

Nomogram for Predicting Suboptimal Weight Loss at Three Years after Roux-en-Y Gastric Bypass Surgery in Chinese Patients with Obesity and Type 2 Diabetes

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Key Points

- Male sex, low body mass index score, and high glycated hemoglobin levels at baseline are predictors of the occurrence of insufficient weight loss (IWL) or weight regain (WR).
- The nomogram accurately predicted 3-year IWL or WR after LRYGB.
- The model provided a convenient tool for predicting IWL/WR before surgery.

Keywords

Roux-en-Y gastric bypass · Suboptimal weight loss · Insufficient weight loss · Weight regain · Nomogram

Abstract

Introduction: Strategies to address suboptimal weight loss after Roux-en-Y gastric bypass (RYGB) can be developed if at-risk patients are identified in advance. This study aimed to build a pre-surgery prediction nomogram for early prediction of insufficient weight loss (IWL) or weight regain (WR) after bariatric surgery in Chinese patients. **Methods:** In this retrospective study, 187 patients with obesity and type 2 diabetes who underwent laparoscopic RYGB were followed yearly for 3 years. Suboptimal weight loss included

IWL and WR. IWL was defined as a total weight loss percentage of <25% at 1 year postoperatively, and WR was defined as a maximum weight loss percentage of >20% at 3 years postoperatively. Multivariate logistic regression was performed to identify independent predictors and to establish a nomogram to predict the occurrence of suboptimal weight loss. **Results:** Multivariate logistic regression revealed that male sex (OR 4.268, 95% CI: 1.413–12.890), body mass index (OR 0.816, 95% CI: 0.705–0.946), and glycated hemoglobin (OR 1.493, 95% CI: 1.049–2.126) were independent predictors of IWL/WR. The AUC value of the nomogram constructed from the above three factors was 0.781. The Hosmer-Lemeshow test showed that the model had a good fit ($p = 0.143$). The calibration curve of the nomogram is close to an ideal diagonal line. Furthermore,

the decision curve analysis demonstrated the good net benefits of the model. **Conclusions:** A nomogram based on pre-surgery factors was developed to predict postoperative IWL/WR. This provides a convenient and useful tool for predicting suboptimal weight loss before surgery.

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Introduction

Bariatric surgery is an efficient treatment that can result in considerable sustained weight loss in patients with obesity, resolve medical comorbidities associated with obesity, and improve quality of life [1, 2]. Today, Roux-en-Y gastric bypass (RYGB), sleeve gastrectomy, and adjustable gastric banding are the most popular and commonly performed bariatric surgeries [3]. However, weight loss trajectories after bariatric surgery are not uniform, and some patients do not achieve or are unable to maintain their expected weight loss. There are two types of suboptimal weight loss: insufficient weight loss (IWL) and weight regain (WR) [4–6]. Suboptimal weight loss is often related to the progression or recurrence of associated medical problems and a decline in the health-related quality of life [7]. However, the etiology and underlying mechanisms of IWL and WR remain unclear.

The contributing factors for IWL/WR are poorly understood, are likely multifactorial, and may include baseline physiology and psychology, socioeconomic status, anatomy, or postoperative behavior [7–9]. An important question is whether baseline demographic or clinical characteristics predict the optimal or suboptimal weight loss. Identifying preoperative factors that affect the occurrence of IWL/WR is clinically significant [10]. By assessing the suboptimal weight loss risks of patients before surgery, clinicians can identify “high-risk” patients, educate the patients about procedures best suited for them, and make better management plans for the specific patient to prevent the occurrence of IWL/WR. However, to date, there have been few reports on the correlation between preoperative clinical factors and postoperative IWL/WR [10], and no risk prediction model for preoperative factors has been established to predict the occurrence of IWL or WR. Nomograms have been widely used as a simple statistical visual tool to predict the occurrence, development, prognosis, and survival of diseases in recent years [11–13]. This retrospective study aimed to establish a predictive nomogram for postoperative

suboptimal weight loss by incorporating the baseline clinical factors in patients with obesity and type 2 diabetes (T2D) who underwent laparoscopic RYGB.

Methods

Study Design and Population

This retrospective study included patients with obesity and T2D who underwent laparoscopic RYGB between February 2011 and January 2020. The inclusion criteria were as follows: diagnosis of T2D according to the 2010 ADA criteria [14], body mass index (BMI) ≥ 27.5 kg/m², age ≥ 18 years. The exclusion criteria were as follows: patients with incomplete baseline or follow-up information at 3 years postoperatively, patients who missed assessment at more than one follow-up, and patients who underwent revisional procedures. All participants were randomly divided into training and validation cohorts in a 1:1 ratio for model development and verification.

