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Gastric bypass procedure for type 2 diabetes patients with BMI <28 kg/m^2

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Abstract
Objectives To evaluate the Roux-en-Y gastric bypass (GBP) procedure for patients suffering from type 2 diabetes mellitus (T2DM) with body mass index (BMI) <28 kg/m^2.
Methods Thirty-one patients suffering from T2DM were selected to undergo laparoscopic Roux-en-Y gastric bypass surgery and were enrolled at Beijing Shijitan Hospital between November 2012 and December 2014. The fasting plasma glucose (FPG), glycosylated hemoglobin (HbA1c), C-peptide, fasting insulin (FINS) and glucagon-like peptide-1 (GLP-1) of all patients were measured before and at 1, 3, 6 months after surgery. The results were compared and analyzed.
Results Thirty-one patients suffering from T2DM successfully underwent GBP surgery (a mean age of 46 years), 14 were male and 17 were female. Among them, 7 patients had hypertriglyceridemia (HTG). The patients were followed up for 6 months. No major complications were found. The average BMI was 26.5 ± 1.4 kg/m^2 before surgery. The average levels of FPG, HbA1c, C-peptide, FINS of all patients were statistically decreased after surgery, respectively, compared to those before surgery ($P < 0.05$). However, the mean GLP-1 of all patients was statistically increased after surgery compared to that before surgery ($P < 0.05$). At 6 months after surgery, 22 patients (71 %) achieved complete remission of T2DM with HbA1c < 6.5 %, 7 patients (23 %) gained partial remission of T2DM with 6.5 % ≤ HbA1c < 7.0 % and 2 patients (6 %) experienced no remission of T2DM. The mean serum triglyceride of 31 patients was statistically decreased after surgery compared to that before surgery ($P < 0.05$).
Conclusions This research shows that the GBP procedure is safe and effective for T2DM patients with BMI <28 kg/m^2, and the condition of patients with HTG was greatly improved. However, further studies with larger samples and long-term follow-up are needed.

Keywords Roux-en-Y gastric bypass · Laparoscopic surgery · Type 2 diabetes mellitus · Low body mass index

Diabetes mellitus has become one of the most severe health-threatening diseases in the world. The Chinese Diabetes Society performed a national study in 2008 and found that the overall prevalence of diabetes mellitus was 9.7 % (male: 10.6 % and female: 8.8 %) among people over 20 years old. It is estimated that the total number of patients with diabetes mellitus in China reached 92,400,000 in 2008, ranking first in the world. To make matters worse, the prevalence of diabetes and metabolic disorders has increased progressively since the survey was completed. Data from 2010 showed that the prevalence of diabetes mellitus had reached 11.6 % [1].

Patients with diabetes mellitus can develop multiple acute and chronic complications. The International

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Diabetes Federation (IDF) reports that the highest number of deaths attributable to diabetes is found in countries with large populations, with 1,271,000 deaths in China, 1,065,000 in India, 386,400 in Indonesia, 197,300 in the Russian Federation and 192,700 in the USA [2]. Therefore, it is urgently required that diabetes mellitus be brought under control in these countries and the rest of the world.

Previously, the treatment of diabetes mellitus was mainly non-surgical. Options include dietary modification, exercise, weight reduction and pharmacologic therapy. However, some patients still have poor glycemic control. Recently, surgical treatment is known to have good clinical outcomes and has been accepted for type 2 diabetes mellitus (T2DM) patients with body mass index (BMI) >35 kg/m^2 [3–5]. However, little is known about the outcome for T2DM patients with BMI <30 kg/m^2, especially for those BMI ≤28 kg/m^2 [6–8]. This project investigates surgical outcomes for 31 diabetic patients with BMI ≤28 kg/m^2 who underwent laparoscopic Roux-en-Y gastric bypass (LRYGB).

