Original Article

Laparoscopic Roux-en-Y gastric bypass for excess weight and diabetes: a multicenter retrospective cohort study in China

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Abstract

Aim: The aims of this study were to better understand the outcomes of Roux-en-Y gastric bypass (RYGB) surgery in patients across multiple hospitals in China along with patients with type 2 diabetes mellitus (T2DM) and to explore the potential preoperative predictors of diabetes outcomes after RYGB.

Methods: This was a retrospective cohort study in Chinese patients who underwent laparoscopic RYGB at five Chinese hospitals from April 2009 to December 2014 and returned for follow-up approximately one-year post-

surgery. The STROCSS guideline checklist was applied.

Results: In total, 130 patients underwent RYGB: 85 males and 45 females; age, 43.4 ± 11.3 years; and preoperative body mass index (BMI), 33.1 ± 9.0 kg/m^2. Of those, 103 (79.2%) had T2DM duration of 6.6 ± 4.7 years and pre-RYGB HbA1c of 8.1 ± 1.9%. Among the patients with T2DM, glycemic control (HbA1c < 7.0%) increased from 28.7% before surgery to 79.3% at 12 months post-procedure, with a concurrent reduction in the use of anti-hyperglycemic agents, including a reduction in insulin requirement from 55.4% to 27.0%. The percentage of excess weight loss was -42.8 ± 44.2%. Among 71 patients with T2DM and data about remission status, 14 (19.7%) achieved T2DM remission at 12 months post-surgery. Age and duration of T2DM were lower in the remission group, while baseline BMI and weight were higher compared with the non-remission group.

Conclusion: RYGB may be effective for weight loss and T2DM control in Chinese patients, and outcomes are consistent with the literature in Western populations. Younger patients with T2DM and with a higher BMI pre-surgery and shorter duration of T2DM were more likely to achieve T2DM remission.

Keywords: Type 2 diabetes, obesity, roux-en-Y gastric bypass, glycemic control, remission

INTRODUCTION

World Health Organization (WHO) estimates that 422 million adults globally were living with type 2 diabetes mellitus (T2DM) in 2014 and that the prevalence of T2DM has doubled since 1980[1]. China has almost 115 million patients with T2DM, with an adult diabetes prevalence of 9.8% that is rapidly increasing, presenting in individuals with higher insulin resistance but with lower body mass index (BMI) and approximately 10 years younger than their Western counterparts[2-4]. A review of the literature about bariatric surgery in China showed a significant increase in the number of procedures performed in China between 2001 and 2015 (a total of 7779 procedures in this period, from 47 surgeries during 2001-2005 to 795 during 2006-2010 and 6937 during 2011-2015); in addition, the proportion of procedures performed to treat obesity-related comorbidities (defined as metabolic surgery) increased from 0% of the total number of procedures performed in 2001 to 70% by 2015[5].

While the growing obesity pandemic is considered a major factor in the growth of T2DM prevalence[6], central adiposity, not BMI *per se*, is considered a primary factor in the rise of T2DM in China[7] and other regions of Asia[8]. BMI distributions in the adult populations differ between the United States and China. Approximately 31% of adults in China[9] are classified as overweight (BMI ≥ 24 to < 28.0 kg/m^2) and 12% as obese (BMI ≥ 28 kg/m^2) compared to 40% obese (BMI ≥ 30.0 kg/m^2) and 8% severely obese (BMI ≥ 40.0 kg/m^2) in the United States in 2016[10]. Therefore, the WHO has defined obesity in terms of abdominal obesity, a waist-hip ratio above 0.90 for males and 0.85 for females, or a BMI > 30.0 kg/m$^{2[6,11]}$ and has recommended health action (such as bariatric surgery) in Asians with T2DM at a BMI 2.5 kg/m^2 lower than in other ethnicities (i.e, BMI 27.5 kg/m^2 *vs.* 30.0 kg/m^2). Globally, bariatric metabolic surgeries such as Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy have emerged as the most effective interventions for sustained weight and diabetes control in patients who are obese[11]. Given the burden of disease in China, metabolic surgery is being undertaken in some patients at even lower BMI[12,13]. Studies showed that laparoscopic RYGB could be beneficial in patients with BMI < 28 kg/m^2, or even < 27.5 kg/m$^{2[12,13]}$.

Although the surgical techniques have been described extensively, evidence of laparoscopic RYGB in Chinese patients who are overweight or obese, with or without T2DM, is still limited. This multicenter study aimed to examine the health outcomes after RYGB surgery and determine the potential preoperative predictors of diabetes remission after RYGB surgery.

METHODS

Study design

This was a retrospective cohort study in Chinese patients who underwent an RYGB procedure between April 2009 and December 2014 at five Chinese academic urban hospitals and returned for follow-up approximately one-year post-surgery. This study was approved by each site's ethics committee, including a waiver for informed consent due to the retrospective nature of this study. The study was registered at ChiCTR.org.cn (#ChiCTR-OOC-15006387). The study was reported in accordance with the STROCSS guideline checklist[14].

