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Original article

A comparative study of the metabolic effects of LSG and LRYGB in Chinese diabetes patients with BMI < 35 kg/m^2

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Abstract

Background: The metabolic effects of laparoscopic sleeve gastrectomy (LSG) and laparoscopic Roux-en-Y gastric bypass (LRYGB) in type 2 diabetes (T2D) patients who do not meet National Institutes of Health indications has not been well studied.

Objectives: To compare the effectiveness of LSG and LRYGB in Chinese T2D patients with body mass index (BMI) <35 kg/m^2.

Setting: University hospital, China.

Methods: A nonrandomized cohort of patients who underwent LRYGB (n = 64) and LSG (n = 19) were followed up for 3 years and the outcomes (weight loss and remission of diabetes and other metabolic parameters) were compared. Univariate and multivariate analyses were applied to find associated parameters of T2D remission.

Results: In total, 5 patients (6%) were lost to follow-up. No significant differences in mean percentage of excess weight loss and BMI were observed between the 2 groups at 2 years. At 3-year follow-up, the LRYGB group had significantly higher percentage of excess weight loss and lower BMI. The total (complete and partial) remission rate achieved with both bariatric procedures was 75.9% at 1 year and 56.4% at 3 years. Surgical safety, diabetes remission, and remission of other obesity-related co-morbidities were comparable between the 2 groups. Patients who achieved complete or partial remission had lower fasting plasma glucose, lower plasma glucose at 2 hours, lower glycated hemoglobin, and higher fasting C peptide than the other patients at baseline. High recurrence rates of hypertension and hyperuricemia were observed at 3 years postoperation.

Conclusions: Both LSG and LRYGB are safe and effective bariatric procedures for T2D in this Chinese population with diabetes and BMI <35 kg/m^2. (Surg Obes Relat Dis 2016;▮:00–00.) © 2016 American Society for Metabolic and Bariatric Surgery. All rights reserved.

Keywords: Bariatric surgery; Roux-en-Y gastric bypass; Sleeve gastrectomy; Type 2 diabetes mellitus; BMI <35 kg/m^2

Type 2 diabetes (T2D) is a worldwide public health problem, with a huge harmful impact on individuals and society [1]. With rapid economic development and changes in lifestyle, China has now become the country with the largest T2D population. A study conducted in 2010 showed that China had nearly 92.4 million adults with diabetes and another 148.2 million adults with prediabetes [2]. The current therapeutic approach, which includes diet, exercise, and medications, is intended not only to control diabetes but also to decrease the incidence of related co-morbidities.

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Unfortunately, despite the availability of new medications, less than 50% of T2D patients are able to achieve the therapeutic targets [3]. Over the last few decades, bariatric surgery, which was designed initially to combat severe obesity, has been proven to be effective in rapidly ameliorating diabetes and related co-morbidities in severely obese T2D patients [4]. This surprising finding brings new hopes to beat T2D, and bariatric surgery is now beginning to be viewed as a standard treatment option in selected T2D patients [5].

The obvious question therefore is, "Which patients with diabetes are eligible for bariatric surgery?" According to the 1991 National Institutes of Health (NIH) consensus criteria for bariatric surgery [6], only patients with T2D and a body mass index (BMI) >35 kg/m^2 are eligible for bariatric surgery. The 2016 American Diabetes Association (ADA) guidelines [5] likewise recommend bariatric surgery only for T2D patients with BMI >35 kg/m^2. The effects of bariatric procedures on metabolic outcomes in individuals who do not satisfy the NIH and ADA criteria are unknown. There are many reports in literature of metabolic improvement and weight loss after bariatric surgery in T2D patients with BMI ≥ 35 kg/m^2, but reports on the effects of this surgery in T2D patients with BMI <35 kg/m^2 are few and inconsistent. It is noteworthy that T2D has distinct epidemiologic features in Eastern populations. Chinese T2D patients, for example, are usually of normal weight or only mildly overweight, manifest abdominal visceral obesity, and experience islet cell function impairment in the early stages of diabetes. Whether this large population is eligible for bariatric surgery, and the outcomes in these patients, remains unclear.

Bariatric surgery, although popular worldwide, is still a new concept in China. As our recent investigation shows, it has been applied in China only for 15 years, with most (89.2%) of the surgeries being performed in the last 5 years [7]. Therefore, the effectiveness of bariatric surgery in Chinese T2D populations is still uncertain. Our unit has been performing laparoscopic bariatric surgeries since 2006. Laparoscopic Roux-en-Y gastric bypass (LRYGB), considered the gold standard procedure, has been our first choice for T2D patients for many years. Laparoscopic sleeve gastrectomy (LSG), because of its relative ease and safety, has proved to be an effective independent weight loss procedure and has rapidly gained in popularity in recent years [8]. We have been using this technique in morbidly obese patients and some selected T2D patients since 2010. Western studies have shown that both procedures are effective in controlling T2D in morbidly obese patients. However, data are scarce on the metabolic effects in Chinese T2D patients who do not meet the NIH criterion. Therefore, we conducted this comparative study to assess the metabolic efficacies of these 2 bariatric procedures in a Chinese clinic-based cohort of T2D patients with BMI <35 kg/m^2.