Materials and methods

Patients

All patients were diagnosed with diabetes mellitus according to the latest American Diabetes Association (ADA) criteria in 2010 [9]. Only those who had a BMI <28 kg/m^2 and were aged between 16 and 65 years old were included. Patients had to have insulin secretion function from their pancreatic islets, and fasting serum C-peptide level could be larger than one half of the lower limit of the normal value. Inclusion criteria also included that subjects had to have undergone medical treatment but with an unsatisfactory outcome, or were unable to continue medical treatment. Patients understood the potential risks of surgery and knew about other alternative therapies. Consent was obtained from all subjects.

Patients with BMI ≥28 kg/m^2 were excluded from this study. Patients with type I diabetes mellitus and patients with gestational diabetes mellitus and other special types of diabetes mellitus were also excluded. Exclusion was also applied to patients with mental diseases that made it difficult for them to cooperate with healthcare staff during the process of surgical care.

The human ethics committee of Beijing Shijitan Hospital, Capital Medical University, approved this study and supervised the entire process on data collection and data analysis.

Surgical technique

All patients underwent general anesthesia with endotracheal intubation and were positioned in the supine position. GBP was performed laparoscopically using 5 trocars. Key surgical steps included creating a gastric pouch (volume 20–30 ml) and transecting a 100-cm length of the small bowel from the ligament of Treitz with a linear stapler. To measure a 100-cm length of the Roux limb from this transection point, the Roux limb is placed in the antecolic, antegastric position. We closed the mesenteric defect with a running permanent suture.

Measures

The age, sex, BMI, comorbidities, duration of T2DM, medication used before surgery as well as any postsurgical complications were recorded. All patients were followed up at 1, 3 and 6 months after surgery. On each visit, we recorded the patient's BMI and surgical complications. Laboratory examinations were performed on patients before the operation and on each of the follow-up visits after the operation. The laboratory reports recorded fasting plasma glucose (FPG), glycosylated hemoglobin (HA1c), glucagon-like peptide-1 (GLP-1), C-peptide, fasting insulin (FINS), triglyceride (TRIG), serum total protein (TP), serum albumin (ALB), hemoglobin (HB), serum iron (Fe), high-density lipoprotein (H-LDL), low-density lipoprotein (L-LDL) and serum calcium (Ca).

Classification of diabetes outcomes

Surgical outcomes were evaluated at the last follow-up visit (6 months after the operation), with the standards of the Chinese Surgery Guidelines for Obesity and Type 2 Diabetes Mellitus (2014) [10]: (1) complete remission: control blood glucose through lifestyle changes instead of any hypoglycemic agent or insulin, HbA1c <6.5 %; (2) partial remission: control blood glucose through lifestyle changes instead of any hypoglycemic agent or insulin, 6.5 % ≤ HbA1c < 7.0 %; (3) no remission: hypoglycemic agents or insulin is still required to control blood glucose, and HbA1c has not changed significantly compared with preoperative levels or is even higher than preoperative levels. In this study, the total rate of improvement was calculated by adding complete and partial remission numbers, while the unimproved rate was gauged from the patients who did not experience remission.

Statistical analysis

Statistical processing and analysis were performed using SPSS software 13.0 (SPSS Institute Inc., Chicago, IL, USA). The data from each parameter were analyzed for normal distribution before significance testing. All data are expressed as mean ± standard deviation (SD) and percentage. Statistical analysis, including one-sample *t* test,

paired-sample t test, one-way analysis of variance (ANOVA) and linear regression, was performed when appropriate. All P values <0.05 were accepted as statistically significant.

Results

A total of 31 patients with T2DM enrolled in this study from November 2012 to December 2014 and received LRYGB procedure at the Department of General Surgery in Beijing Shijitan Hospital. Among them, there were 14 men and 17 women (mean age 46.2 ± 11.1 years old, ranging from 23 to 65 years old). The mean of duration after diagnosis (T2DM) was 8.3 ± 5.7 years (range 0.3–21 years). Before the operation, the mean BMI of the patients was 26.5 ± 1.4 kg/m^2 (range 22.5–27.4 kg/m^2) (Table 1). Seven patients (23 %) presented with hypertriglyceridemia, 5 patients (16 %) presented with hypertension, 2 patients (6 %) presented with retinopathy and 1 patient (3 %) presented with peripheral neuropathy. Before surgery, 20 patients (65 %) received insulin treatment (65 %), 6 patients (19 %) received oral hypoglycemic agent treatment, and 5 patients (16 %) received no treatment (Table 2).