The inclusion criteria were: (1) underwent an RYGB procedure; (2) aged 20-60 years; and (3) had outcome data recorded [at least one of glycated hemoglobin (HbA1c), fasting plasma glucose, or fasting insulin levels] in their medical charts at approximately 12 months after surgery.

Study interventions

All participating hospitals assessed each patient who underwent RYGB through a multidisciplinary and integrated health unit, including a bariatric surgeon, endocrinologist, psychiatrist, cardiologist, and dietician. Weight, BMI, T2DM duration, anthropometric measures, systolic and diastolic blood pressures, glycemic control (HbA1c, fasting blood glucose, and insulin), lipid profile, and other laboratory and clinical evaluations recorded in the patient's medical record were analyzed. Given the retrospective design, not all outcome measures were available for all patients, and those outcomes available were not always available at all study time points.

Outcomes

The primary outcome was the resolution of T2DM. The secondary outcomes were weight reduction, improvements in glycemic control, vital signs, blood lipids, liver function, and adverse events (AEs).

Statistical analysis

The study was not statistically powered, and data from all patients who had an RYGB procedure during the study period and met the eligibility criteria were analyzed. For the total study population, interest focused on changes in anthropometric characteristics, vital signs, glycemic parameters, serum lipids, and liver function tests. In addition, for subjects with T2DM, changes in concomitant T2DM medication were of interest as well as the remission of T2DM, which was defined as fasting glucose levels < 110 mg/dL and HbA1c < 6.0% without the use of anti-hyperglycemic agents (AHAs) at 12 months after surgery.

Summary statistics for the outcome parameters were calculated, as well as their change from baseline. For all analyses, baseline was defined as the last available measurement taken on or before the date of RYGB surgery. For the mean change from baseline, 95% confidence intervals were estimated, and the one-sample *t*-test or the Wilcoxon rank-sum test was applied. No multiplicity adjustments were made to *P*-values for testing the change from baseline. Given the retrospective design of the study and sparseness of data at all available time points post-surgery for some parameters, the last observation carried forward (LOCF) approach was used. For each parameter, the latest value observed in the first 12 months after surgery was identified and used to evaluate the change from baseline to Month 12. Change in BMI was summarized by baseline BMI subgroup based on the WHO cutoff points. A significance level of 0.05 was considered statistically significant, and all reported p-values are nominal *P*-values.

To explore which factors could be associated with T2DM remission or non-remission, univariable and multivariable analyses were performed. Summary statistics for baseline demographic and clinical characteristics as well as post-surgery weight and BMI change were generated for patients with and without

Table 1. Demographics and baseline characteristics

Characteristic	Overall (*n* = 130)		T2DM (*n* = 103)	
	n	Mean ± SD/*n* (%)	*n*	Mean ± SD/*n* (%)
Age (years)	130	43.4 ± 11.3	103	46.2 ± 10.1
Sex				
Female	130	45 (34.6)	103	33 (32.0)
Male	130	85 (65.4)	103	70 (68.0)
BMI (kg/m^2)	127	33.1 ± 9.0	101	31.2 ± 7.9
Weight (kg)	130	94.7 ± 29.6	103	87.9 ± 24.2
Waist circumference (cm)	102	108.0 ± 21.4	86	104.2 ± 18.7
Female	35	108.2 ± 18.4	27	105.5 ± 19.3
Male	67	107.9 ± 22.9	59	103.6 ± 18.6
Waist-to-hip ratio	76	0.96 ± 0.10	75	0.96 ± 0.10
Female	24	0.93 ± 0.14	24	0.93 ± 0.14
Male	52	0.97 ± 0.06	51	0.97 ± 0.06
Duration of T2DM (years)	NA	NA	102	6.6 ± 4.7

BMI: Body mass index; NA: not applicable; SD: standard deviation; T2DM: type 2 diabetes mellitus.

T2DM remission. Logistic regression analyses with T2DM remission as the dependent variable were also performed using backward selection to determine what variables were independently associated with T2DM remission when considering all predictors simultaneously. All statistical analyses were performed with SAS®, Cary, NC.

RESULTS

Patient characteristics

In total, 130 Han Chinese patients met the eligibility criteria, of whom 103 patients (79.2%) had a diagnosis of T2DM. Demographics and baseline characteristics are presented in Table 1.