Methods

Patient population

Patients were included if they had 1) a diagnosis of T2D based on ADA criteria [9] with no serious hyperglycemia-associated complications; 2) fasting C peptide (FCP) value $\geq$50% of normal or a twofold increase in FCP during an oral glucose tolerance test (OGTT) at 2 hours (2 h-CP); 3) BMI 27.5–35 kg/m^2; and 4) age $\geq$18 years. Patients were excluded if they had 1) history of unstable psychiatric illness or alcohol or drug abuse; 2) severe systemic infection or malignancy; 3) inability or reluctance to attend long-term follow-up; or 4) obvious contraindications to surgery.

From January 1, 2010, to December 31, 2012, 83 consecutive patients who met the aforementioned criteria were enrolled in this study. Preoperatively, all patients underwent gastroscopy, abdominal ultrasound, electrocardiography, pulmonary function testing, and laboratory tests (including fasting plasma glucose [FPG], glycated hemoglobin [HbA1C], FCP, fasting insulin [FINS], OGTT, and blood lipids). Homeostatic model assessment of insulin resistance (HOMA-IR) was calculated according to the formula: FINS (mU/L) $\times$ FPG (mmol/L)/22.5. Waist circumference was recorded to the nearest centimeter. All surgeries were performed according to the standard procedures by the same surgeon (C.Z.), who has performed >300 bariatric surgeries.

This study was approved by the Research and Ethics Committee of West China Hospital, and informed consent was obtained from all patients.

Follow-up

After surgery, patients were followed up every 6 months for the first year and yearly thereafter. At follow-up, patients underwent physical examination and routine laboratory tests. An OGTT was also performed. A nutritionist and an endocrinologist monitored patients for possible malnutrition and hyperglycemia. Patients were questioned about major and minor surgical complications; a major complication was defined as any condition necessitating rehospitalization for medical or surgical interventions.

The primary endpoints of this study were the percentage of excess weight loss (%EWL) and T2D remission rate. Secondary endpoints were resolution or improvement (R/I) of other obesity-related co-morbidities (i.e., hypertension, dyslipidemia, hyperuricemia, and sleep apnea). With regard to weight loss, the bariatric procedure was considered inadequate if the %EWL was 30%–50% at the end of 1 year after surgery and a failure if $<30\%$. The criteria for R/I of co-morbidities were as follows: With respect to T2D, complete remission was achieved if FPG was <5.6 mmol/L and HbA1C was $<6.0\%$, while improvement was defined as FPG of 5.6–6.9 mmol/L and HbA1C of $<6.5\%$ without any antidiabetes medication [9]. For hypertension, remission was defined as blood pressure ≤120/80 mm Hg without medication, and improvement was defined as any reduction in antihypertensive medication. For hyperlipidemia and hyperuricemia, remissions were defined as serum cholesterol and triglycerides, or serum uric acid, maintained below the cutoff point without use of medication; any reduction in medication was considered as improvement. For sleep apnea, remission was diagnosed when breathing pauses during sleep were no longer experienced; obvious reduction (>50% decrease) of episodes was considered as improvement.

Statistical analysis

Continuous data were presented as means ± SD. The independent samples *t* test was used to compare continuous variables, and either the χ^2 test or Fisher's exact test (2-sided) was used for categorical variables. Logistic regression analysis was used to identify associated parameters of T2D remission at 1-year follow-up. SPSS 17.0 (SPSS Inc., Chicago, IL) was employed for all analyses. GraphPad Prism 6.0 (GraphPad Software Inc., San Deigo, CA) was used for generating the graphics. Statistical significance was set at $P < .05$.

Results

General characteristics

Eighty-three patients were included in this study. Of these, 64 underwent the LRYGB procedure and 19 underwent the LSG procedure. All patients completed 1 year of follow-up; 2 LRYGB patients and 1 LSG patient were lost to follow-up at 2 years, and another 1 LRYGB patient and 1 LSG patient failed to attend follow-up at the end of 3 years.