Of the 31 patients undergoing LRYGB, only one patient presented with mild gastroplegia. We administered medicine to promote gastrointestinal motility, and he recovered in 1 week. No severe operation-related complications were observed during the follow-up. The average BMI of the patients decreased significantly at 1, 3 and 6 months after surgery ($P < 0.05$) (Table 3).

Indicators related to diabetes mellitus showed that the mean FPG of 31 patients was (11.2 ± 3.1) mmol/L before surgery and decreased significantly at 1, 3 and 6 months after surgery compared with that before surgery ($P < 0.05$). However, no significant changes were observed in FPG at 3 and 6 months after the operation compared with those at 1 month post-surgery ($P = 0.385$, 0.455). This suggested that the FPG level tended to be stable 3 months after the surgery (Table 4). The average of HbA1c of 31 patients was (7.8 ± 1.7) % before surgery and significantly decreased at 1, 3 and 6 months after the operation ($P < 0.05$) (Table 4). The mean GLP-1 level was (2.6 ± 1.8) pmol/L before surgery and significantly increased at 1, 3 and 6 months after the operation ($P < 0.05$) (Table 4). The average C-peptide and FINS levels were (2.6 ± 0.9) ng/ml and (11.0 ± 4.6) μIU/L, respectively, and both levels decreased at 1, 3 and 6 months after the operation ($P < 0.05$) (Table 4).

The outcomes of surgical treatment were classified according to the HbA1c levels at 6-month follow-up after LRYGB for all 31 patients: 22 patients (71 %) were complete remission, 7 patients (23 %) were partial remission and 2 patients (6 %) were no remission. The total improved rate was 94 % (29/31), and unimproved rate was 6 % (2/31) at 6 months after LRYGB (Table 5). We divided the patients into three groups (complete remission, partial remission and no remission) based on outcome and compared pre- and post-operation categorical data to determine the differences among the three groups. The mean C-peptide level of the patients at 6 months after surgery was significantly lower in the no remission group (1.0 ± 0.1 ng/ml) than in the remission group (1.7 ± 0.4 ng/ml, $P = 0.03$) and in the partial remission group (1.6 ± 0.3 ng/ml, $P = 0.016$). However, the FINS level of the patient at 6 months after surgery was significantly higher in the no remission group (10.6 ± 2.8 μIU/L) than in the remission group (4.9 ± 1.8 μIU/L, $P = 0.001$) and in the partial remission group (6.0 ± 2.4 μIU/L, $P = 0.009$). No significant differences in mean BMI and mean GLP-1 level of the patients at 6 months after surgery were noted among the three groups ($P > 0.05$) (Table 6). Although the mean T2DM duration of the patients was significantly longer in the no remission group (20.5 ± 0.7 years) than in the remission group (7.3 ± 4.9 years, $P = 0.001$) and in the partial remission group (8.1 ± 4.7 years, $P = 0.003$) (Table 6). Linear regression analysis showed that no preoperative factor including age, duration of T2DM, BMI, HbA1c, C-peptide, FINS and GLP-1 was associated with the decrease in FPG

Table 1 Patient demographics

Age (years)	T2DM duration (years)	BMI (kg/m^2)
46.2 ± 11.1	8.3 ± 5.7	26.5 ± 1.4

Data are given as mean values ± standard deviation

One-sample t test, all P values <0.005

Table 2 Preoperative comorbidity and treatment

	N
Comorbidity	
Hypertriglyceridemia	7
Hypertension	5
Retinopathy	2
Peripheral neuropathy	1
Preoperative treatment	
Injection of insulin	20
Administration of oral hypoglycemic agents	6
Without any treatment	5