Data Collection

Medical history, age, height, weight, waist circumference, hip circumference, blood pressure, and current medications were recorded before surgery and at 6 months, 1 year, 2 years, and 3 years after surgery. BMI was calculated as weight (kg)/height² (m²). Data on the duration of diabetes were collected before surgery according to the date of diagnosis in the patient’s previous clinical records. Fasting plasma glucose (FPG), fasting C-peptide (FCP), glycated hemoglobin (A1C), total cholesterol, triglycerides, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, alanine aminotransferase, aspartate aminotransferase, blood urea nitrogen, serum creatinine, and C-reactive protein levels were measured preoperatively [15]. The homeostasis model assessment of beta-cell function (HOMA2-% β) and insulin resistance (HOMA2-IR) were calculated from FCP and FPG with HOMA calculator version 2.2.3 software [16] (Diabetes Trials Unit, University of Oxford, <https://www.dtu.ox.ac.uk/homacalculator>).

Definitions

IWL was defined as total weight loss percentage (%TWL) $< 25\%$. %TWL = $100 \times (\text{pre-surgery weight} - 1\text{-year post-surgery weight}) / \text{pre-surgery weight}$ [17]. WR was defined as maximum weight loss percentage (%MWL) $\geq 20\%$. %MWL = $100 \times (\text{maximum weight postnadir weight} - \text{nadir weight}) / (\text{pre-surgery weight} - \text{nadir weight})$. The maximum weight, post-nadir weight, and nadir weight definitions are described in a previous study [18].

Suboptimal weight loss was defined as patients who underwent IWL 1-year post-surgery or WR 3-year post-surgery. The percentage of excess weight loss (%EWL) = $([\text{Initial weight}] - [\text{Postoperative weight}] / ([\text{Initial weight}] - [\text{Ideal weight}])$ (in which ideal weight is defined by the weight corresponding to a BMI of 25 kg/m²).

Development and Assessment of the Nomogram

Univariate logistic regression analysis was performed to identify the potential predictors of IWL/WR after RYGB. All potential predictors (p value <0.05) in the univariate analysis were included in the multivariate analysis. Multivariate logistic regression analysis was performed to identify independent predictors, and a stepwise method was used to identify a useful combination of factors that could most precisely predict IWL/WR. The variance inflation factor was used to detect the presence of multicollinearity among variables included in the regression model. A nomogram of the IWL/WR was created based on a multivariate logistic regression model.

Receiver operating characteristic (ROC) curve analysis was used to compare the predictions concerning accuracy and precision. Nomogram performance was evaluated using the concordance index (area under the ROC curve [AUC]) and calibration plots with bootstrap samples. Calibration was validated based on Hosmer-Lemeshow goodness-of-fit tests. A Hosmer-Lemeshow goodness-of-fit test with a p value >0.05 was considered to indicate good calibration consistency between predicted IWL/WR by the model and observed suboptimal weight loss. Additionally, decision curve analysis (DCA) reflected the net benefit of the model for patients.

Statistical Analysis

Continuous variables were presented as mean $\pm$ standard deviation, and skewed distributed data were presented as median (interquartile range). Categorical variables were presented as frequencies (percentages). Paired t tests were used for normally distributed variables to compare the two groups, whereas the Mann-Whitney U test was used for non-normally distributed variables. The chi-square test was used to compare categorical variables between the groups. Shapiro-Wilk normality tests and histograms were used to verify whether the continuous variables had a normal distribution. All statistical analyses were performed using IBM SPSS Statistics 24.0 (IBM Corp., Armonk, NY, USA) and R statistical software (R Foundation for Statistical Computing, Vienna, Austria) with “rms,” “pROC,” “ggplot2,” and “dca” packages. All statistical tests were two-sided, and a p value <0.05 was considered significant.

Results

Patient Characteristics

A total of 187 eligible subjects were involved, including 86 males and 101 females, with a mean age of 47 ± 12 years, and mean values of 6.9 ± 4.9 years, 31.8 ± 3.4 kg/m², of $8.3 \pm 1.9\%$, 105.8 ± 10.0 cm, and 3.0 ± 0.8 mmol/L for duration of diabetes, BMI, A1C, waist circumference, and LDL, respectively. In addition, 157 subjects (84.0%) completed all five follow-up visits over 3 years. Specifically, the assessment was obtained in 171 of 187 participants (91.5%) at the 6-month follow-up, 187 of 187 participants (100%) at the 1-year follow-up, 173 of 187 participants (92.6%) at the 2-year follow-up, and 187 participants (100%) at the 3-year follow-up. During the 3-year follow-up, 114 individuals (60.9%) experienced IWL, 83 (44.3%) experienced WR, and 136 (72.7%) experienced either IWL or WR. The dataset was randomly divided into the training ($n = 94$) and validation ($n = 93$) cohorts. Table 1 shows that the occurrence rates of IWL/WR between the two groups were 72.3% and 73.1%, with no statistically significant differences ($p = 1.000$). Additionally, there were no statistically significant differences between the two groups in terms of age, sex, duration of diabetes, BMI, blood pressure, A1C, or other variables listed in Table 1.