Surgical interventions and outcomes

RYGB procedures and postoperative care were performed per the standard of care at each hospital. The mean length of the biliopancreatic limb was 74.9 ± 37.0 cm, and the Roux limb was 97.5 ± 36.6 cm. All 130 procedures were successfully completed laparoscopically across a broad BMI range of 20.8-65.3 kg/m^2 (2.4% for BMI 18.5 to < 23.0 kg/m^2; 29.9% for BMI 23.0 to < 27.5 kg/m^2; 27.6% for BMI 27.5 to < 32.5 kg/m^2; and 40.2% for BMI > 32.5 kg/m^2). The mean operative time was 179 ± 59 min. The mean length of stay (surgery-to-discharge) was 8.8 ± 5.7 nights.

For the total population, weight pre-surgery and at 12 months was available for 90 patients and was reduced by 16.5 ± 12.8%. Meaningful reductions in BMI were also observed (-6.2 ± 5.6 kg/m^2) at 12 months with LOCF. Excessive weight loss was not observed as the lowest postoperative BMI reported was 18.1 kg/m^2. Meaningful improvements were also observed in the total population through 12 months for glycemic control, vital signs, blood lipids, and liver function [Table 2]. Among 53 procedure-related AEs, 24 (45.3%) were recorded as Clavien-Dindo Grade 1, 20 (37.7%) were Grade 2, and 9 (17.0%) were Grade 3. The more serious events (all Grade 3, no Grade 4) included ileus (*n* = 2), anastomotic leak (*n* = 1), anastomotic stenosis (*n* = 1), gastric fistula (*n* = 1), gastric ulcer (*n* = 1), intestinal obstruction (*n* = 1), post-procedural edema (*n* = 1), and small intestinal obstruction (*n* = 1). Six patients (4.6%) reported nine AEs within 30 days after the procedure, including five patients (six AEs) with GI disorders. Five patients experienced AEs requiring reoperation, and these AEs included small bowel obstruction, anastomotic leakage, anastomotic stenosis, ileus, gastric fistula, and anastomotic edema. Every AE requiring reoperation was resolved.

PATIENTS WITH T2DM AND RISK ANALYSIS

Following RYGB surgery in patients with T2DM, statistically significant and clinically meaningful improvements in anthropometric characteristics and laboratory values were observed 12 months after

Table 2. Anthropometric characteristics, vital signs, and laboratory values for patients with T2DM using last observation in Year 1 carried forward

Variable	*n*	Baseline	Month 12	Δ, 0 to 12 mo	*P*
Weight					
Weight (kg)	87	87.7 ± 23.9	72.7 ± 20.4	-15.0 ± 15.2	< 0.001
Change in weight (%)	87	NA	NA	-15.9 ± 12.5	< 0.001
%EWL[†]	87	NA	NA	-42.8 ± 44.2	< 0.001
BMI (kg/m^2)	78	30.9 ± 7.9	24.9 ± 5.8	-6.0 ± 5.5	< 0.001
Blood pressure					
Systolic blood pressure (mmHg)	88	129.4 ± 13.8	123.0 ± 14.3	-6.4 ± 15.9	< 0.001
Diastolic blood pressure (mmHg)	88	80.3 ± 9.2	77.6 ± 9.4	-2.7 ± 11.6	0.034
Glycemic outcomes					
HbA1c (%)	87	8.0 ± 1.9	6.1 ± 1.5	-1.9 ± 2.2	< 0.001
FBG (mg/dL)	100	165.8 ± 64.9	116.6 ± 37.6	-49.2 ± 70.3	< 0.001
Fasting C-peptide (ng/mL)	85	2.5 ± 1.5	1.5 ± 0.7	-1.0 ± 1.4	< 0.001
Fasting insulin (miu/L)	75	19.4 ± 14.9	7.7 ± 8.8	-11.7 ± 15.0	< 0.001
Serum lipids					
HDL-C (mg/dL)	95	44.6 ± 12.1	51.0 ± 14.7	6.4 ± 114.0	< 0.001
LDL-C (mg/dL)	95	107.1 ± 35.7	84.2 ± 23.7	-22.9 ± 33.9	< 0.001
Triglycerides (mg/dL)	94	229.9 ± 254.4	120.7 ± 155.7	-109.2 ± 254.1	< 0.001
TC (mg/dL)	95	188.0 ± 54.9	153.3 ± 32.7	-34.7 ± 58.5	< 0.001
Liver function					
ALT (U/L)	96	37.9 ± 25.0	27.4 ± 15.9	-10.5 ± 27.8	< 0.001
AST (U/L)	88	30.1 ± 16.5	25.1 ± 14.1	-5.0 ± 21.6	0.032

Data are shown as mean ± standard deviation. [†]%EWL is based on a target BMI of 19.0 kg/m^2. ALT: Alanine aminotransferase; AST: aspartate aminotransferase; BMI: body mass index; FBG: fasting blood glucose; HbA1c: glycosylated hemoglobin; HDL-C: high-density lipoprotein cholesterol; %EWL: percent excess weight loss; LDL-C: low-density lipoprotein cholesterol; NA: not applicable; TC: total cholesterol.