Table 3 Changes and comparisons of BMI before and at 1, 3 and 6 months after surgery

	Preoperatively	1 month	3 months	6 months
BMI (kg/m^2)	26.5 ± 1.4	24.9 ± 1.6	23.6 ± 1.5	21.9 ± 1.1

Data are given as mean values ± standard deviation

One-sample *t* test, paired-sample *t* test, all *P* values <0.05

Table 4 Changes and comparisons of FPG, HbA1c, GLP-1, C-Peptide, FINS before and at 1, 3 and 6 months after surgery

	Preoperatively	1 month	3 months	6 months
FPG (mmol/L)	11.2 ± 3.1	6.9 ± 2.0	7.2 ± 2.8	6.9 ± 1.5
HbA1c (%)	7.8 ± 1.7	6.9 ± 1.0	6.7 ± 1.5	6.5 ± 0.6
GLP-1 (pmol/L)	2.6 ± 1.8	3.9 ± 1.9	4.1 ± 1.7	4.8 ± 1.5
C-peptide (ng/ml)	2.6 ± 0.9	2.2 ± 0.6	1.9 ± 0.5	1.7 ± 0.4
FINS (μIU/L)	11.0 ± 4.6	9.3 ± 4.0	6.5 ± 3.1	5.5 ± 2.4

Data are given as mean values ± standard deviation

One-sample *t* test, all *P* values < 0.05

Paired-sample *t* test, all *P* values <0.05 except $P_{\text{FPG 1 month vs. FPG 3 months}} = 0.385$, $P_{\text{FPG 3 months vs. FPG 6 months}} = 0.455$

Table 5 Outcomes of 31 patients at 6 months after LRYGB surgery

Outcomes	*N*
Completely remission	22
Partially remission	7
No remission	2

at 6 months after surgery. No factor was a significant predictor for T2DM remission ($P > 0.05$) (Table 7).

The mean TRIG level of 31 patients was (3.0 ± 3.7) mmol/L (normal value range 0.56–1.70 mmol/L) before surgery and was 0.98–1.70 mmol/L (1.5 ± 0.2 mmol/L) at 6 months after the operation, having recovered to the normal range and significantly decreased compared with preoperative levels ($P < 0.05$) (Table 8).

Indicators related to nutrition indicate that the mean TP, ALB, HDL-C, LDL-C and Ca levels were in the normal value range before and at 1, 3 and 6 months after the operation, and no significant changes were found between preoperative and postoperative levels ($P > 0.05$). The mean HB level decreased at 1 month and 3 months after the operation compared with preoperative level ($P = 0.001$, 0.021), but no significant changes were observed between HB level at 6 months after the operation and preoperative level ($P = 0.713$). The average Fe level at 1 month after the operation was (14.05 ± 4.03) μmol/L, which decreased compared with the preoperative level (16.72 ± 5.95) μmol/L ($P = 0.003$), but it was still in the normal value range. No significant changes were observed in the mean Fe level at 3 and 6 months after the operation compared with the preoperative level ($P = 0.086$, 0.083), which was in the normal value range (Table 9).