Table 1
Baseline features of patients

Characteristics	LRYGB (n = 64)	LSG (n = 19)	*P* value	Total (n = 83)
Men (%)	21 (32.8)	4 (21.1)	0.33	25 (30.1)
Age (yr)	42.3 ± 9.4	39.2 ± 9.0	0.21	41.6 ± 9.3
Duration of T2D (yr)	5.0 ± 4.2	3.5 ± 3.4	0.17	4.7 ± 4.1
BMI (kg/m^2)	31.20 ± 3.4	32.1 ± 2.8	0.30	31.5 ± 3.2
Waist circumference (cm)	93.7 ± 10.3	95.3 ± 9.4	0.56	94.1 ± 9.9
Family history of T2D (%)	24 (37.5)	5 (26.3)	0.37	29 (34.9)
FPG (mmol/L)	9.0 ± 2.0	8.7 ± 1.9	0.62	8.9 ± 1.9
2 h-PG (mmol/L)	11.5 ± 2.1	11.0 ± 2.1	0.34	11.4 ± 2.1
HbA1C (%)	9.3 ± 1.8	8.8 ± 2.3	0.39	9.1 ± 1.9
FCP (nmol/L)	0.71 ± .46	0.87 ± .61	0.22	0.75 ± .5
2 h-CP (nmol/L)	1.8 ± .95	2.1 ± .80	0.18	1.9 ± .9
FINS (mU/L)	23.8 ± 9.6	23.7 ± 6.9	0.99	23.8 ± 9.0
HOMA-IR	9.1 ± 3.2	8.9 ± 2.2	0.81	9.1 ± 3.0
Preoperative treatment			0.85	
OHGA alone n, (%)	14 (21.9)	5 (26.3)		19 (22.9)
Insulin only (%)	35 (54.7)	9 (47.4)		44 (53.0)
Both (%)	15 (23.4)	5 (26.3)		20 (24.1)
SBP (mm Hg)	132.2 ± 27.5	123.4 ± 30.5	0.24	130.2 ± 28.3
DBP (mm Hg)	90.0 ± 20.0	85.3 ± 20.9	0.36	89.1 ± 20.2
TC (mmol/L)	6.5 ± .8	6.2 ± .7	0.13	6.4 ± .8
LDL (mmol/L)	4.5 ± .5	4.6 ± 0.6	0.47	4.5 ± .5
HDL (mmol/L)	2.1 ± .6	2.3 ± .7	0.22	2.2 ± .6
Triglycerides (mmol/L)	1.8 ± .3	1.7 ± .5	0.28	1.7 ± .3
UA (umol/L)	338.2 ± 87.6	306.2 ± 75.9	0.15	321.3 ± 81.2
Other Co-morbidities, n (%)				
Hypertension	27 (42.2)	7 (36.8)	0.68	34 (50.0)
Dyslipidemia	26 (40.6)	7 (36.8)	0.77	33 (39.8)
Hyperuricemia	8 (12.5)	2 (10.5)	>.99*	10 (12.0)
Sleep Apnea	18 (28.1)	6 (31.6)	0.77	24 (28.9)
Operation time (min)	122.3 ± 27.0	87.7 ± 21.8	<0.01†	114.3 ± 29.6
Hospital day (days)	6.4 ± 7.5	4.5 ± 1.7	0.29	6.0 ± 6.7
Major complications, n (%)	2 (3.1)	0 (0)	>.99*	2 (2.4)

LRYGB = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy; T2D = type 2 diabetes; BMI = body mass index; FPG = fasting plasma glucose; 2 h-PG = plasma glucose at 2 hours of OGTT test; HbA1C = glycated hemoglobin; FCP = fasting C peptide; 2 h-CP = C peptide at 2 hours of OGTT test; FINS = fasting insulin; HOMA-IR = homeostatic model of assessment-insulin resistance; OHGA = oral hypoglycemic agents; SBP = systolic blood pressure; DBP = diastolic blood pressure; TC = total cholesterol; LDL = low-density lipoprotein; HDL = high-density lipoprotein; UA = uric acid.

*Fisher's exact test (2-sided).

†$P < .05$.

As shown in Table 1, gender, age, BMI, waist circumference, duration of T2D, family history, and preoperative treatment were comparable between the 2 groups. The mean values of FPG, plasma glucose at 2 hours of OGTT, HbA1C, FCP, 2 h-CP, FINS, HOMA-IR, blood pressure, blood lipids, uric acid, and the prevalence of other co-morbidities were not significantly different between the 2 groups. The mean operation time was significantly shorter in the LSG group. Hospital days and major complication rates were comparable in the 2 groups. In the LRYGB group, 2 patients underwent rehospitalization, one for incomplete intestinal obstruction and another for mild upper gastrointestinal bleeding; both recovered after conservative medical therapy. Minor complications were seen in both groups: 6 LRYGB patients and 1 LSG patient had gastroesophageal reflux; 2 LSG patients developed marginal ulcer; 2 LRYGB patients developed mild dumping syndrome; and 1 LRYGB patient had hair loss. All of these complications either resolved spontaneously or were cured with outpatient medication.

Primary outcomes

After bariatric surgery the mean BMI was significantly lower than preoperative BMI at every follow-up visit in both groups (Fig. 1A, dotted line). The mean %EWL was highest at 1 year after surgery in both groups, after which it began decreasing; the decrease was greater in the LSG group (Fig. 1B). The mean BMI and waist circumference also began to increase 1 year after surgery, and this too was more obvious in the LSG group. No significant differences were observed between the groups in mean BMI and %EWL at 6, 12, and 24 months. At 3-year follow-up, however, the mean %EWL in the LRYGB group was significantly higher than that in the LSG group (67.9 ± 10.9% versus 60.3 ± 11.1%; $P < .05$; Fig. 1B), and consequently the LRYGB group also had significantly lower BMI at 3-year follow-up (27.8 ± 2.4 kg/m^2 versus 29.2 ± 2.3 kg/m^2; $P < .05$; Fig. 1A). At both 2-year and 3-year follow-up, the mean waist circumferences in LRYGB patients was significantly lower than in LSG patients (88.3 ± 7.5 cm and 88.9 ± 6.7 cm, respectively, in LRYGB versus 93.0 ± 7.3 cm and 93.2 ± 6.6 cm, respectively, in LSG; $P < .05$; Fig. 2A).