Risk Prediction Nomogram Development

Univariate analysis was used to evaluate the relationship between baseline clinical factors and the occurrence of IWL/WR. Clinical factors included sex, age, diabetes duration, BMI, waist circumference, hip circumference, SBP, DBP, A1C, FPG, FCP, HOMA2-% β , HOMA2-IR, total cholesterol, triglycerides, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, alanine aminotransferase, aspartate aminotransferase, blood urea nitrogen, serum creatinine, C-reactive protein, use of hypoglycemic agents, use of insulin, history of hypertension, and history of hyperlipidemia. BMI score, A1C and FPG levels, and sex were significantly associated with IWL/WR (Table 2). Next, we performed multivariate logistic regression analysis with these associated factors using a stepwise method. The results suggested that male sex (OR 4.268, 95% confidence interval [CI]: [1.413–12.890], $p = 0.010$), BMI (OR 0.816, 95% CI: [0.705–0.946], $p = 0.007$), and A1C (OR 1.493, 95% CI: [1.049–2.126], $p = 0.026$) were independent influential factors and that a combination of these factors most precisely predicted IWL/WR (Table 2). Furthermore, the collinearity diagnostic analysis demonstrated that the variance inflation factors of those risk factors were less than 2, indicating that there is no strong indication of multicollinearity among variables.

Table 1. Baseline characteristics of RYGB patients in the training and validation cohorts

Variable	Training cohort (n = 94)	Validation cohort (n = 93)	p value
Women, n (%)	50 (53.1)	51 (54.8)	0.884
Age, years	48±11	47±12	0.464
Diabetes duration, years	7.1±5.0	6.7±4.8	0.616
BMI, kg/m ²	31.7±3.4	31.8±3.3	0.839
Waist circumference, cm	105.5±9.5	106.1±10.6	0.723
Hip circumference, cm	108.1±9.1	108.3±9.2	0.865
SBP, mm Hg	130 (120–140)	130 (120–140)	0.191
DBP, mm Hg	80 (78–90)	84 (80–90)	0.181
HbA _{1c} , %	8.4±1.9	8.3±2.0	0.743
FPG, mmol/L	8.4±2.4	8.4±3.0	0.969
FCP, ng/mL	2.8±1.4	2.8±1.3	0.824
HOMA2-%β	163.2±89.0	182.1±105.8	0.190
HOMA2-IR	7.2±3.7	7.3±3.3	0.854
TG, mmol/L	1.9 (1.4–2.6)	2.1 (1.5–3.1)	0.309
TC, mmol/L	5.0±1.1	5.3±1.4	0.138
LDL-c, mmol/L	3.0±0.8	3.0±0.9	0.861
HDL-c, mmol/L	1.0±0.2	1.0±0.2	0.599
ALT, U/L	35.5±22.1	32.6±20.9	0.369
AST, U/L	25.3±14.0	25.6±16.3	0.910
BUN, mmol/L	5.1±1.5	4.9±1.3	0.399
Cr, μmol/L	63.0±16.6	62.5±20.7	0.866
CRP	3.0 (1.2–4.0)	2.0 (1.1–4.1)	0.998
Hypoglycemic agents use, n (%)	90 (95.7)	86 (92.4)	0.372
Insulin use, n (%)	44 (46.8)	45 (48.3)	0.884
Hypertension, n (%)	63 (67.0)	50 (53.7)	0.074
Hyperlipidemia, n (%)	72 (76.5)	70 (75.2)	0.865
MWL, %	18.7±17.0	19.7±15.7	0.659
TWL, %	22.4±6.7	23.8±6.8	0.153
WR, n (%)	39 (41.4)	44 (47.3)	0.463
IWL, n (%)	60 (63.8)	54 (58.0)	0.456
IWL/WR, n (%)	68 (72.3)	68 (73.1)	1.000

Data are expressed as mean ± standard deviation, median (interquartile range) or n (%). BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA_{1c}, glycated hemoglobin A1c; FPG, Fasting plasma glucose; FCP, fasting C-peptide; HOMA2-%β, homeostasis model assessment 2 for β-cell function; HOMA2-IR, homeostasis model assessment 2 of insulin resistance; TG, triglyceride; TC, total cholesterol; LDL-c, low-density lipoprotein cholesterol; HDL-c, high-density lipoprotein cholesterol; ALT, alanine transaminase; AST, aspartate aminotransferase; BUN, blood urea nitrogen; Cr, creatinine; CRP, C-peptide response; MWL, maximum weight loss; TWL, total weight loss; WR, weight regain; IWL, insufficient weight loss.