Discussion

Bariatric surgery is effective for severely obese T2DM patients [11, 12]. Currently, many studies have reported [5, 13, 14] that patients with T2DM and BMI ≥35 kg/m^2 who underwent LRYGB surgery obtained longer-term weight loss and their blood glucose and quality of life improved. However, Asian populations present T2DM differently from those in the West. In Asian populations, only 2 % T2DM patients have a BMI ≥35 kg/m^2. However, the percentage of patients with BMI ≥30 kg/m^2 is approaching 10 %, and patients with BMI ≥27.5 kg/m^2 account for about 25 % [15]. Recent results from a Chinese obesity and metabolic syndrome survey indicate that the prevalence of DM among Chinese people who are overweight (BMI 25.0 to <27.5 kg/m^2) and obesity (BMI ≥27.5) is 12.8 and 18.5 %, respectively. Ninety percent of DM patients are diagnosed with T2DM, and their mean BMI is 25 kg/m^2 [11]. Therefore, the Asian Consensus Meeting on Metabolic Operation (ACMOMS) revised the standards for surgical treatment of diabetes mellitus for the Asian population in 2010 and recommended that Asian BMI guidelines be lowered for surgery indicators [16]. Currently, many reports on T2DM patients with BMI 28–35 kg/m^2 [8, 17, 18] demonstrate that the LRYGP outcomes are satisfactory, but long-term follow-up is required. However, reports on surgical treatment of T2DM patients with BMI <28 kg/m^2 were scattered. To our knowledge, there are no available data for setting up surgical guidelines on Chinese patients with T2DM. We are filling the gap in investigating the surgical outcome on

Table 6 Comparisons of pre- and post-operation categorical data in three groups

	Complete remission group ($N = 22$)	Partial remission group ($N = 7$)	No remission group ($N = 2$)
Before surgery			
Age (years)	46.5 ± 12.0	45.4 ± 8.8	57.0 ± 0.0
T2DM duration (years)[a]	7.3 ± 4.9	8.1 ± 4.7	20.5 ± 0.7
BMI (kg/m^2)	26.5 ± 1.5	26.2 ± 1.4	26.6 ± 0.2
FPG (mmol/L)	10.7 ± 2.8	13.1 ± 3.8	10.8 ± 1.4
HbA1c (%)	7.4 ± 1.3	8.9 ± 2.3	8.6 ± 0.3
C-peptide (ng/ml)	2.7 ± 0.9	2.6 ± 0.7	1.3 ± 0.9
FINS (μIU/L)	11.6 ± 4.9	10.0 ± 4.1	8.6 ± 2.5
GLP-1 (pmol/L)	2.8 ± 2.0	2.3 ± 1.1	1.4 ± 0.4
After surgery			
BMI (kg/m^2)	22.0 ± 1.5	21.7 ± 1.0	21.0 ± 0.0
FPG (mmol/L)[b]	6.4 ± 0.6	6.7 ± 0.2	12 ± 1.3
HbA1c (%)[b]	6.3 ± 0.4	6.7 ± 0.5	8.1 ± 0.1
C-peptide (ng/ml)[c]	1.7 ± 0.4	1.6 ± 0.3	1.0 ± 0.1
FINS (μIU/L)[d]	4.9 ± 1.8	6.0 ± 2.4	10.6 ± 2.8
GLP-1 (pmol/L)	5.0 ± 1.7	4.5 ± 1.1	4.6 ± 0.3

Data are given as mean values ± standard deviation

One-way analysis of variance (ANOVA), all P values > 0.05 except a, b, c, d

[a] $P_{\text{no remission group vs. complete remission group}} = 0.001$, $P_{\text{no remission group vs. partial remission group}} = 0.003$

[b] $P_{\text{no remission group vs. complete remission group}} = 0.000$, $P_{\text{no remission group vs. partial remission group}} = 0.000$

[c] $P_{\text{no remission group vs. complete remission group}} = 0.03$, $P_{\text{no remission group vs. partial remission group}} = 0.016$

[d] $P_{\text{no remission group vs. complete remission group}} = 0.001$, $P_{\text{no remission group vs. partial remission group}} = 0.009$

Table 7 Linear regression analysis to identify predictors for the remission of T2DM

Preoperative factor	Unstandardized coefficients		Standardized coefficients	t	P
	B	SE	Beta		
Age	−0.033	0.026	−0.108	−1.285	0.212
T2DM duration	−0.098	0.051	−0.163	−1.931	0.066
BMI	−0.124	0.173	−0.051	−0.719	0.480
HbA1c	0.005	0.162	0.002	0.028	0.978
C-peptide	0.628	0.374	0.168	1.680	0.107
FINS	−0.012	0.070	−0.016	−0.164	0.871
GLP-1	0.069	0.139	0.036	0.498	0.624