The remission rates of T2D at 1-year and 3-year follow-up are listed in Table 2. Complete and partial remission rates at 1-year and 3-year follow-up were comparable between the 2 groups. In this cohort of 83 patients, remission (either complete or partial) was achieved in 75.9% (63/83 cases) at 1 year and in 56.4% (44/78 cases)

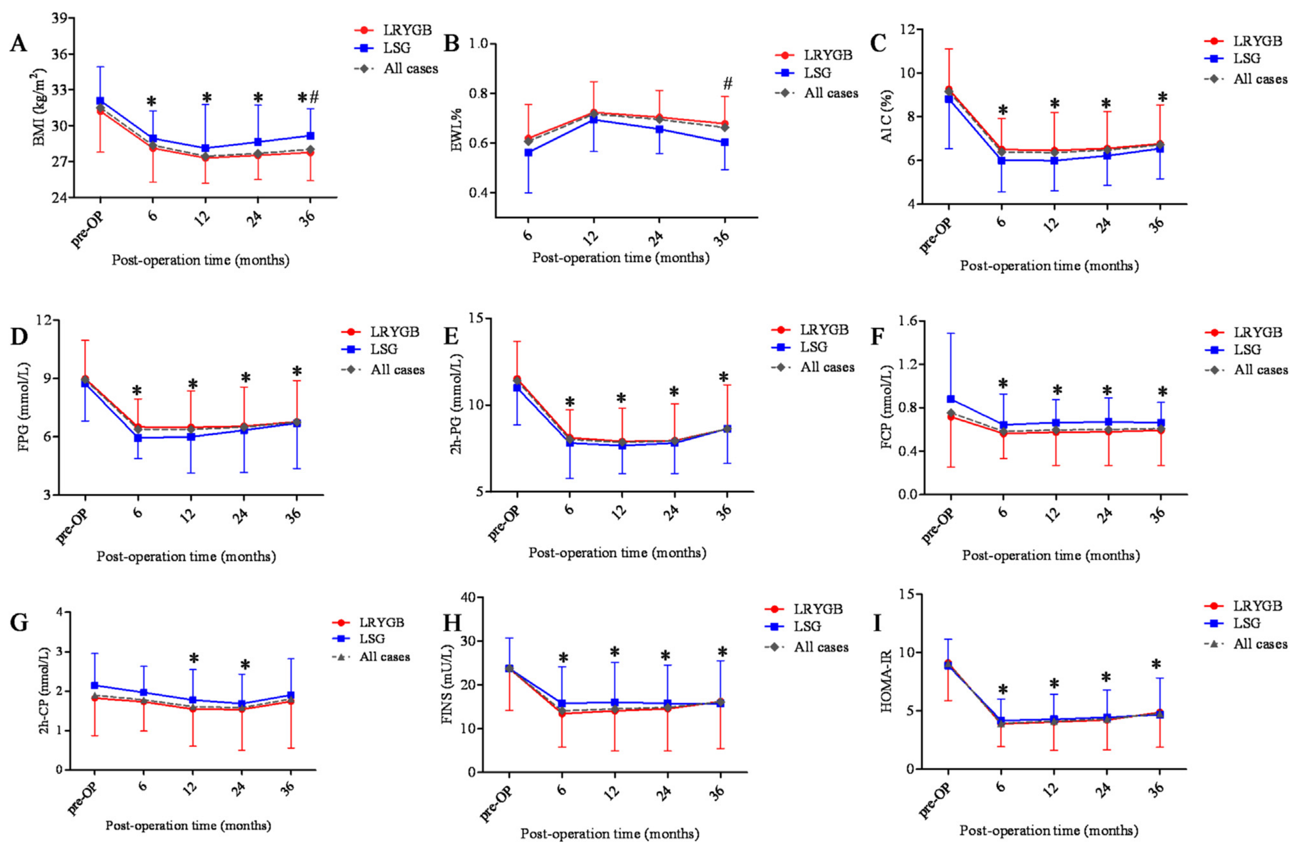

Fig. 1. Changes in mean values of (A) body mass index, (B) excess weight loss, (C) glycated hemoglobin, (D) fasting plasma glucose, (E) plasma glucose at 2 hours of oral glucose tolerance test (OGTT, (F) fasting C peptide, (G) C peptide at 2 hours of OGTT, (H) fasting insulin, and (I) homeostatic model of assessment-insulin resistance over time. *Compared with preoperative value, $P < .05$, dotted line. #Compared between LRYGB and LSG groups, $P < .05$.