Table 2. Univariate and multivariate logistic regression analyses of IWL/WR for nomogram

Variable	Univariate analysis		Multivariate analysis	
	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value
Gender (male vs. female)	4.222 (1.507–11.830)	0.006	4.268 (1.413–12.890)	0.010
Age (years)	1.005 (0.964–1.047)	0.826		
Diabetes duration (years)	1.056 (0.958–1.164)	0.276		
BMI (kg/m ²)	0.842 (0.736–0.965)	0.013	0.816 (0.705–0.946)	0.007
Waist circumference (cm)	0.977 (0.932–1.023)	0.321		
Hip circumference (cm)	0.951 (0.904–1.001)	0.053		
SBP (mm Hg)	0.985 (0.952–1.019)	0.385		
DBP (mm Hg)	0.985 (0.937–1.036)	0.558		
HbA _{1c} (%)	1.389 (1.019–1.893)	0.038	1.493 (1.049–2.126)	0.026
FPG (mmol/L)	1.402 (1.098–1.789)	0.007		
FCP (ng/mL)	0.996 (0.714–1.391)	0.982		
HOMA2-%β	1.000 (0.999–1.001)	0.243		
HOMA2-IR	0.994 (0.861–1.148)	0.935		
TC (mmol/L)	0.997 (0.993–1.001)	0.186		
TG (mmol/L)	1.394 (0.907–2.145)	0.130		
HDL-c (mmol/L)	1.138 (0.019–1.018)	0.052		
LDL-c (mmol/L)	0.576 (0.318–1.042)	0.068		
ALT (U/L)	1.066 (0.985–1.028)	0.588		
AST (U/L)	1.017 (0.978–1.056)	0.399		
BUN (mmol/L)	0.882 (0.648–1.201)	0.426		
Cr (μmol/L)	1.024 (0.992–1.058)	0.143		
CRP	1.012 (0.885–1.199)	0.888		
Hypoglycemic agents (nonuse vs. use)	1.154 (0.115–11.621)	0.903		
Insulin (nonuse vs. use)	0.499 (0.195–1.275)	0.146		
Hypertension	1.481 (0.545–4.021)	0.441		
Hyperlipidemia	1.026 (0.352–2.992)	0.963		

IWL, insufficient weight loss; WR, weight regain; OR, odds ratio; CI, confidence interval; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA_{1c}, glycated hemoglobin A1c; FPG, Fasting plasma glucose; FCP, fasting C-peptide; HOMA2-%β, homeostasis model assessment 2 for β-cell function; HOMA2-IR, homeostasis model assessment 2 of insulin resistance; TG, triglyceride; TC, total cholesterol; LDL-c, low-density lipoprotein cholesterol; HDL-c, high-density lipoprotein cholesterol; ALT, alanine transaminase; AST, aspartate aminotransferase; BUN, blood urea nitrogen; Cr, creatinine; CRP, C-peptide response.

A nomogram for IWL/WR was created based on these three factors (Fig. 1). The Hosmer-Lemeshow χ^2 value was 12.179 ($p = 0.143$), indicating a good fit for the model. In the training cohort, the AUC was 0.781 (95% CI: [0.681–0.880]), with a significant p value of 0.000 (Fig. 2a). The calibration curve is close to the ideal diagonal line (Fig. 2b). Furthermore, DCA demonstrated a better net benefit in the predictive model (Fig. 2c).

Validation of the Nomogram

The predictive accuracy and consistency of the nomograms were tested in the validation cohort. The AUC was 0.737 (95% CI: [0.635–0.839]), reflecting the good accuracy of the nomogram (Fig. 3a). Additionally, the model showed good consistency, and the calibration curve of the validation cohort was close to the ideal diagonal line (Fig. 3b). Moreover, DCA showed a