Dependent variable: the decrease in FPG at 6 months after surgery

Table 8 Changes and comparisons of TRIG before and at 1, 3 and 6 months after surgery

	Preoperatively	1 month	3 months	6 months
TRIG mmol/L	3.0 ± 3.7	1.4 ± 0.2	1.5 ± 0.2	1.5 ± 0.2

Data are given as mean values ± standard deviation

One-sample t test, all P values <0.05

Paired-sample t test, all P values <0.05, except $P_{\text{1 month vs. 3 months}} = 0.068$, $P_{\text{1 month vs. 6 months}} = 0.105$, $P_{\text{3 months vs. 6 months}} = 0.642$

patients with BMI <28 kg/m^2. We are delighted to see surgical treatment with LRYGP achieved satisfactory results in our patients with mean BMI 26.5 kg/m^2. Our outcomes are consistent with the result reported by Yin et al. [19]. In our opinion, LRYGB procedure for patients with non-obese T2DM is the effective treatment. As listed in Table 6, no remission patients in our study have a longer duration of T2DM, and it should be used with caution for such patients.

Table 9 Changes and comparisons of TP, ALB, HDL-C, LDL-C, Ca, Fe, HB before and at 1, 3 and 6 months after surgery

	Preoperatively	1 month	3 months	6 months
TP (g/L)	74.2 ± 7.4	72.0 ± 5.7	72.9 ± 4.2	72.0 ± 4.4
ALB (g/L)	47.7 ± 5.3	48.2 ± 4.8	48.3 ± 4.5	45.4 ± 4.9
HDL-C (mmol/L)	1.08 ± 0.20	1.15 ± 0.20	1.21 ± 0.20	1.17 ± 0.22
LDL-C (mmol/L)	2.80 ± 0.67	2.60 ± 0.68	2.67 ± 0.67	2.51 ± 0.58
Ca (mmol/L)	2.32 ± 0.12	2.37 ± 0.13	2.37 ± 0.20	2.40 ± 0.18
Fe (μmol/L)	16.72 ± 5.95	14.05 ± 4.03	15.10 ± 4.06	14.90 ± 4.26
HB (g/L)	142 ± 17.4	133 ± 12.2	135 ± 10.9	141 ± 14.8

Data are given as mean values ± standard deviation

One-sample *t* test, all *P* values <0.05

Paired-sample *t* test, all *P* values >0.05 except $P_{HB\ Preoperatively\ vs.\ HB\ 1\ month} = 0.001$, $P_{HB\ Preoperatively\ vs.\ HB\ 3\ months} = 0.021$, $P_{Fe\ Preoperatively\ vs.\ Fe\ 1\ month} = 0.003$

The mechanism of GBP surgery for T2DM is complicated. Most studies have reported that blood glucose is controlled well after weight loss [20, 21]. However, several reports showed that weight loss is not the main reason for changes in blood glucose level, as the weight rebounded after the weight loss surgery but no rebound was found in blood glucose [18]. The results of this present study indicate that although the postoperative BMI decreased, the decrease range was small. In our opinion, for patients with non-obese T2DM, the mechanism of blood glucose decrease after surgery may be strongly related to weight loss, and weight loss may not be the main factor in blood glucose improvement.

Some studies have demonstrated [22, 23] that gastrointestinal hormones play an important role in blood glucose control. le Roux [24] considered that GLP-1 is produced from the L cells after RYGB and acts as an incretin, releasing insulin and improving pancreatic β cell function. GLP-1 can increase insulin secretion and the sensitivity of insulin, improving insulin resistance and glucose tolerance, thus decreasing blood glucose. Gallwitz [25] reported that GLP-1 secretion is changed significantly after weight loss surgery, and it can promote weight loss and improve blood glucose. The results of this present study showed that postoperative GLP-1 level at 1 month after the operation significantly increased compared with preoperative level and continuously increased with the increase in the passage of time. The LRYGP procedure can change GLP-1 level in patients with non-obese T2DM. Meanwhile, we found that when GLP-1 level increased, the mean FPG and HbA1c levels decreased. We believe that the effects of improved blood glucose in patients with non-obese T2DM produced by GLP-1 may be down to the same mechanism as in patients with obese T2DM. The GLP-1 level can also be used as an indicator to determine surgical efficacy.

