Original Article

Patient Age Predicts Long Term Insufficient Weight Loss after Laparoscopic Sleeve Gastrectomy

Kotaro Wakamatsu Takashi Oshiro* Natsumi Kitahara
Yuuki Moriyama Taiki Nabekura Yu Sato
and Masaru Tsuchiya

Department of Surgery, Toho University Sakura Medical Center, Chiba, Japan

ABSTRACT

Introduction: Laparoscopic sleeve gastrectomy (LSG) is the most popular and effective treatment for patients with morbid obesity. However, some patients experience insufficient weight loss after surgery. Detecting insufficient weight loss in the early postoperative phase and acknowledging insufficient weight loss predictive factors are crucial to apply fast interventions for those patients. We explored the appropriate timing of insufficient weight loss diagnosis and predictive factors for insufficient weight loss after LSG.

Methods: Patients who underwent LSG at our single institution were analyzed retrospectively. Patients were divided into three groups according to percentage total weight loss (%TWL) at 3 months after surgery: %TWL ≤ 10%, 10%-20%, and ≥ 20%. The %TWL values of these groups were compared up to 5 years after surgery. The %TWL ≤ 10% and ≥ 20% groups were compared to identify insufficient weight loss predictive factors.

Results: A total of 198 patients were included in this study. Thirty-four patients with %TWL ≤ 10%, 138 patients with 10%-20%, and 26 patients with ≥ 20% were identified. The %TWL ≤ 10% group showed significantly less weight loss postoperatively up to 5 years. Patient age was the only clinical factor that differed significantly between the groups after a multiple logistic regression analysis. Receiver operating characteristic analysis revealed that patient age of 47 years was the optimal cutoff for predicting %TWL ≤ 10% at 3 months after surgery.

Conclusions: %TWL ≤ 10% at 3 months after LSG is an early indicator for long-term insufficient weight loss, and patient age of 47 years is a predictor for %TWL ≤ 10%.

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KEYWORDS: bariatric and metabolic surgery, laparoscopic sleeve gastrectomy, insufficient weight loss

Introduction

Laparoscopic sleeve gastrectomy (LSG) is an effective long-term intervention for patients with severe obesity.[1, 2] After surgery, patients experience consecutive linear weight loss and concomitant decreasing obesity-related comorbidities such as hypertension, type 2 diabetes mellitus, hyperlipidemia, and sleep apnea syndrome. Approxi-

*Corresponding Author: Takashi Oshiro, 564-1 Shimoshizu, Sakura, Chiba 285-8741, Japan, tel: +81-43-462-8811
e-mail: oshiro@sakura.med.toho-u.ac.jp
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mately 1 to 1.5 years later, the extent of weight loss reaches a nadir, the lowest weight loss period after surgery, and some degree of weight regain is observed. This weight-loss pathway is known to be universal. During this weight-loss pathway, some patients encounter one or both major clinical obstructions of obesity treatment: insufficient weight loss (IWL) and weight regain (WR).

Although standardized definitions of IWL and WR have not been established, IWL is considered inadequate weight loss during the consecutive linear weight loss phases.[3] Importantly, IWL is reported to be the most common cause of revisional surgery for inadequate weight loss.[4] Therefore, early identification of IWL has a clinical importance in making decisions for a fast intervention obtaining optimal weight loss health outcomes. Obesity is a chronic inflammatory state caused by excessive adipocyte accumulation,[5] and fast and effective interventions to reduce excessive adipocytes are lifesaving. To achieve faster weight loss, early identification of IWL after surgery is critical.