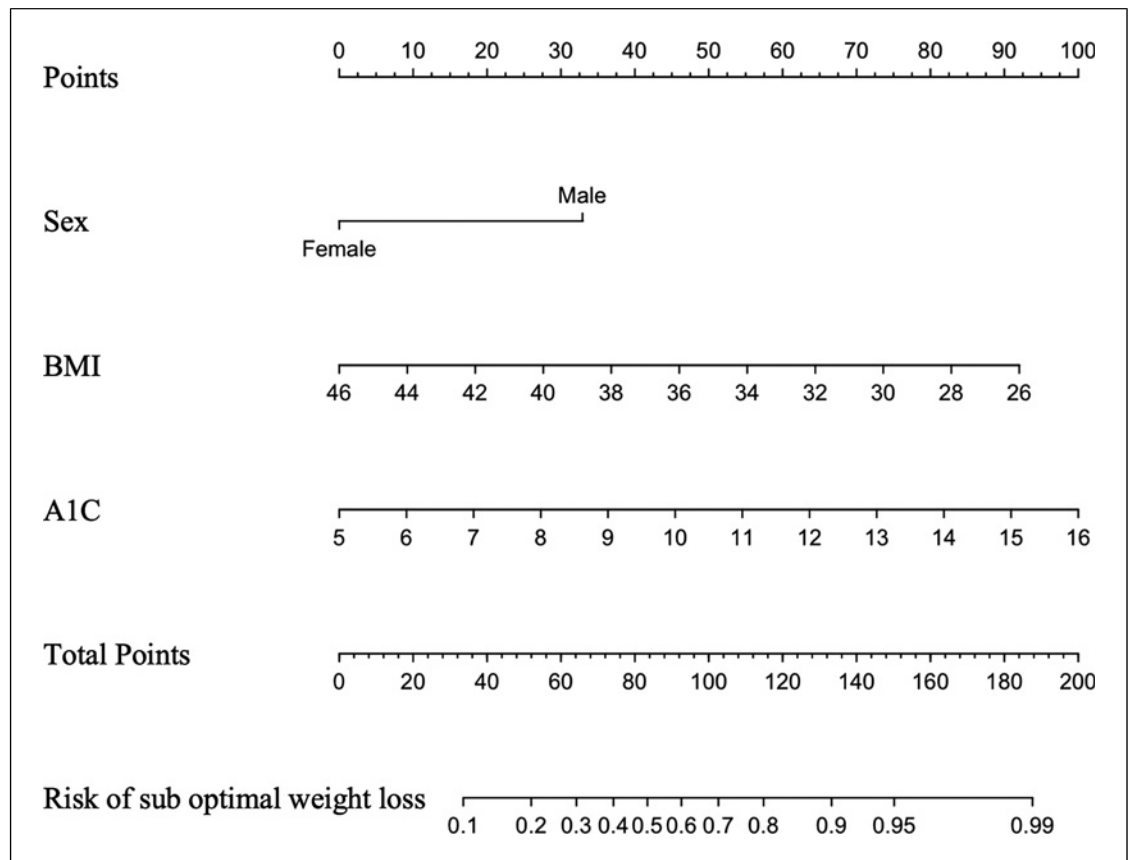


Fig. 1. Nomogram for predicting IWL/WR after RYGB in Chinese patients with obesity and T2D. To estimate the probability of IWL/WR, we marked the patient values on each axis: draw a straight line perpendicular to the point axis, and sum the points for all variables. Next, the sum is marked on the total point axis, and a straight line is drawn perpendicular to the probability axis. IWL, insufficient weight loss; WR, weight regain; RYGB, Roux-en-Y gastric bypass; T2D, type 2 diabetes.

significant net benefit in the predictive model, as well as in the validation cohort (Fig. 3c). These data demonstrate that our nomogram has significant potential for clinical decision-making.

Discussion

In this study, we developed a stepwise regression model for the occurrence of IWL/WR using baseline clinical factors. Our study suggests that male sex, low BMI score, and high A1C levels at baseline are predictors of the occurrence of IWL/WR 3 years after bariatric surgery. To the best of our knowledge, this study is the first to establish a nomogram for accurately predicting suboptimal weight loss after laparoscopic RYGB in patients with obesity and T2D.

The clinical significance of IWL and WR has been poorly investigated because of the lack of standardized definitions for IWL and WR [19]. Our research group conducted preliminary studies to standardize the measurement of weight loss and WR after bariatric surgery in Chinese patients with obesity. The IWL was assessed by comparing the percentage of %TWL and the percentage of %EWL to predict metabolic syndrome remission 1 year after bariatric surgery in 430 patients. The results showed that poor responders to bariatric surgery should be defined as those with %TWL <25% [17]. Additionally, a recent study found that WR, quantified as the %MWL, predicted glycemic metabolism deterioration 3 years after bariatric surgery better than other parameters in Chinese patients with obesity and T2D. The optimal cutoff point was 20% [18]. Although IWL and WR have different suboptimal