surgery [Table 2]. There were significant reductions in the glycemic outcomes (HbA1c, fasting blood glucose, fasting c-peptide, and fasting insulin) from baseline to Month 12. In addition, patients had improved blood pressure values (systolic and diastolic), lipid values (increased high-density lipoprotein cholesterol and decreased low-density lipoprotein cholesterol, triglycerides, and total cholesterol), and liver function values (decreased alanine aminotransferase and aspartate aminotransferase). Patients lost 15.9 ± 12.5% of their weight, with higher weight loss observed in those with higher BMI at baseline [Tables 2 and 3]. Severely obese individuals (BMI ≥ 32.5 kg/m^2) lost 20.7 ± 16.5% of their weight on average. Figure 1 demonstrates an overall trend towards reduced health risk based on BMI classification. The only patient with BMI < 23 kg/m^2 remained in this category at 12 months. Among the 21 patients with BMI 23-27.5 kg/m^2 before surgery, 10 (47.6%) remained in the same BMI category, while 11 (52.4%) were downgraded to < 23 kg/m^2. Among the 32 patients with BMI > 27.5 kg/m^2 before surgery, 9 (28.1%) remained in the same BMI category, 13 (40.6%) were downgraded to 23-27.5 kg/m^2, and 10 (31.3%) were downgraded to < 23 kg/m^2. Therefore, 63% of the patients with T2DM reduced their WHO BMI risk category by at least one category after RYGB.

As shown in Figure 2, the percentage of patients diagnosed with T2DM and achieving glycemic control (HbA1c < 6.0%) significantly increased from baseline (11.5%) to 12 months post-procedure (56.3%). An overall reduction in the use of AHAs occurred during the first year after surgery [Figure 3], including a decrease in the number of patients with insulin requirement, from 55.4% at baseline to 27.0% over 12 months. Patients with T2DM requiring no AHA increased from 16.2% at baseline to 33.8% at 12 months post-procedure. The percentage of patients taking antihypertensive medication decreased (baseline to Month 12) from 28.4% to 18.9%, and those taking dyslipidemia medication decreased from 8.1% to 4.1%.

There were 71 patients with data available for the assessment of T2DM remission and any potential predictive factor. Fifty-seven patients (80.3%) showed improvements and near-remission and 14 patients

Table 3. Anthropometric characteristics and laboratory values for patients with T2DM (stratified by BMI group) using last observation in Year 1 carried forward

Variable	Δ, 0 to 12 mo							
	BMI Group 0 (< 23.0 kg/m^2)		BMI Group I (23.0 to < 27.5 kg/m^2)		BMI Group II (27.5 to < 32.5 kg/m^2)		BMI Group III ($\geq$ 32.5 kg/m^2)	
	n	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD
Weight								
Weight (%)	1	-13.4	34	-11.8 ± 10.2	28	-16.9 ± 9.8	24	-20.7 ± 16.5
BMI (kg/m^2 %)	1	-8.2	31	-12.7 ± 9.4	28	-18.0 ± 9.4	18	-27.1 ± 14.4
Glycemic outcomes								
HbA1c (Δ%)	1	-1.7	34	-1.6 ± 2.2	27	-1.9 ± 2.3	24	-2.5 ± 2.1
FBG (mg/dL)	3	-16.9 ± 19.8	35	-51.6 ± 70.0	31	-36.2 ± 78.1	30	-66.8 ± 61.1
Serum lipids								
HDL-C (mg/dL)	3	-8.8 ± 4.8	32	6.6 ± 15.2	31	6.5 ± 15.5	28	7.1 ± 10.5
LDL-C (mg/dL)	3	-25.6 ± 14.4	32	-15.5 ± 40.6	31	-21.6 ± 31.4	28	-32.7 ± 29.0
Triglycerides (mg/dL)	3	-31.0 ± 12.9	32	-158.5 ± 393.1	30	-53.5 ± 152.9	28	-123.3 ± 112.2
TC (mg/dL)	3	-36.3 ± 28.2	32	-26.4 ± 59.1	31	-37.7 ± 76.9	28	-41.5 ± 33.7