Zethelius et al. [26] reported that T2DM is improved by multiple factors. Insulin resistance and impairment of secretion function of B cells are the main pathological changes. The results of this present study show that the mean fasting blood glucose level and glycosylated hemoglobin level at 1 month after LRYGB are significantly decreased. Postoperative GLP 1 is increased, but fasting C-peptide and insulin are decreased, compared with preoperative levels. Our results suggest that in patients with non-obese T2DM, their insulin resistance may decrease due to the effects of GLP-1 and insulin sensitivity enhancing after LRYGB. This effect leads to a decrease in blood glucose. However, the results may be not related to the improvement in pancreatic islet β cell function. Large-sample and long-term studies are required in the future to confirm our statement.

In our study, 71 % patients were complete remission, 23 % patients were partial remission and 6 % patients were no remission at 6 months after surgery. Comparing pre- and postoperative data, we found the differences in the C-peptide, FINS level at 6 months after surgery and the duration of T2DM between no remission group and remission groups (complete and partial). We also used linear regression to analyze preoperative factors of three group patients to identify predictors for diabetes control. However, we did not find any preoperative factor that can be a predictor for the remission of T2DM.

Some studies have reported that RYGB surgery can achieve weight loss for obese patients and improve their comorbidity such as T2DM, hyperlipidemia, hypertension and other complications [27, 28]. We found that the mean preoperative TRIG level of 31 patients was higher than normal, but recovered to normal levels at 6 months after surgery. This indicated that the LRYGB procedure can also improve complicated hypertriglyceridemia in patients with non-obese T2DM and, thus, can decrease the risk of cardiovascular and cerebrovascular disease caused by hypertriglyceridemia. This is helpful for improving the quality of life of such patients and prolonging their survival.

However, weight loss surgery can lead to certain complications. Short-term surgical complications are mainly

anastomotic leakage, obstruction or stenosis. Long-term surgical complication is malnutrition [29–32]. These surgical complications must be carefully considered. Currently, there are no data to suggest that complications and mortality from the LRYGB operation on obese diabetes mellitus patients are significantly higher than for other existing surgeries. No intraoperative complication was found among the patients in this study. Gastroplegia was observed in 1 patient at postoperative day 2, but the patient recovered quickly with conservative treatment. At the end of the follow-up, no severe surgical complications or deaths occurred. At 6 months after the operation, indicators for serum nutrition showed that TP, ALB, HGB, HDL-C, LDL-C, Fe and Ca were in the normal range, and no malnutrition was found during the follow-up. In our opinion, the RYGB procedure is a safe treatment for patients with non-obese T2DM. Further long-term studies are required, considering the short follow-up period in our study.

Conclusion

Our study demonstrates that GBP procedure is safe and effective as a treatment for patients with non-obese T2DM. The operation can elevate GLP-1 level, decrease insulin resistance and increase insulin sensitivity so as to control blood glucose more successfully. Meanwhile, GBP can also significantly improve the complicated hypertriglyceridemia in patients with T2DM and assist in decreasing risks related to diabetes mellitus. We recommend that patients with non-obese T2DM, who have poor glycemic control after non-surgical therapy and a short duration of diabetes mellitus, receive GBP treatment. Further studies with larger samples and long-term follow-ups are needed.

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Compliance with ethical standards

Disclosures Ke Gong, Kai Li, Nengwei Zhang, Bin Zhu, Dexiao Du, Dongdong Zhang, Zhen Zhang and Jirun Peng have no conflicts of interest or financial ties to disclose.

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