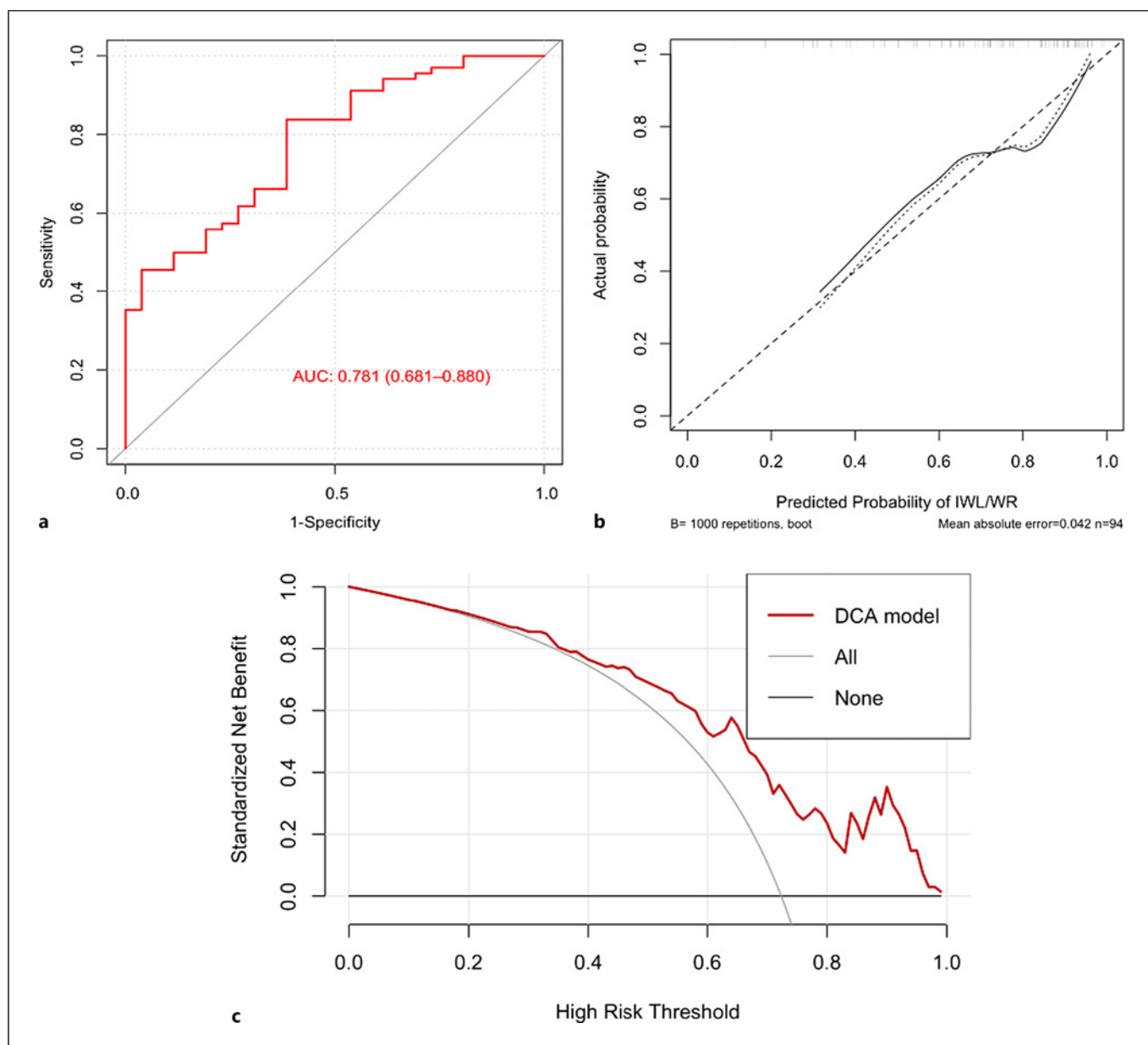


Fig. 2. The performance of the prediction model in the training cohort. **a** ROC curves for the prediction model. **b** Calibration curve of the prediction model. **c** Decision curve analysis in prediction of IWL/WR. ROC, receiver operating characteristic; AUC, area under the ROC curve; IWL, insufficient weight loss; WR, weight regain.

weight loss outcomes after bariatric surgery, patients in both situations require more attention [20]. Therefore, patients at high risk for both outcomes should be identified preoperatively to help achieve long-term successful weight loss as much as possible.

Given the prevalence of obesity and the effectiveness and acceptance of bariatric surgery as a therapeutic strategy for obesity, the maintenance of weight loss, and

sustained metabolic symptom remission after surgery are currently major clinical concerns. Therefore, IWL and WR after bariatric surgery need to be adequately studied and interpreted so that subsequent management strategies can be developed to prevent adverse outcomes such as negative emotions, decreased quality of life, and comorbidity recurrence [7, 21]. Predictive modeling can help solve this problem by determining the correlation

