Just like how receiving surgical treatment in the early stages of cancer leads to more favorable outcomes, having surgery in the early stages of obesity increases the likelihood of achieving desired weight and improves overall outcomes for patients. According to the study conducted by Elnabil-Mortada et al,[27] it has been found that LSG is a remarkably efficient method for managing obesity in individuals who are only mildly affected, and individuals with a higher BMI may not experience the same positive outcomes as those with a lower BMI. A study by Alqahtani AR et al[28] found good postoperative outcomes in grade I patients with obesity underwent LSG. Various pieces of evidence indicate that LSG is highly effective in treating patients with Class I obesity.

Based on this foundation, we conducted a correlation analysis between patients' preoperative BMI and their %EWL at 1, 3, 6, and 12 months after surgery. Our findings revealed a negative correlation between patients' preoperative BMI and postoperative %EWL during the follow-up period. Furthermore, the results of our linear regression analysis confirmed that preoperative BMI can influence the patients' postoperative %EWL. Patient's preoperative BMI is closely associated with postoperative weight loss outcomes, which may be related to metabolic rate differences, hormonal regulation, dietary behaviors and lifestyles, gut microbiota, genetics, and genetic manifestations,[29–31] but the exact mechanism remains to be further explored. Finally, the results of the ROC curves suggest that preoperative BMI has some clinical value in predicting whether patients can achieve a normal weight after surgery. In conclusion, patients with Class I obesity undergoing LSG can attain a satisfactory level of weight loss, and such patients are also more likely to experience "obesity remission".

Moreover, aside from its efficacy in facilitating weight loss, the utilization of LSG as a therapeutic strategy for managing type 2 diabetes mellitus (T2DM) in individuals with obesity has garnered significant interest. Numerous studies have explored the use of LSG for managing T2DM, and the results have consistently shown that LSG is effective in treating this condition. The mechanisms of remission in T2DM can be categorised as weight-dependent and non-weight-dependent, but our study did not find significant differences in T2DM remission rates between the groups. The main pathogenic mechanisms of T2DM are thought to be a relative lack of insulin due to insulin resistance and reduced insulin secretion due to reduced function of pancreatic β cells. In our previous study, insulin resistance was found to be largely alleviated in patients treated with LSG,[32] which may be the main cause of diabetes remission. Decreased levels of leptin and ghrelin in patients treated with LSG as well as a remission of chronic inflammation lead to a remission of insulin resistance.[33–35]

All individuals diagnosed with dyslipidemia experienced improvement following LSG treatment when compared to their preoperative condition. Furthermore, 68.09% of these patients achieved remission, and there was no notable variation in remission rates among different groups following the surgical procedure (P>0.05). This indicates that LSG is an effective treatment for dyslipidemia. Additionally, the preoperative BMI did not have an impact on the remission of dyslipidemia. A study conducted by Elnabil-Mortada et al[27] similarly found no notable variation in the remission rate of dyslipidemia among patients with different BMI. Similarly, when we compared the rate of hypertension remission in the postoperative groups, we found that the remission rate was highest in Class III patients with obesity, but the difference between the groups was not statistically significant (P>0.05). At present, there is no clear mechanism for the remission of hypertension after LSG, and the mainstream view is that it is caused by the action of multiple pathways after LSG, such as sympathetic excitability changes, hormonal changes, adipokine changes, weight loss, etc.[36] From the present study LSG is an effective measure for the treatment of obesity combined with hypertension. Based on the results of the QOL scores, we observed improvement in all patient groups' QOL compared to their preoperative QOL. Upon comparing postoperative QOL scores within each group, we found that patients with Class I obesity exhibited significantly higher scores than those with Class II and Class III obesity. This may be closely related to the higher proportion of patients achieving "obesity remission" in the Class I category. No patient deaths occurred in this study, again demonstrating the safety of the LSG procedure.

This study still has some shortcomings and limitations. First, due to some irresistible factors, this study only analyzed the short-term efficacy of the patients after surgery and did not explore the influence of different BMI on the long-term efficacy of LSG after surgery. Secondly, this study retrospectively analyzed the efficacy of LSG in patients with different levels of obesity and did not compare the efficacy of different surgical modalities with LSG, so it was not possible to determine which surgical modality was more suitable for patients with different BMIs. Third, this study is a single-center, small-sample study. We will add to these in subsequent studies.

Conclusion

Individuals with obesity for varying BMI can experience favorable outcomes following LSG surgery. It is advisable to consider LSG treatment for patients with Class I obesity.

Ethics Approval Statement

The Ethics Committee at the First Affiliated Yijishan Hospital of Wannan Medical College approved this study. We obtained informed consent from all participants involved in this research.

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Disclosure

The authors report no conflicts of interest in this work.

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