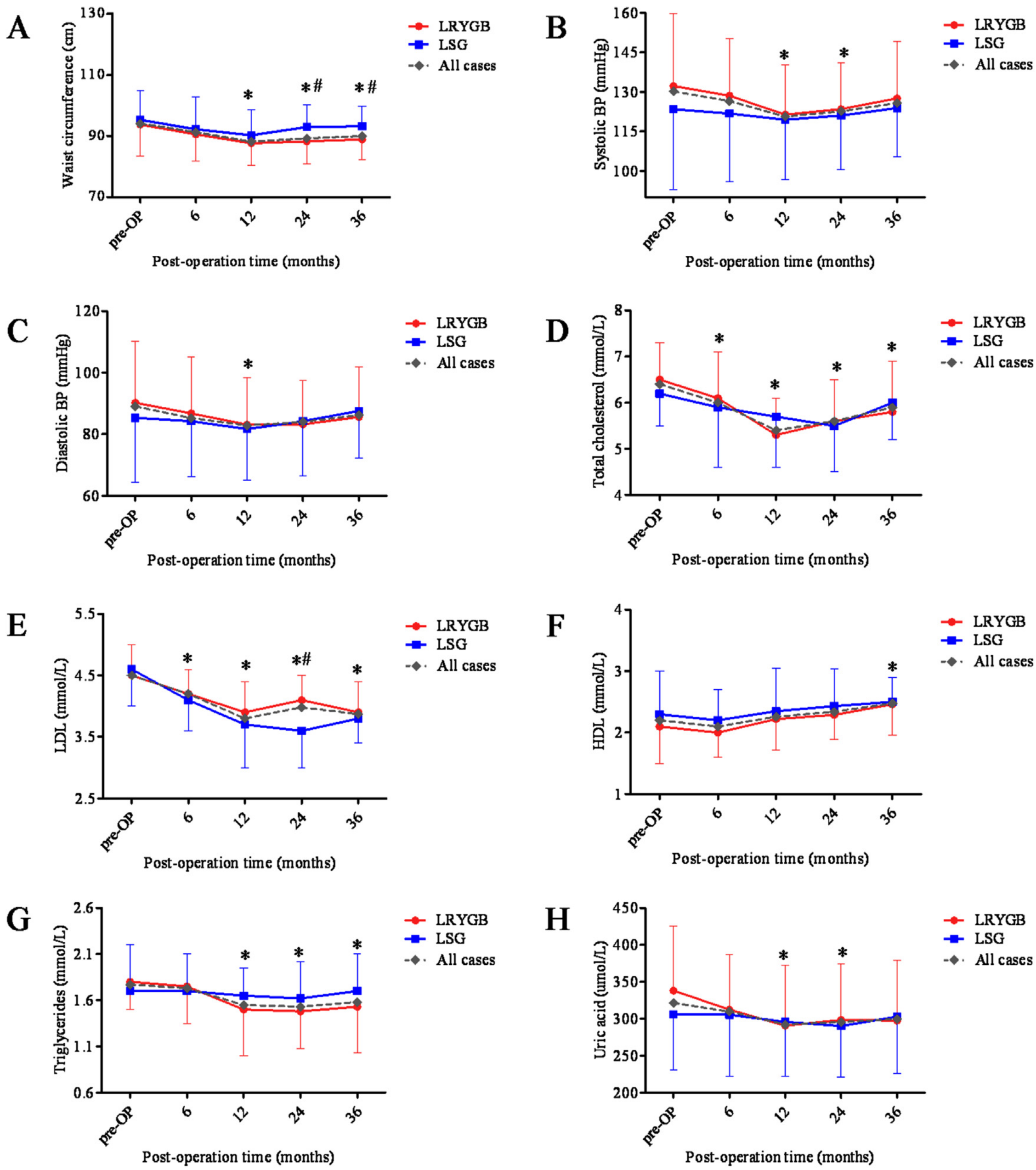

Fig. 2. Changes in mean values of (A) waist circumference, (B) systolic blood pressure, (C) diastolic blood pressure, (D) total cholesterol, (E) low-density lipoprotein, (F) high-density lipoprotein, (G) triglycerides, and (H) uric acid over time. *Compared with preoperative value, $P < .05$, dotted line. #Compared between laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy groups, $P < .05$.

at 3 years. There were no significant differences between the 2 groups in the postoperative values of diabetes-related laboratory tests. (Fig. 1C–I).

As Table 3 shows, patients who achieved complete or partial remission at 1 year had lower FPG, lower plasma glucose at 2 hours of OGTT, lower HbA1C, and higher FCP at baseline than the other patients. There were no significant differences between remission and nonremission patients in terms of age, preoperative BMI, %EWL at 1 year, and surgical approach. Logistic regression analysis showed that lower HbA1C and higher FCP were associated with diabetes remission at 1 year after bariatric surgery in this population (Table 4).

Secondary outcomes

At 1-year follow-up, both groups showed good R/I of hypertension, dyslipidemia, hyperuricemia, and sleep apnea, with remission rates being ≥50% (Table 2 and Fig. 2). However, at 3-year follow-up, R/I of hypertension and hyperuricemia were unsatisfactory in both groups, with the rates being ≤30%. At 3 years, 50% of patients with

Table 2
Metabolic effects of bariatric surgery at 1-year and 3-year follow-ups

	1-year outcome					3-year outcome				
	LRYGB		LSG			LRYGB		LSG		
	Pre-OP	R/I (%)	Pre-OP	R/I (%)	*P* value	Pre-OP	R/I (%)	Pre-OP	R/I (%)	*P* value
T2D	64	48 (75.0)	19	15 (78.9)	*NS*	61	35 (57.4)	17	9 (52.9)	*NS*
Hypertension	27	16 (59.3)	7	4 (57.1)	*NS*	26	8 (30.8)	7	2 (28.6)	*NS*
Dyslipidemia	26	18 (69.2)	7	4 (57.1)	*NS*	24	12 (50.0)	6	3 (50.0)	*NS*
Hyperuricemia	8	4 (50)	2	1 (50)	*NS*	8	2 (25.0)	2	0 (0)	*NS*
Sleep apnea	18	8 (44.4)	6	3 (50)	*NS*	17	7 (41.2)	5	3 (60)	*NS*

T2D = type 2 diabetes; LRYGB = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy; Pre-OP = preoperation; R/I = resolution or improvement; NS = not significant.

hypertension in both LRYGB (8/16) and LSG (2/4) groups, as well as 50% of patients with hyperuricemia in LRYGB (2/4) and 100% of patients in LSG (1/1), had relapsed. No significant difference of remission rates of all co-morbidities were found between the 2 groups.