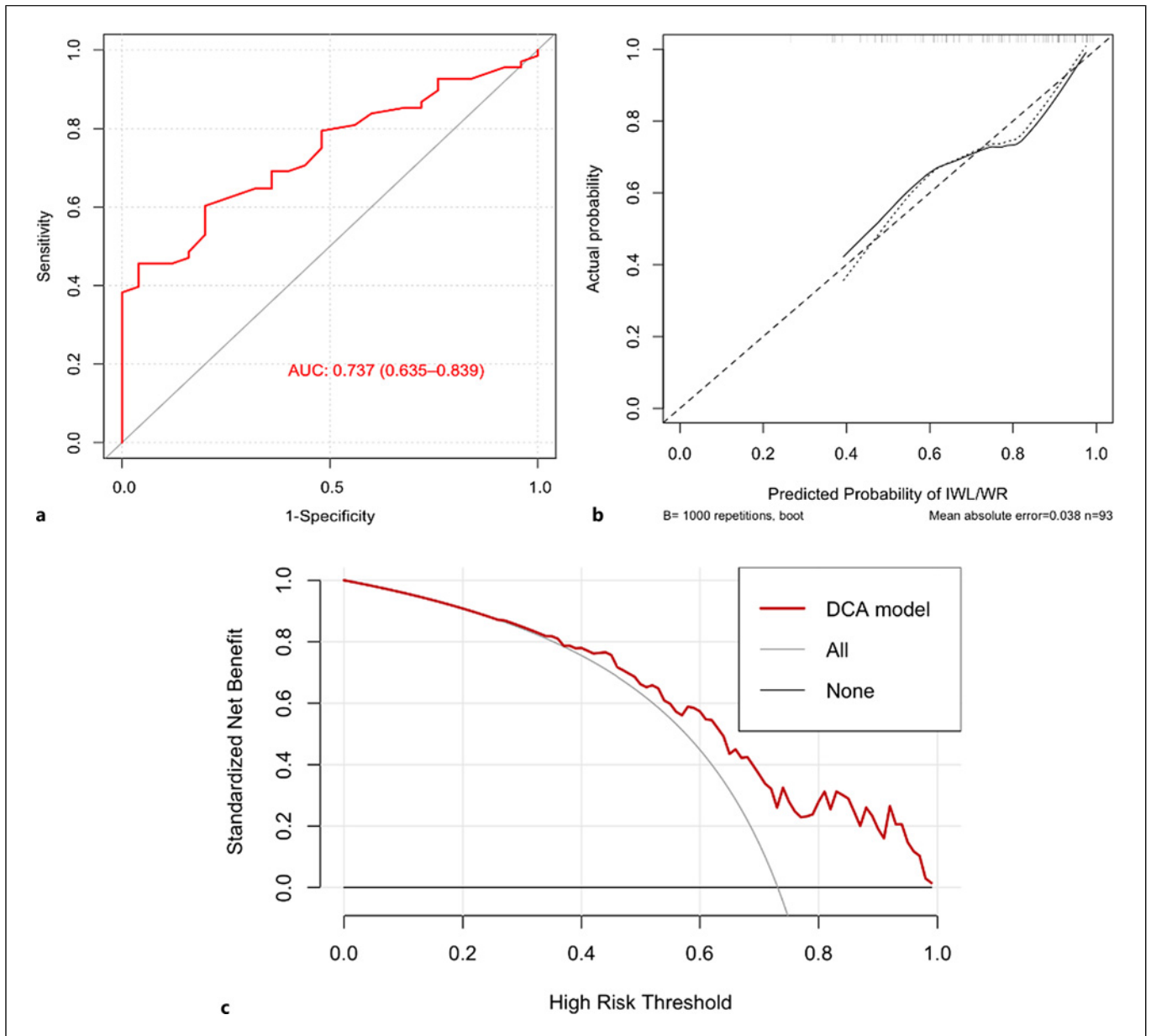


Fig. 3. The performance of the prediction model in the validation cohort. **a** ROC curves for the prediction model. **b** Calibration curve of the prediction model. **c** Decision curve analysis in prediction of IWL/WR. ROC, receiver operating characteristic; AUC, area under the ROC curve; IWL, insufficient weight loss; WR, weight regain.

between preoperative factors and future weight loss. This knowledge gained through predictive modeling can help doctors immensely, as once high-risk patients are identified, doctors can start a more targeted approach and warn patients of the risks of IWL/WR. This is clinically important for preventing and delaying IWL and WR. In the last few years, technological developments in the surgical field have been rapid and are continuously

evolving. One of the most revolutionizing breakthroughs was the introduction of the IoT concept within surgical practice [22]. The prediction model developed in this study assesses the effect of weight loss after bariatric surgery. In the future, it will be possible to use the IoT to more intelligently and efficiently assess the effect of weight loss on patients after bariatric surgery. The IoT can also remotely guide patients' diet and exercise after

surgery to reduce the incidence of IWL or WR after bariatric surgery.

In our cohort of Chinese patients with obesity and T2D who were followed up for 3 years after laparoscopic RYGB, we observed that baseline BMI score was a clinically important predictor of the occurrence of IWL/WR; lower the baseline BMI score, higher the risk of postoperative IWL/WR. Previous studies on the correlation between baseline BMI score and IWL/WR have yielded inconsistent results [10, 23–26]. A retrospective study by Cottam et al. [10] which included 48 studies found that BMI was one of the most important variables influencing postoperative weight loss. The results indicated that of the 11 relevant studies, 9 suggested a positive correlation between BMI score and IWL, and 2 suggested a negative correlation. This discrepancy may stem from differences in the parameters used to assess weight loss. %EWL was often used to assess weight loss in those studies that concluded a positive correlation, whereas weight or BMI reduction was preferred in those studies that concluded a negative correlation. The use of %TWL [17] as an indicator for assessing IWL in this study may be one of the reasons why baseline BMI score is a negative predictor of IWL. Another systematic review conducted by Livhits et al. [23], which included 115 studies, indicated that the relationship between BMI and the effect of weight loss correlated with baseline BMI score. They found that studies in which BMI was a negative predictor of IWL had a relatively smaller mean baseline BMI score than those with a positive predictor (43 kg/m^2 vs. 47 kg/m^2). Similar conclusions were reached in studies assessing the correlation between WR and baseline BMI after bariatric surgery; that is, the relationship between WR and baseline BMI correlated with the choice of WR parameters [7, 27–29]. A prospective study of T2D patients after RYGB found that lower baseline BMI scores were significantly associated with WR, as assessed using %MWL, which is consistent with our findings [28]. In summary, considering the characteristics of the patients included in our study, the baseline BMI score ($31.8 \pm 3.4 \text{ kg/m}^2$), and the parameters we used to assess IWL and WR, we found that lower baseline BMI was a predictor of postoperative IWL/WR.