The trend of surgery for patients with morbid obesity in Japan revealed a unique character: approximately 95% of patients with clinically severe obesity undergo LSG.[6] By contrast, according to the 7th IFSO Global Registry Report, 61% LSG, 26% Roux-en-Y gastric bypass, and 4.5% one-anastomosis gastric bypass of a total of 278,581 patients were performed worldwide in 2022. The steep deviation to the LSG procedure in Japan stems from the Japanese government's Health Insurance System, in which only LSG is covered as an obesity surgery option. Therefore, despite greater reduction in weight loss and improvements in obesity-related comorbidities reported after gastric bypass procedures, patients in Japan are restricted to undergo LSG. Although some surgical outcomes of bypass procedures have been reported in Japan,[7, 8] a direct comparison between LSG and gastric bypass regarding weight loss in the Japanese population remains lacking. Considering this unique situation in Japan, optimizing LSG is a demanding issue to provide maximum weight loss outcomes for patients with morbid obesity. This current study aims to explore a practical diagnosis measure to detect early IWL after LSG and its predictive factors.

Methods

Participants and subgrouping according to weight loss after surgery

This retrospective analysis was conducted on 235 patients who underwent bariatric and metabolic surgery between July 2010 and September 2022 at a Japanese academic hospital, and their clinical data were obtained from an institutional database. Two hundred patients underwent LSG, and 35 underwent gastric bypass procedures. Only patients who had undergone LSG were included in this analysis. Patients were grouped according to the extent of weight loss 3 months after surgery. Two patients with missing weight measurements were excluded in further analysis, and only 198 patients were included. Percentage total weight loss (%TWL) was used to measure the extent of postoperative weight loss, and patients were grouped into three groups according %TWL at 3 months after surgery. The three groups were %TWL $\leq$ 10%, %TWL = 10%-20%, and %TWL $\geq$ 20%. LSG was indicated according to the criteria established in 2005 by the Asia-Pacific Bariatric Surgery Group Consensus meeting.[9] All patients were provided with up-to-date and detailed information regarding the available surgery options, including postoperative complications and nutritional requirements.

Patient selection by the review board for LSG

Our hospital uses a multidisciplinary approach to the treatment of obesity. Each patient was admitted to the Center of Diabetes, Endocrine and Metabolism for approximately 2 weeks before BMS, during which internal physicians and dietitians performed routine physical checkups to exclude secondary obesity and provided physical activity and nutritional advice. Pharmacotherapy for obesity-related comorbidities was also standardized, and consultations with psychiatrists and psychologists were initiated to rule out and support psychosocial problems and mental disorders. Finally, eligibility for LSG was discussed at our hospital's board conference based on the Japanese Joint Consensus Statement for the Treatment of Obesity.[10] If eligibility was confirmed, patients were referred to surgeons as candidates for LSG. After discharge, patients periodically consulted physicians, dieticians, psychiatrists, and psychologists.

Clinical variables

Physical examination (age, weight, and height), biochemical values (levels of total serum protein, albumin, C-reactive protein [CRP], glutamic oxaloacetic transaminase [GOT], glutamic pyruvic transaminase [GPT], gamma-glutamyl transpeptidase [γ-GTP], hemoglobin A1c [HbA1c], and creatinine), and peripheral blood cell counts were obtained preoperatively and at every hospital visit for up to 5 years after LSG. The estimated glomerular filtration rate (eGFR) was calculated from the serum creatinine (Cre) values using the following equation:

For male patients, eGFR (mL/min/1.73 m^2) = 194 × [Cre]$^{-1.094}$ × [Age]$^{-0.287}$.

For female patients, eGFR (mL/min/1.73 m^2) = 194 × [Cre]$^{-1.094}$ × [Age]$^{-0.287}$ × 0.789.[11]

The microalbumin concentration in urine samples was measured preoperatively. The %TWL was calculated using the following equation:

%TWL = ([Preoperative weight] − [current weight])/[Preoperative weight] × 100.

Postsurgical patient management

The detailed LSG procedure has been previously described.[12] After undergoing LSG, patients were placed in the intensive care unit overnight to monitor their vital signs. Patients were usually discharged on the fourth postoperative day with proper dietary instructions from dieticians, and proton pump inhibitors were continued for at least 6 months. Follow-up visits were scheduled at 6, 9, 12, 18, and 24 months and annually thereafter. Laboratory evaluation and weight measurements were performed at each visit.