BMI: Body mass index; FBG: fasting blood glucose; HbA1c: glycosylated hemoglobin; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; SD: standard deviation; TC: total cholesterol.
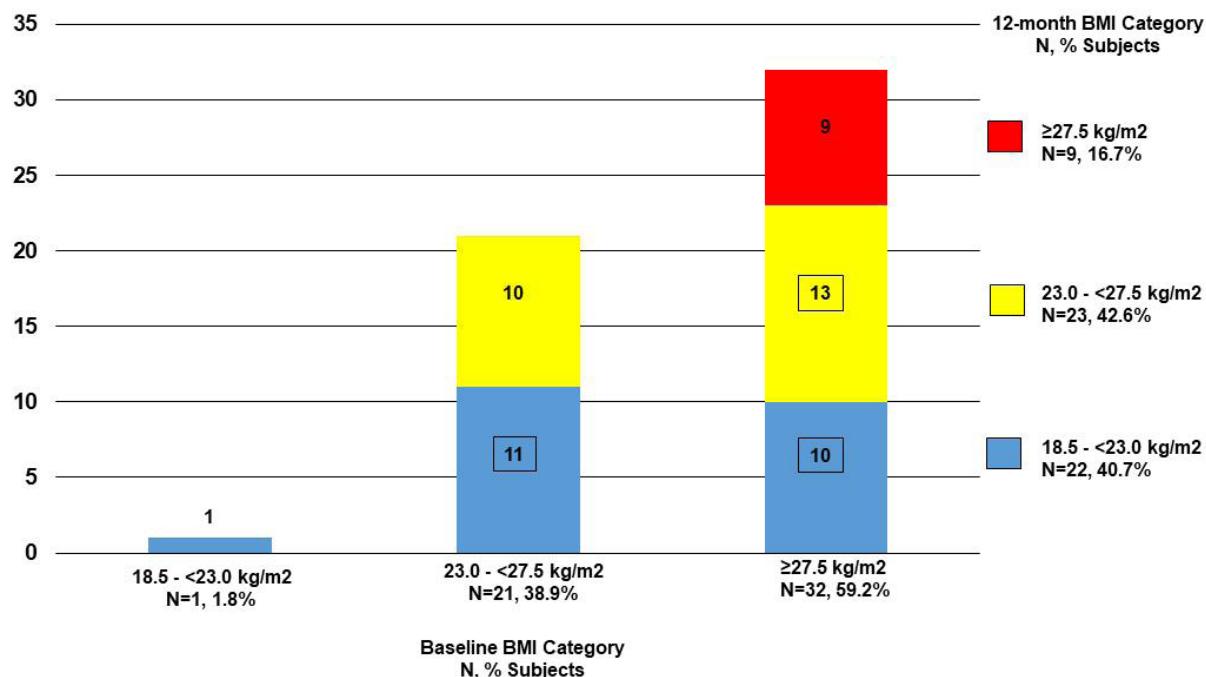
Figure 1. Change in BMI Risk Category after RYGB. The patients with T2DM (*N* = 54) were placed into three groups, dependent on their baseline BMI. The x-axis shows the baseline BMI category distribution, while the y-axis shows the redistribution of the BMI groups at 12 months post-surgery. RYGB: Roux-en-Y gastric bypass; T2DM: type 2 diabetes mellitus; BMI: body mass index.