In addition, our results showed that higher baseline A1C levels were significant predictors of IWL/WR after surgery. A recent study by Rebelos et al. [30] found that higher baseline A1C levels were associated with postoperative IWL/WR. In addition, many studies have reported that patients with T2D at baseline are more likely to undergo IWL or WR [31–33]. Therefore, it is important to understand the

relationship between T2D and IWL/WR after bariatric surgery. This could shed light on the relationship between glucose metabolism disorders and weight loss, although a direct link between the two has not yet been found. Some possible mechanisms include alterations in hormone secretion, eating habits, satiety, and reward signaling in patients with T2D [30, 34, 35]. Previous studies have shown that patients with T2D have significantly different hormone levels, such as lower adiponectin and glucagon levels and higher ghrelin and leptin levels, compared to control patients. Elevated or decreased levels of these hormones are associated with IWL and WR [36]. Therefore, in agreement with previous studies, we conclude that high A1C levels in patients before RYGB are a risk factor for suboptimal weight loss. Thus, glycemic management before bariatric surgery may have important clinical implications.

The role of sex in weight change after bariatric surgery is complex and multifactorial [36–38]. Few studies have reported increased weight loss in men after bariatric surgery [36]. Most studies concluded that women experience greater weight loss [37], have a lower incidence of WR [38], and are protected against the recurrence of comorbidities [39] after bariatric surgery. The results of a German national survey on bariatric surgery showed significantly higher complication rates in male patients resulting from increased rates of hypertension, T2D, and sleep apnea [39]. Our study also found that the occurrence of IWL/WR was associated with the male sex. One factor that may explain our findings is the sex-related distribution of adiposity. Central adiposity is predominant in male patients, and increased visceral fat has been associated with the development of insulin resistance [40]. In addition, estrogen may have beneficial effects on insulin sensitivity [41]. Differences in adipokine levels, such as higher adiponectin levels, may also contribute to greater insulin sensitivity in women than in men [41]. These factors may explain why men are less likely to lose weight or maintain weight loss after bariatric surgery. The influence of sex requires further investigation to optimize the outcomes of bariatric surgery. More attention should be paid to sex-specific aspects of bariatric surgery indications and surgical modality selection.

This study had some limitations. First, this was a single-center retrospective study with a relatively small sample size, which may have introduced a selection bias. All patients we included were diagnosed with obesity and T2D, to ensure that the backgrounds of the participants were relatively consistent. Second, only basic clinical parameters of preoperative patients were included in our study, while the patients' mental status, dietary habits, endocrine hormone levels, and genetic

material were not analyzed because of a lack of relevant data. Previous studies have shown that these factors are associated with IWL/WR [42, 43]. Therefore, in future studies, we will evaluate additional potential indicators and combine them with clinical characteristics to establish a more comprehensive and accurate predictive model for IWL/WR. Third, as the definitions of IWL and WR have not been established, the results may not be entirely consistent with studies that have used other parameters to define IWL and WR. Additionally, we reported higher rates of IWL and WR compared to a few previous studies. Specifically, we found that 60.9% of patients experienced IWL and 44.3% of patients experienced WR. These higher rates may be partially due to the criteria we selected. It is important to note that Karmali et al. [44] reported that WR can vary significantly, ranging from 19% to 87% under different criteria. Furthermore, many studies have recommended using %TWL and %MWL to define IWL and WR [45]. We also verified that these two parameters are superior to other common parameters in our cohort. Finally, both our training and validation sets were patients in our center. In the future, we will seek to conduct external validation assessments in multicenter studies.

Conclusion

In summary, male sex, levels of BMI, and A1C at baseline were predictors of the occurrence of IWL/WR 3 years after laparoscopic RYGB in Chinese patients with obesity and T2D. Based on these predictors, we built a nomogram for the early prediction of IWL/WR. For each patient, a higher total score reflected a greater risk of suboptimal weight loss. The visual and personalized model of baseline predictors provides clinicians with a simple and intuitive tool for early detection and identification of suboptimal weight loss, which may significantly reduce the risk of suboptimal outcomes.

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Statement of Ethics

This study protocol was reviewed and approved by the Ethics Committee of Shanghai Jiao Tong University School of Medicine Affiliated Sixth People's Hospital, Approval No. [ChiCTR1900028513]. Written informed consent was obtained from all participants before the start of the study.

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Conflict of Interest Statement

The authors have no competing interests to declare.

Author Contributions

Yuqian Bao and Haoyong Yu designed the study. Yiming Si, Hongwei Zhang, and Yinfang Tu collected the data. Yiming Si analyzed the data and wrote the draft. Xiaojing Ma, Xiaodong Han, and Weijie Liu contributed to the conduction of the study. Yuqian Bao and Haoyong Yu revised the manuscript and contributed to the discussion. All of the authors read and approved the final manuscript.

Data Availability Statement

The data that support the findings of this study are not publicly available due to their containing information that could compromise the privacy of research participants but are available from the corresponding author (Yuqian Bao) upon reasonable request.

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