Discussion

Bariatric surgery has been widely accepted as the most effective treatment for patients with T2D and BMI $\geq$35 kg/m^2. However, for the T2D patients with BMI $<$35 kg/m^2, diverse recommendations exist (Table 5). In the West, most guidelines or statements are not in favor of bariatric surgery in T2D patients with BMI $<$35 kg/m^2; these include NIH 1991 [6], ADA 2016 [5], and International Federation for the Surgery of Obesity-European Chapter 2013 [10] (Table 5). Some Western associations have ambiguous recommendations [11–15]: patients with T2D and BMI $<$35 kg/m^2 are primarily offered intensive diabetes management, including pharmacotherapy and nonsurgical weight loss. Bariatric surgery is only recommended when diabetes and metabolic syndrome are uncontrolled. However, the recommendations from Eastern countries are more lenient (Table 5) [16–18]. Indeed, this may be necessary, as in Eastern populations, obesity phenotypes are totally different from that in the West. In Eastern populations, obese people with T2D often have severe intra-abdominal fat accumulation and present islet function deficiency at an early stage of diabetes [19]. The suitability of Western guidelines for these populations needs to be re-examined.

The Roux-en-Y gastric bypass, which has been carried out for over 50 years, is still the gold standard surgery and the first choice in many bariatric teams. LRYGB has proven to be capable of achieving sustained resolution of diabetes in morbidly obese individuals [14]. However, there is no consensus on its effects in T2D patients with normal or moderately elevated BMI. Cohen et al. [20] found that gastric bypass could achieve a T2D remission rate of 88% in obese class I patients for as long as 6 years. Others have reported T2D remission rates as low as 25% at 3 years [21]. The LSG procedure is even more controversial.

Table 3
Comparison of patient characteristics between T2D remission and non-remission groups at 1 year

	Complete/partial remission		*P* value
	Yes (n = 63)	No (n = 20)	
Men (%)	20 (31.7)	5 (25.0)	0.57
Age (yr)	42.1 ± 9.1	39.8 ± 10.1	0.33
Duration of T2D (yr)	4.9 ± 4.3	3.6 ± 2.8	0.13*
BMI (kg/m^2)	32.6 ± 2.3	31.9 ± 2.6	0.25
Waist circumference (cm)	94.5 ± 8.7	93.8 ± 10.7	0.77
Family history of T2D (%)	21 (33.3)	8 (40.0)	0.59
FPG (mmol/L)	8.7 ± 2.0	9.8 ± 1.7	0.03†
2 h-PG (mmol/L)	11.1 ± 2.2	12.4 ± 1.6	0.01†
HbA1C (%)	8.5 ± 1.7	11.2 ± 1.3	<0.01†
FCP (nmol/L)	0.87 ± .51	0.38 ± .23	<0.01*,†
2 h-CP (nmol/L)	2.0 ± 1.01	1.7 ± .60	0.23*
FINS (mU/L)	24.0 ± 9.3	23.0 ± 8.3	0.65
HOMA-IR	8.9 ± 3.1	9.5 ± 2.5	0.44
SBP (mm Hg)	131.6 ± 28.7	125.8 ± 27.1	0.43
DBP (mm Hg)	90.1 ± 20.6	86.0 ± 19.1	0.43
Operation time (min)	115.5 ± 30.2	110.8 ± 28.1	0.54
Hospital day (days)	6.0 ± 7.1	5.9 ± 5.5	0.94
Preoperative treatment			0.33
OHGA alone n, (%)	14 (22.2)	5 (25.0)	
Insulin only (%)	36 (57.1)	8 (40.0)	
Both (%)	13 (20.6)	7 (35.0)	
%EWL at 1 y	72.1 ± 10.5	70.8 ± 11.2	0.64
BMI at 1 y (kg/m^2)	27.1 ± 2.5	28.1 ± 2.3	0.12
Surgical approach			>.99
LRYGB	48 (80.0)	16 (81.8)	
LSG	15 (20.0)	4 (19.2)	
Other Co-morbidities, n (%)			
Hypertension	27 (42.9)	7 (35)	0.53
Dyslipidemia	28 (44.4)	5 (25)	0.12
Hyperuricemia	6 (9.5)	4 (20)	0.24
Sleep Apnea	19 (30.2)	5 (25)	0.66
Major complications, n (%)	1 (1.6)	1 (5)	0.43

T2D = type 2 diabetes; BMI = body mass index; FPG = fasting plasma glucose; 2 h-PG = plasma glucose at 2 hours of OGTT test; HbA1C = glycated hemoglobin; FCP = fasting C peptide; 2 h-CP = C peptide at 2 hours of OGTT test; FINS = fasting insulin; HOMA-IR = homeostatic model of assessment-insulin resistance; SBP = systolic blood pressure; DBP = diastolic blood pressure; OHGA = oral hypoglycemic agents; %EWL = excess weight loss; LRYGB = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy.