(19.7%) achieved the defined remission criteria at 12 months after surgery. Preoperative factors in patients with and without T2DM remission were assessed [Table 4]. Univariable analyses identified the age and T2DM duration as being significantly lower and baseline BMI and weight as being significantly higher in the remission group than those in the non-remission group. These findings were confirmed in the multivariable analyses, although the small sample size of subjects with complete data at 12 months limited the generalizability of the results from the regression model.
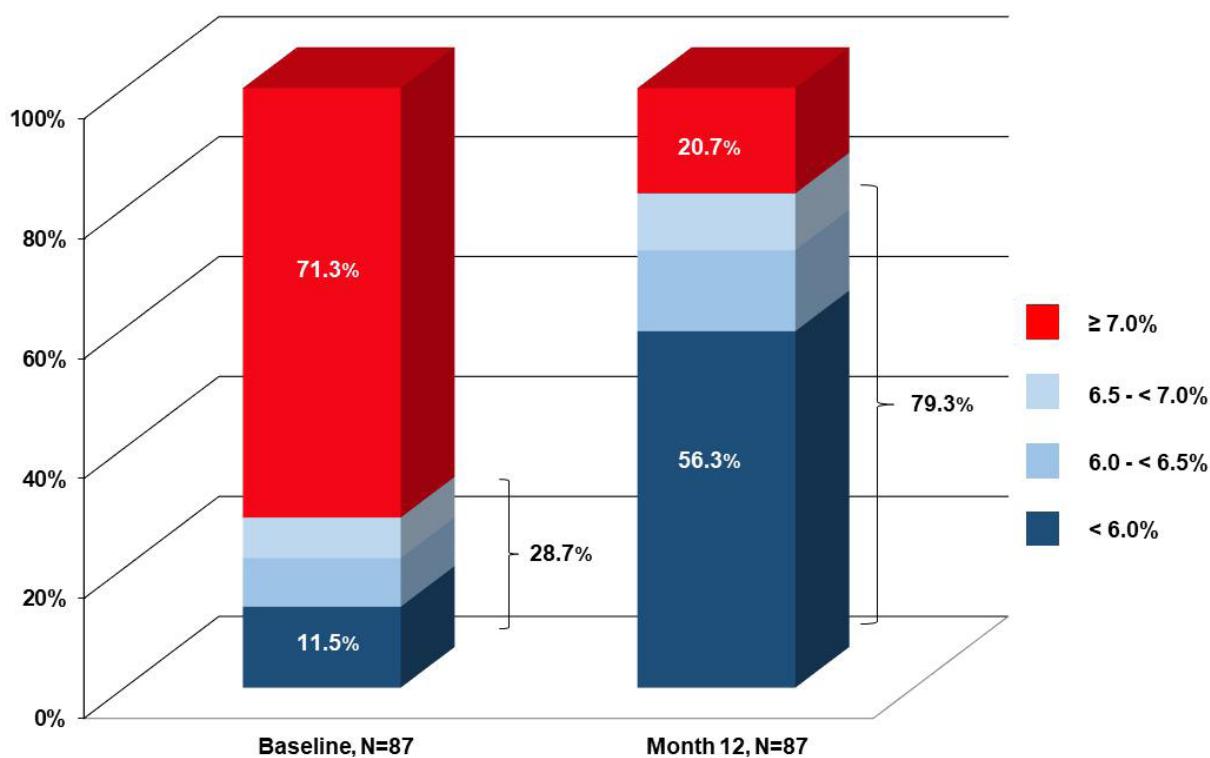
Figure 2. Glycemic control based on HbA1c for patients with T2DM. Patients were separated into four different HbA1c ranges (*N* = 87). The increase in the number of patients under glycemic control (HbA1c < 6.0%) and the decrease in the number of patients with a high HbA1c (≥ 7.0%) are shown. T2DM: Type 2 diabetes mellitus; HbA1c: glycosylated hemoglobin.
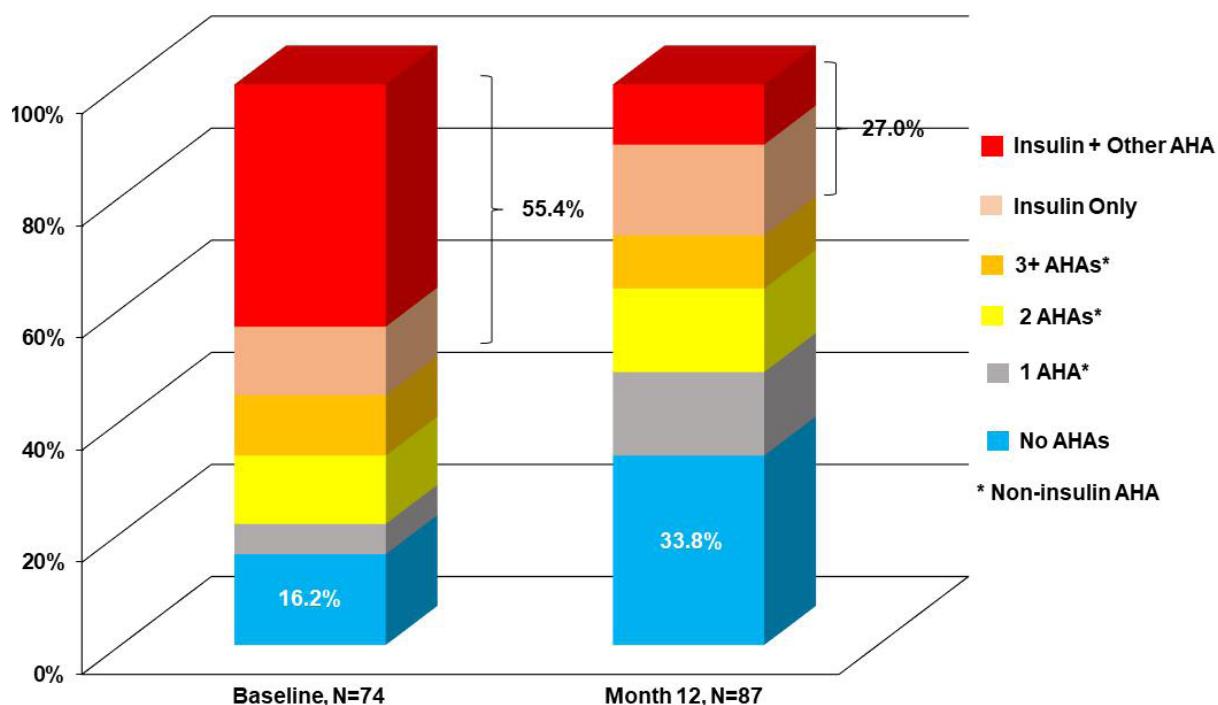
Figure 3. Medication use (anti-hyperglycemic agents) for patients with T2DM (*N* = 74). The decrease in insulin usage is shown. T2DM: Type 2 diabetes mellitus.