Statistical analyses

All statistical analyses were conducted using the R project (version 2.3-0) with EZR on the R commander (version 1.35). Continuous variables were shown as means and standard deviations (SD) or medians and interquartile ranges, whereas categorical variables were shown as numbers and percentages. Parametric data were compared using the unpaired Student's *t*-test, whereas nonparametric data were analyzed using the Mann-Whitney U test. Categorical variables were compared using the chi-square test. One-way ANOVA test was used to compare three parametric data. Multiple logistic regression analysis was performed to build a model to predict IWL at 3 months after LSG. Clinical variables with $p < 0.10$ in the comparison were included as explanatory variables. The response variables, namely, %TWL ≤ 10% and %TWL ≥ 20%, were assigned numerical numbers 0 and 1, respectively. The receiver operating characteristic (ROC) curve was used to determine %TWL ≤ 10% at 3 months after LSG. A two-sided p-value < 0.05 was set as statistical significance.

Results

Patient's background and their weight-loss tracking after LSG

Among the 198 patients, 34 (%TWL ≤ 10%), 138 (%TWL = 10% to 20%), and 26 (%TWL ≥ 20%) patients were identified. The consecutive %TWL values after LSG with %TWL ≤ 10% patients were as follows: 3 months, 7.8% ± 1.8%; 6 months, 10.7% ± 4.1%; 1 year, 12.3% ± 5.7%; 3 years, 5.7% ± 11.0%; and 5 years, 0.3% ± 11.3%. The consecutive %TWL values after LSG with %TWL = 10%-20% patients were as follows: 3 months, 14.8% ± 2.5%; 6 months, 10.6% ± 4.1%; 1 year, 22.3% ± 8.4%; 3 years, 18.1% ± 9.5%; and 5 years, 14.4% ± 8.7%. The consecutive %TWL values after LSG with %TWL ≥ 20% patients were as follows: 3 months, 22.2% ± 3.5%; 6 months, 27.7% ± 4.3%; 1 year, 31.5% ± 8.6%; 3 years, 27.0% ± 10.9%; and 5 years, 15.7% ± 2.1%. In the comparison of the consecutive %TWL values between three groups, %TWL ≤ 10% patients indicated significant less weight loss after LSG up to 5 years (p-value < 0.01 at 3 months, 6 months, 1 year, 3 years, and 5 years). Patients' backgrounds were compared among the groups, and the %TWL ≤ 10% group included significantly older patients (%TWL ≤ 10%, 50.1 ± 9.8 years old; %TWL = 10%-20%, 44.1 ± 9.3 years old; and %TWL ≥ 20%, 39.4 ± 9.8 years old; p < 0.01). The male-to-female ratio and initial weight were comparable among the groups (Table 1). The three groups revealed linear weight loss until 1 year and maximum weight loss at 1 year after LSG. After 1 year, each group experienced gradual WR and the %TWL ≤ 10% group returned to preoperative weight at 5 years (Fig. 1). The subgrouping with %TWL at 3 months clearly differentiated weight loss after LSG, and the %TWL ≤ 10% group was renamed as IWL and %TWL ≥ 20% as good responder (GR) for the following analysis.

Weight loss subgroup analysis after LSG

Preoperative clinical variables were compared between IWL and GR. In the IWL and GR groups, patients' ages (50.1±9.8 vs. 39.4±9.8 years, respectively, $p < 0.01$), serum albumin concentration (4.1±0.5 vs. 4.4±0.4 g/dL, respectively, $p = 0.02$), and serum GPT concentrations (26 [18-40] vs. 36 [24-57] IU/L, respectively, $p = 0.02$) showed significant differences. Although the initial BMI, serum CRP, hemoglobin, HbA1c, and estimated GFR levels showed no significant statistical differences between the groups (p-values: 0.08, 0.06, 0.07, 0.06, and 0.06 respectively), along with patients' age, serum albumin, and GPT, these values were included as independent variables in a following multiple logistic regression analysis to predict IWL (Table 2). Only patient age was the variable that showed a significant difference in the multiple logistic regression analysis (β = −0.02, $p = 0.02$; Table 3). ROC curve analysis revealed that patient age of 47 years was the optimal cutoff value