*Fisher's exact test (2-sided).

†$P < .05$.

Table 4
Logistic regression analysis for assessing variables associated with T2D remission

Variables	β	OR	95% CI	*P* value
FPG (lower versus higher)	-0.207	0.813	0.475-1.391	0.45
2 h-PG (lower versus higher)	-0.416	0.660	0.388-1.121	0.12
HbA1C (lower versus higher)	-1.434	0.238	0.096-0.591	<0.01*
FCP (lower versus higher)	4.665	106.1	2.9-3873.9	0.01*

T2D = type 2 diabetes; FPG = fasting plasma glucose; 2 h-PG = plasma glucose at 2 hours of OGTT test; HbA1C = glycated hemoglobin; FCP = fasting C peptide.
* $P < .05$.

LSG, which originated from biliopancreatic diversion with duodenal switch operation, was initially designed as a first-step procedure in super-obese or high-risk patients to reduce complication rates. Over the years, LSG has been proved to be an effective independent weight loss procedure and gradually increased in popularity [22]. However, LSG is classified as a restrictive type of bariatric procedure, as no switch or exclusion of the intestine is performed. Therefore, there are doubts about the metabolic efficacy of LSG on T2D, especially in patients with normal or slightly elevated BMI. Emerging data from Western countries suggest that LSG may be as effective as LRYGB in achieving T2D remission [23]. One of these studies is the well-known prospective randomized clinical trial (RCT) from Switzerland [24], which showed that the rates of T2D resolution in both LSG and LRYGB were very high and similar. However, it should be noted that all enrolled patients had BMI >35 kg/m^2. In our study, we, too, found satisfactory and comparable T2D remission in the LRYGB and LSG groups at both 1-year and 3-year follow-ups, confirming the metabolic efficacy of the 2 procedures in Chinese patients with BMI of 27.5–35 kg/m^2. Our findings suggest that LSG could be effective as a standalone metabolic operation in people with diabetes. However, it should be noted that there might have been a selection bias in our study. As Table 1 and Fig. 1 show, LSG patients were younger, had shorter T2D durations, and had higher BMI, higher preoperative FCP, and lower HbA1C than LRYGB patients, although these differences were not statistically significant.

The factors identified as predictors of remission of T2D after bariatric surgery vary widely in the literature. In this study, although statistical analysis showed HbA1C and FCP to be independent predictors of T2D remission at 1 year, we cannot confidently affirm this as the small sample size and the lack of randomization make these results open to question. Several studies have reported that age and diabetes duration are important factors in predicting the remission of T2D. [25]. Lee's "ABCD" scoring also considers age and duration of diabetes as important indices for predicting outcomes [26].

Our findings, although not totally consistent with these earlier studies, also indicated the importance of pancreatic islet function in the response to metabolic surgery. As we know, the pathogenesis of T2D involves an initial insulin resistance, followed by a compensatory increase in insulin secretion, with progressive beta cell dysfunction occurring due to chronic insulin resistance. Thus, in the early stage of T2D, the major cause of hyperglycemia is insulin resistance, and beta cell secretory function is still good or satisfactory. Bariatric surgery affects the whole endocrine regulation network, and one important outcome is enhanced insulin sensitivity. Therefore, the influences of age and diabetes duration on the outcome of T2D remission might be produced by impairment of pancreatic cell function, which is part of the natural progression of T2D. However, we still believe that age and diabetes duration are important factors to be considered during selection of patients for bariatric surgery.

A secondary goal of this study was to assess the remission or improvement of other obesity-associated comorbidities following surgery. In this cohort, both LRYGB and LSG procedures had similar and satisfactory effects on hypertension, dyslipidemia, hyperuricemia, and sleep apnea at 1-year follow-up. A systematic review in the literature has shown that LSG has significant effect on hypertension and could be a viable surgical option in obese patients with hypertension [27]. In this study, however, we observed high recurrence rates of hypertension and hyperuricemia at 3 years after surgery. Others have also reported high relapse rates for hypertension [28]. Long duration of hypertension, severity of hypertension, and concomitant diabetes have been found to be associated with poor outcomes [29]. Many studies have reported significant decrease of serum uric acid after bariatric surgery [14], but these studies were all on patients with BMI >35 kg/m^2. Whether LRYGB and LSG are as effective in controlling hypertension and hyperuricemia in patients with lower BMI—or whether they are less effective, as our results indicated—needs further investigation.

An another important finding was that LRYGB was superior to LSG in ability to achieve weight loss, with statistically significant difference between the groups in terms of BMI and %EWL attained at 3 years postsurgery. An interesting phenomenon was that, in both groups, a significant difference in waist circumference occurred before the changes in BMI and %EWL. Whether this was a result of the presence of intra-abdominal obesity that is characteristic of Eastern populations, or just a statistical artefact due to the small number of cases, needs to be investigated. So far, there has been no consensus in the literature on whether these 2 procedures are comparable or different in their efficacy in achieving weight loss [24,30,31]. In this study, we also found that the complication rates were comparable between the 2 types of procedures, but this, too, needs to be confirmed in studies with larger number of patients.