Table 4. Univariable analysis of preoperative and postoperative factors in patients with and without T2DM remission

Factor	Remission[†] (*n* = 14)	No remission (*n* = 57)	*P*
Age (years)	37.8 ± 8.4	47.2 ± 9.8	0.002
Weight (kg)	109.3 ± 36.1	86.2 ± 19.8	0.035
BMI (kg/m^2)	36.3 ± 10.1	30.5 ± 6.9	0.013
Waist circumference (cm)	115.6 ± 25.7	102.8 ± 16.6	0.184
Fasting blood glucose (mg/dL)	188.4 ± 77.9	163.8 ± 63.5	0.218
HbA1c (%)	8.6 ± 2.2	7.8 ± 1.9	0.197
Duration of T2DM (years)	3.1 ± 3.6	6.2 ± 4.9	0.030
Number of T2DM medications	1.8 ± 1.9	2.4 ± 1.4	0.249
Weight change (kg)	-25.0 ± 13.2	-18.2 ± 17.2	0.295
Percent weight change (%)	-26.4 ± 10.5	-18.6 ± 13.1	0.123
BMI change (kg/m^2)	-8.4 ± 4.6	-6.6 ± 6.3	0.435

Data are shown as mean ± standard deviation. Results are consistent with the results of multivariable logistic regression, although the sample size was too small to support formal statistical modeling robustly. †Remission was defined as fasting blood glucose < 110 mg/dL, HbA1c < 6.0%, and without the use of anti-hyperglycemic agents at 12 months after surgery. BMI: Body mass index; HbA1c: glycosylated hemoglobin; T2DM: type 2 diabetes mellitus.

DISCUSSION

This study showed that RYGB may be effective for weight loss and control of T2DM in Chinese patients who are obese and overweight considering the low remission rate. Patients with T2DM who were younger, had a higher BMI at baseline, and had a shorter T2DM duration were more likely to achieve T2DM remission. In patients with T2DM, significant improvements in anthropometric characteristics were observed at 12 months after surgery. Significant and meaningful improvements were concurrently observed in glycemic and lipid measurements. The outcomes reported in this retrospective study for RYGB appear consistent with recently published literature seen in Western patients with T2DM[11] and Asian patients with T2DM[15].

Nevertheless, a major difference should be noted. In Western countries, about 80% of the patients who undergo bariatric surgery are female, mainly because of greater worries about the physical appearance and higher awareness of the impact of overweight on health than men[16]. In the present study, most patients were male (65%). In the study of the bariatric surgeries performed between 2001 and 2015 in China, Du *et al.*[5] reported that males represented 48% of the patients, significantly more than in Western countries. The exact reason for this discrepancy is difficult to explain, as highlighted by Du *et al.*[5], and additional study is necessary.

The WHO has previously presented health action points for BMI categories in Asian populations. The suggested categories were: underweight, < 18.5 kg/m^2; increasing but acceptable risk, 18.5-23 kg/m^2; increased risk, 23-27.5 kg/m^2; and high-risk, ≥ 27.5 kg/m$^{2[4]}$. The Diabetes Surgery Summit II (DSS-II) concluded that there is sufficient clinical and mechanistic evidence to support the inclusion of metabolic surgery among antidiabetic interventions for patients with T2DM and obesity, and it should be considered for Asian patients with T2DM and BMI 27.5-32.4 kg/m^2 if hyperglycemia is inadequately controlled with either oral or injectable medications[17]. In this study, we found that there was a redistribution of the BMI groups at 12 months after RYGB. In patients in the high-risk category (≥ 27.5 kg/m^2) at baseline, risk was reduced by one or more categories in ≥ 70% of patients, and, among those in the increased risk category (23.0 to < 27.5 kg/m^2) at baseline, over 50% reached the increasing but acceptable risk category (18.5 to < 23.0 kg/m^2). This result is consistent with the conclusions made by the DSS-II.

In the present study, the T2DM remission rate at 12 months was 19.7%, which is lower than that reported in the Swedish Obese Subject study, where the remission rate with surgery was 72.3% at two years, but it decreased to 30.4% at 15 years[18]. A meta-analysis reported a remission rate of 78.1%[19]. The exact criteria

for remission and the timing of evaluation may affect the results. In the present study, using strict criteria, remission was observed in 19.7%, but near-remission was observed in the remaining 80.3% of the patients. Of note, LOCF had to be used to account for missing values in many patients.