Table 1 Subgrouping laparoscopic sleeve gastrectomy patients according to percentage total weight loss at 3 months after surgery

	Total	%TWL ≦ 10%	%TWL 10%-20%	%TWL ≧ 20%	*p*-value
n	198	34	138	26	
Gender					
Female (%)	105 (52%)	18 (52%)	72 (52%)	15 (57%)	
Male (%)	95 (48%)	11 (48%)	66 (48%)	11 (43%)	0.87 *1)
Age (years)	44.6 ± 9.8	50.1 ± 9.8	44.1 ± 9.3	39.4 ± 9.8	< 0.01 *2)
Initial weight (kg)	113.6 ± 25.2	112.6 ± 24.3	114.7 ± 25.9	107.4 ± 22.9	0.388
%TWL (n)					
3 months	14.4% ± 4.4% (192)	7.8% ± 1.8% (34)	14.8% ± 2.5% (138)	22.2% ± 3.5% (26)	< 0.01 *2)
6 months	18.9% ± 6.7% (176)	10.7% ± 4.1% (27)	10.6% ± 4.1% (126)	27.7% ± 4.3% (23)	< 0.01 *2)
1 year	22.1% ± 9.5% (156)	12.3% ± 5.7% (22)	22.3% ± 8.4% (113)	31.5% ± 8.6% (21)	< 0.01 *2)
3 years	17.5% ± 10.9% (76)	5.7% ± 11.0% (9)	18.1% ± 9.5% (59)	27.0% ± 10.9% (8)	< 0.01 *2)
5 years	12.5% ± 9.8% (48)	0.3% ± 11.3% (6)	14.4% ± 8.7% (38)	15.7% ± 2.1% (4)	< 0.01 *2)

%TWL, percentage total weight loss. *p-value< 0.05 is statistically significant. 1) Chi-square test and 2) one-way ANOVA test.

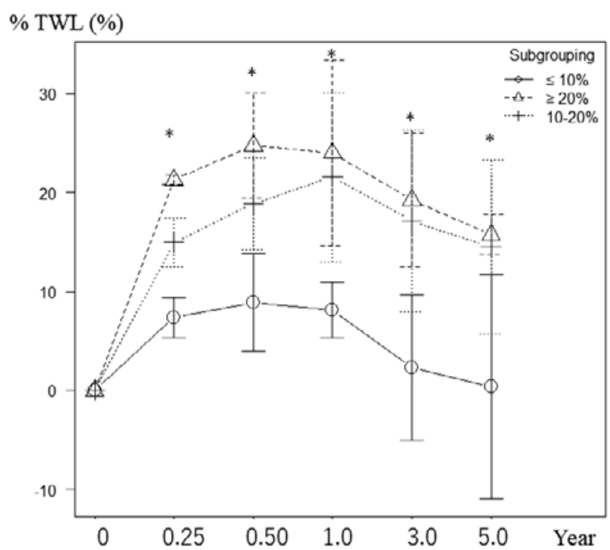

Fig. 1 Weight-loss tracking after laparoscopic sleeve gastrectomy.
The average percentage total weight loss (%TWL) is shown at each following period (0.25 year, 0.5 year, 1 year, 3 years, and 5 years) after laparoscopic sleeve gastrectomy (LSG), stratified by the %TWL at 3 months (0.25 year) after LSG; ≤ 10%, 10%-20%, and ≧ 20%. The results are mean ± SD. Statistical significance was determined using the one-way ANOVA test. *p< 0.01.

for predicting IWL (area under the ROC curve, 0.781; 95% confidence interval, 0.659-0.903; specificity, 64.7%; and sensitivity, 84.6%; Fig. 2).