Table 5
Guidelines or statements of bariatric and metabolic surgery from different associations or countries

	Guidelines/ statements	Year	Applied Countries or Regions	Indications		
				Weight loss surgery	T2D surgery	Statements for BMI <35
West	NIH [6]	1991	Worldwide	BMI >40	BMI >35	Not suitable for surgery
	IDF [11]	2011	Worldwide	NM	BMI >35, or BMI >30 conditional	1. Under some circumstances people with a BMI of 30–35 should be considered for surgery 2. For Asian and some other ethnicities of increased risk, the BMI action points for surgery can be lower (e.g., 27.5–32.5)
	ADA [5]	2016	Worldwide	NM	BMI >35	There is currently insufficient evidence to generally recommend surgery in T2D patients with BMI ≤35
	IDO [15]	2016	Worldwide	NM	BMI >35, or BMI >30 conditional	1. Surgery should also be considered for patients with T2D and BMI 30.0–34.9 if hyperglycemia is inadequately controlled despite optimal treatment with either oral or injectable medications 2. These BMI thresholds should be reduced by 2.5 for Asian patients
	AACE/TOS/ ASMBS [12]	2013	Worldwide	BMI ≥40	BMI >35, or BMI >30 conditional	Patients with BMI of 30–34.9 with diabetes or metabolic syndrome may also be offered a bariatric procedure
	IFSO-EC [10]	2013	Czech, Belgium, Spain, Netherlands	BMI >40	BMI >35	Patients with BMI of 30–35 should be considered on an individual case basis
	Australian NHMRC [13]	2013	Australia	BMI >40	BMI >35, or BMI >30 conditional	BMI >30 could be consider when patients have poorly controlled T2D and are at increased cardiovascular risk, while also taking into account their individual situations
	UK NICE [14]	2014	United Kingdom	BMI >50 after lifestyle options are unsuccessful	BMI >35, or BMI >30 conditional	Considering an assessment if BMI were within 30–35, poor control of T2D and duration <10 years
East	IFSO-APC [16]	2011	Taiwan, Japan	BMI ≥35 with or without co-morbidities	BMI ≥30 conditional	1. Asian candidates with BMI ≥30 while T2D were inadequately controlled by lifestyle alternations and medical treatment 2. The surgical approach may be considered as a nonprimary alternative to treat inadequately controlled T2D, or metabolic syndrome, for suitable Asian candidates with BMI ≥27.5
	KSSO [17]	2014	Korea	BMI >35 with or without co-morbidities	BMI ≥30 conditional	BMI >30 with co-morbidities
	CSMBS [18]	2014	China	BMI ≥32 with or without co-morbidities	BMI ≥27.5 conditional	BMI ≥27.5 with one or more co-morbidities (poor control)

NIH = National Institutes of Health; IDF = International Diabetes Federation; ADA = American Diabetes Association; IDO = International Diabetes Organizations; AACE = American Association of Clinical Endocrinologists; TOS = the Obesity Society; ASMBS = American Society for Metabolic & Bariatric Surgery; IFSO-EC = International Federation for the Surgery of Obesity-European Chapter; NHMRC = National Health and Medical Research Council; UK = the United Kingdom; NICE = National Institute of Clinical Excellence; IFSO-APC = International Federation for the Surgery of Obesity-Asia Pacific Chapter; KSSO = Korean Society for the Study of Obesity; CSMBS = Chinese Society for Metabolic and Bariatric Surgery; T2D = type 2 diabetes; BMI = body mass index; NM = not mentioned.

Limitations

The present study has several limitations. First, the small sample size and the lack of randomization were major weaknesses of this study. Therefore, a selection bias might exist. Second, loss to follow-up, a common problem in retrospective studies, was >5% at 3 years after surgery, although less than 10%, and this undoubtedly affected the mid-term outcome assessment. Third, in this study we did not use a standard complication reporting table, such as the US Accordion Classification, to record complications. In addition, the complications were not graded according to severity. Fourth, we used FCP, 2 h-CP, and HOMA-IR to estimate beta cell function and insulin resistance. Future studies should consider using insulin clamp, the gold standard measure, to assess insulin sensitivity precisely. Last, this was only a clinic-based study; there was no attempt to study mechanisms of action or assay gastrointestinal hormones, including gastric inhibitory peptide, glucagon-like peptide 1, peptide YY, ghrelin, and others, that are associated with the islet cells.

Conclusions

Both LSG and LRYGB are safe and effective bariatric procedures for control of diabetes and other obesity-related diseases in Chinese T2D patients with BMI <35 kg/m^2. However, the recurrence rates of hypertension and hyperuricemia at 3 years after surgery were high in both LSG and LRYGB patients. LRYGB seems to be superior to LSG with regard to mid-term weight loss. Further prospective RCTs or pair-matched cohort studies with large samples and long follow-up are needed to confirm these preliminary findings.

Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

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