Nevertheless, this study confirms the results of other work on the effectiveness of RYGB for weight loss in China and contributes to the growing body of evidence that RYGB can slow the progression of weight-related diabetes, even inducing remission in some and improving control with fewer AHAs in the vast majority. Notably, more than half of those on insulin at baseline achieved glycemic control without insulin at 12 months after RYGB surgery. Preventing or reducing the need for insulin treatment is important both from a patient's quality of life perspective and from a healthcare utilization perspective[20]. In the present study, RYGB allowed at least a partial remission in all patients. Those with a short T2DM duration were at a higher likelihood of achieving remission, while those with a longer duration can nevertheless obtain some benefits from RYGB. Previous studies generally agree that younger age, shorter duration of diabetes, higher C-peptide levels, higher baseline BMI, and higher baseline visceral fat area are associated with remission after surgery[21-30]. Three prediction models based on different combinations of those variables are available (the DiaRem, ABCD, and individualized metabolic surgery scores)[21,31-33]. In the present study, no score could be derived from the data because of the limited data, but age and T2DM duration were lower and baseline BMI and weight were higher in the remission group than in the non-remission group, as supported by the previous models[21,31-33] and studies[21-30]. Nevertheless, patients with higher BMI at baseline had a higher probability of achieving remission than those with a lower BMI. There is currently no accepted explanation for this phenomenon, but there is the possibility that the disease characteristics (such as insulin resistance and other metabolic disturbances) are different between the two groups of patients[21]. This will have to be examined using metabolic studies to determine possible differences in energy metabolism among patients that could account for the differences in weight loss. Because the BMI cutoff points are not the same between Chinese and Western patients, it is possible that the percent change in excess weight loss (%EWL) is also different. In the present study, the %EWL was -42.8% ± 44.2%, indicating that, although the excess weight was cut by half in most patients, there was a wide variability among patients. In addition, %EWL was not associated with remission, while some previous Western studies associated %EWL with remission[11,23]. A meta-analysis showed ethnic differences in %EWL after metabolic surgery, although Asian patients were not included[34]. In addition, around 60% of the patients in this study had a BMI lower than 32.5 kg/m^2, which may be very different from Western populations.

In the present study, the operative time and length of stay were longer than those usually observed in Western countries. The present study covered the 2009-2014 period, and Du *et al.*[5] showed that, even though bariatric surgery has been performed in China since 2001, most of the cases were in the 2011-2015 period, suggesting that the experience during 2009-2014 was relatively low, leading to longer surgeries. Regarding the length of stay, there is a shortage of general practitioners in China, and the Chinese healthcare system is based on specialists[35]. Therefore, patients are generally discharged when all symptoms and signs are resolved, leading to longer lengths of stay.

STRENGTHS AND LIMITATIONS

The strength of this report is the multicenter approach of data collection, capturing data from five Chinese hospitals. This report provides one of a limited number of multicenter studies available from China[12]. This study has several limitations, including the retrospective design, no comparative arm, a single procedure (RYGB) evaluated, exclusion of patients without 12-month data, a small patient population, lack of complete outcome data reported on the majority of patients at 12 months (e.g, BMI values were only available in 78 out of 103 T2DM subjects), and the short-term follow-up. The data were from the first sites in China that conducted RYGB surgery, and it took time for patients to accept the new treatment pathway.

Further work in prospective, multicenter, long-term follow-up designed studies is warranted to support RYGB as an effective, long-lasting treatment option in both morbidly and non-morbidly obese Chinese patients with T2DM.

In conclusion, This study supplements the evidence showing that RYGB is an important surgical option for the control of obesity and weight-related T2DM in Chinese patients. Half of the patients with insulin requirements at the time of RYGB can expect to maintain glycemic control with non-insulin AHAs after RYGB. Those not taking insulin prior to RYGB can expect to achieve glycemic control with fewer AHAs, and, if a patient has a short T2DM duration, glycemic control can even be achieved without the need for AHAs.

DECLARATIONS

Acknowledgments

Authors' contributions
Execution, data collection and interpretation, manuscript preparation, and final approval: Yang W
Execution, data collection, and manuscript review and final approval: Zhu S, Cheng Z, Zhang N, Wu L, Chen Y, Yang J, Yu S
Clinical study design, data interpretation, and manuscript review and final approval: Yang TF, Ding D
Clinical study design, data interpretation, manuscript preparation, and final approval: Waggoner JR
Clinical study design, data interpretation, manuscript review and final approval: Schwiers ML, Fegelman EJ
Execution, data collection and interpretation, and manuscript review and final approval: Wang CC

Availability of data and materials
Not applicable.

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Conflicts of interest
Yang W, Zhu S, Cheng Z, Zhang N, Wu L, Chen L, Yang J, Yu S, Wang CC declare that they have no conflict of interest. Yang TF and Ding D are employed by Johnson & Johnson Medical (Shanghai) LTD. Waggoner JR, Schwiers ML and Fegelman EJ are employed by Ethicon Endo-Surgery, Inc.

Ethical approval and consent to participate
This study was approved by the Ethical Committee of the First Affiliated Hospital of Jinan University, Guangzhou, China. It also was registered on the Chinese Clinical Trial Registry website (www.chictr.org.cn) with Registration Number: ChiCTR-OOC-15006387. The informed consent was waived due to the retrospective nature of this study.

Consent for publication
Not applicable.

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