Discussion

The prevalence of IWL after LSG has been reported to range from 20% to 40% without clear definitions.[13–15] In a previous study, an excess weight loss of < 50% at 18 months[16] or %TWL of < 20% at 24 months was reported as IWL.[17] In this current study, we defined %TWL ≤ 10% at 3 months after LSG as an IWL surrogate definition based on our finding of the successful subgrouping of long-term weight loss achievement using the definition. Using our definition, 17% of patients who underwent LSG experienced IWL. One advantage of this definition is its ability to detect IWL at an early stage after LSG. Early IWL prediction could help surgeons to consult their patients regarding weight loss failure and the possibility of additional interventions, such as revision surgery, at the earliest opportunity. Fortunately, promising results of LSG-to-bypass conversion surgery, with additional weight loss and acceptable complication rates, have been reported recently.[18, 19] According to these reports, patients with IWL could anticipate an additional weight loss of approximately 20% of the %TWL. This result is encouraging, especially for Japanese patients whose primary surgery is LSG.

Previous randomized controlled studies have shown that weight-loss power is comparable between LSG and gastric bypass procedures for up to 5 years after surgery.[20, 21] However, gastric bypass procedures result in greater weight loss in patients with super-obesity (BMI ≥ 50 kg/m^2).[22] Unfortunately, we did not perform sufficient bypass cases to determine the weight-loss effect. However, randomized controlled studies comparing LSG and gastric bypass procedure should be conducted to optimize primary surgery in Japanese patients.

Table 2 Comparison of clinical variables between the insufficient weight loss and good responder groups

	IWL (n = 34)	GR (n = 26)	*p*-value
Age (years)	50.1 ± 9.8	39.4 ± 9.8	< 0.01 ** 1)
BMI (kg/m^2)	44 ± 7.3	40.6 ± 7.3	0.08 * 1)
TP (g/dL)	7.6 ± 1.1	7.7 ± 0.5	0.72 1)
Albumin (g/dL)	4.1 ± 0.5	4.4 ± 0.4	0.02 ** 1)
CRP (mg/dL)	0.7 [0.4-1.5]	0.5 [0.2-0.9]	0.06 * 1)
Peripheral blood cells			
WBC ($\times 10^3/\mu L$)	6.8 [5.9-8.1]	7.1 [6.2-8.7]	0.56 2)
Neutrophil (%)	63.4 ± 8.4	62.6 ± 7.3	0.71 1)
Lymphocyte (%)	27.0 ± 8.7	29.1 ± 6.1	0.31 1)
Hemoglobin (g/dL)	14.0 ± 1.9	14.8 ± 1.3	0.07 * 1)
Platelet ($\times 10^4/\mu L$)	25.8 ± 7.2	27.1 ± 6.3	0.45 1)
Liver enzymes			
GOT (IU/L)	25 [18-34]	25 [22-37]	0.18 2)
GPT (IU/L)	26 [18-40]	36 [24-57]	0.02 ** 2)
γ-GPT (IU/L)	32 [23-47]	34 [25-52]	0.53 2)
HbA1c (%)	6.8 ± 1.8	6.2 ± 0.7	0.06 * 1)
Kidney functions			
Creatinine (mg/dL)	0.67 [0.57-0.99]	0.71 [0.60-0.83]	0.81 2)
Microalbumin (mg/g Cr)	7.4 [5.2-19]	7.4 [3.7-15]	0.59 2)
eGFR (mL/min/1.73 m^2)	74 [51-87]	86 [73-95]	0.06 * 2)

IWL, insufficient weight loss; GR, good responder; BMI, body mass index; TP, total protein; CRP, C-reactive protein; WBC, white blood cell; GOT, glutamic oxaloacetic transaminase; GPT, glutamic pyruvic transaminase; γ-GTP, gamma-glutamyl transferase; HbA1c, hemoglobin A1c; eGFR, estimated glomerular filtration rate. Statistical significance was set at $p < 0.05$ (*). $p < 0.10$ variables were included in the multiple logistic regression analysis as explanatory variables. 1) Unpaired Student's t-test and 2) Mann-Whitney U test.

Table 3 Multiple logistic regression analysis to predict insufficient weight loss or good responders after laparoscopic sleeve gastrectomy

Explanatory variables	β	*p*-value
Age (years)	0.09	0.04 *
BMI (kg/m^2)	0.06	0.29
Albumin (g/dL)	0.74	0.45
CRP (mg/dL)	0.95	0.15
Hemoglobin (g/dL)	−0.23	0.31
GPT (IU/L)	−0.02	0.27
HbA1c (%)	0.42	0.29
eGFR (mL/min/1.73 m^2)	−0.01	0.49

The response variables insufficient weight loss (IWL) and good responders (GR) as categorical variables were assigned numerical numbers 0 and 1, respectively. β, regression coefficient estimates; BMI, body mass index; CRP, C-reactive protein; GPT, glutamic pyruvic transaminase; HbA1c, hemoglobin A1c; eGFR, estimated glomerular filtration rate. Statistical significance was set at $p < 0.05$ (*).

The LSG outcomes in older adult patients are controversial. Some studies have indicated comparable weight-loss outcomes regardless of patient age.[23, 24] However, other reports have revealed less weight loss among older adults.[25, 26] Several studies have shown that patient age is an indicator of IWL.[27–30] In line with these findings, our study also showed that patient's age is the predictor of IWL. In addition, patient age, particularly age over 47 years, is a cutoff age for defining IWL, suggested by the result from the ROC analysis. When treating this patient group, adding promising antiobesity medications such as GLP-1 analogs could be used as LSG enhancement treatment. In the future, it is intriguing to conduct prospective research to investigate the additional weight-loss power of antiobesity medications on LSG for an IWL candidate. It is noteworthy to emphasize that this study is the first study to define IWL for Japanese patients who underwent LSG and to discover the patients' age as a practical indicator of IWL.

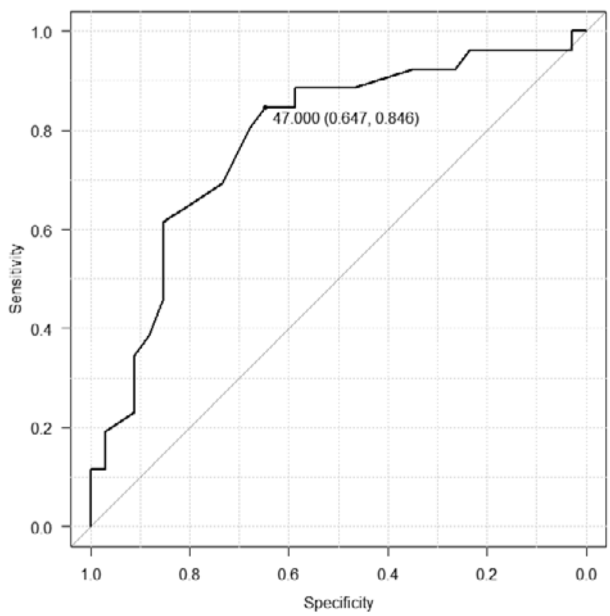

Fig. 2 ROC curve of patient age with insufficient weight loss at 3 months after laparoscopic sleeve gastrectomy. Patient age at 47 years is the optimal cutoff value for predicting IWL (area under the ROC curve, 0.781; 95% confidence interval, 0.659-0.903; specificity, 64.7%; and sensitivity, 84.6%).

Limitations of the study

Our study had several limitations. This was a retrospective, single-center study with a relatively small number of patients. Multicenter studies with an adequate number of cases and a prospective design are required to draw concrete conclusions and establish a model to predict IWL.

Conclusions

To track the weight-loss pathway of LSG, a clinically relevant definition of IWL as %TWL $\leq$ 10% was proposed. Using this definition, patient age was identified as an IWL predictor. This finding could facilitate the early recognition of IWL and early treatment interventions in the future. In particular, patient over 47-year-old would face difficulty in terms of effective weight loss after LSG. These patients would be benefited by receiving additional antiobesity treatment to optimize weight-loss outcomes.

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Ethics statement: The study protocol was approved by the Ethics Committee of Toho University Sakura Medical Center (#S22033). Written informed consent was obtained from all participants involved in the study. All procedures involving human participants were performed in accordance with the ethical standards of the Institutional Research Committee and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Details regarding the research were disclosed on the institutional website, and potential participants were given the opportunity to opt out.

Conflicts of interest: None declared.

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