

# Laparoscopic sleeve gastrectomy combined with single-anastomosis duodenal-jejunal bypass in the treatment of type 2 diabetes mellitus of patients with body mass index higher than 27.5 kg/m<sup>2</sup> but lower than 32.5 kg/m<sup>2</sup>

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## Abstract

This study aimed to introduce this surgical technique laparoscopic sleeve gastrectomy combined with single-anastomosis duodenal-jejunal bypass (LDJB-LSG), and to confirm this new surgical technique was safe in the treatment of type 2 diabetes mellitus (T2DM) of patients with body mass index (BMI) higher than 27.5 kg/m<sup>2</sup> but lower than 32.5 kg/m<sup>2</sup>.

A total of 34 T2DM patients with (BMI) higher than 27.5 kg/m<sup>2</sup> but lower than 32.5 kg/m<sup>2</sup> were admitted to our department between January 2014 and October 2016, of whom 25 received laparoscopic gastric bypass surgery (LRYGB) and 9 received LDJB-LSG. The efficacy and safety were compared between the 2 groups.

None in both groups died and had severe postoperative complications. All the surgeries were performed by laparoscopy, and none received switching to open surgery. Patients received regular follow-up after surgery and none were lost to follow-up.

Our study indicates LDJB-LSG is similar to LRYGB in the improvements of the body weight, blood glucose, insulin resistance, islet  $\beta$  cell function, blood lipid profile and serum uric acid, and thus LDJB-LSG is applicable in T2DM patients with 27.5 kg/m<sup>2</sup>  $\leq$  BMI  $\leq$  32.5 kg/m<sup>2</sup> and risk for gastric cancer. However, long-term therapeutic effects need to be evaluated by studies with multicenter, large sample size, and long-term follow-ups.

**Abbreviations:** BMI = body mass index, EWL% = percent of excess weight loss, FBG = fasting blood glucose, FINS = fasting Insulin, HbA1c = blood glycosylated hemoglobin, HOMA = homeostasis model assessment, LDJB-LSG = loop duodeno-jejunal bypass with laparoscopic sleeve gastrectomy, LRYGB = laparoscopic Roux-en-Y gastric bypass, MS = metabolic syndrome, T2DM = type 2 diabetes mellitus.

**Keywords:** duodenal-jejunal bypass, laparoscopic sleeve gastrectomy, single-anastomosis, type 2 diabetes mellitus

## 1. Introduction

The incidence of type 2 diabetes mellitus (T2DM) is significantly increasing in China with the accelerated urbanization, population aging, change in life style and increase in obese and overweight population, and T2DM has been a public problem threatening the human health.<sup>[1]</sup> According to the Guideline for the Surgical Treatment of Obesity and Type 2 Diabetes Mellitus in China (2014),<sup>[2]</sup> bariatric surgery is preferred for T2DM patients with body mass index (BMI)  $\geq$ 32.5 kg/m<sup>2</sup>, and it can effectively improve the obesity and T2DM. For T2DM patients with BMI

higher than 27.5 kg/m<sup>2</sup> but lower than 32.5 kg/m<sup>2</sup>, bariatric surgery can be considered if they have uncontrollable blood glucose even after pharmacotherapy and have concomitant hyperlipemia, hypercholesteremia, and hyperuricemia. However, whether the long term efficacy after surgery is superior to that of intensified pharmacotherapy is still unclear.<sup>[2]</sup> Moreover, there is still controversy on the approach used for bariatric surgery.<sup>[3,4]</sup> In this study, T2DM patients with BMI higher than 27.5 kg/m<sup>2</sup> but lower than 32.5 kg/m<sup>2</sup> who received laparoscopic Roux-en-Y gastric bypass (LRYGB) or loop duodeno-jejunal bypass with laparoscopic sleeve gastrectomy (LDJB-LSG) in our department between January 2014 and October 2016 were retrospectively reviewed, and the efficacy and safety were compared between them according to the findings from regular follow-up.

## 2. Materials and methods

### 2.1. Inclusion criteria

According to the Guideline for the Surgical Treatment of Obesity and Type 2 Diabetes Mellitus in China (2014), the inclusion criteria were as follows: patients were diagnosed with T2DM; BMI was higher than 27.5 kg/m<sup>2</sup>, but lower than 32.5 kg/m<sup>2</sup>; the course of disease was no longer than 15 years; islet  $\beta$  cells have the capability to secrete insulin; the fasting serum peptide C was  $\geq$  1/2 of normal lower limit; patients received bariatric surgery for

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the treatment of T2DM, and accompanied with hyperlipemia, hypercholesteremia, or hyperuricemia other than T2DM; patients older than 18 year old; the bariatric surgery was introduced to patients, and they knew the risk of postoperative complications, understood the importance of changes in postoperative lifestyle and diet for postoperative recovery, and could cooperate postoperative follow-up.

## 2.2. Exclusion criteria

Patients were diagnosed with type 1 diabetes mellitus or special type of diabetes mellitus; islet  $\beta$  cells lost function, and serum C peptide level was low or serum peptide C release curve was flat after glucose loading; BMI was lower than  $27.5 \text{ kg/m}^2$ , or higher than  $32.5 \text{ kg/m}^2$ ; patients had drug abuse, alcohol addiction or other uncontrollable metal illnesses; patients had ASA grade IV or higher before surgery and were intolerant to surgery.

## 2.3. General characteristics

A total of 34 patients with BMI higher than  $27.5 \text{ kg/m}^2$ , but lower than  $32.5 \text{ kg/m}^2$  who received LRYGB ( $n=25$ ) or LDJB-LSG ( $n=9$ ) between January 2014 and October 2016 were included into present study. There were 21 males and 13 females; the mean age was  $44.24 \pm 10.56$  years (range: 20–62 years), the mean course of T2DM was  $4.18 \pm 4.38$  years (range: 1–15 years). Oral glucose-lowering treatment was noted in 9 patients (26.47%), insulin treatment was found in 10 patients (29.41%), 6 patients received oral glucose lowering treatment and insulin treatment (17.65%), and 9 patients did not received any glucose lowering treatment (26.47%).

## 2.4. Preoperative preparations

Patients received routine preoperative examinations (such as gastroscopy, abdominal ultrasonography, electrocardiography, and chest CT). In addition, the weight, height, blood glycated hemoglobin (HbA1c), fasting blood glucose, 2-h postprandial blood glucose, fasting C-peptide, fasting insulin, percent of excess weight loss (EWL%), blood lipids, and blood cholesterol were also detected. Then, the BMI, homeostasis model assessment (HOMA) -IR and HOMA- $\beta$  were calculated. This study was approved by the Ethics Committee of our hospital, and informed consent was obtained from each patient before surgery. In all the patients, the surgery was performed by the same surgeon group with rich experience on laparoscopic bariatric surgery.

## 2.5. Surgical approach

According to the reviewing of medical history and adjunctive examinations, LDJB-LSG was preferred if the patients had a family history of gastric cancer, *Helicobacter pylori* infection, atrophic gastritis, or intestinal metaplasia of gastric mucosa; LRYGB was employed if patients had gastroesophageal reflux disease or no above medical history.

## 2.6. Surgical procedures

Patients were placed in a dorsal elevated position ( $30^\circ$ ) with the left elevation of  $15^\circ$ . The surgeon in charge stood between 2 legs of the patient, and 5-port laparoscopic technique was employed (Fig. 1). A 10-mm longitudinal incision was made along the umbilicus (port 1), followed by creation of pneumoperitoneum

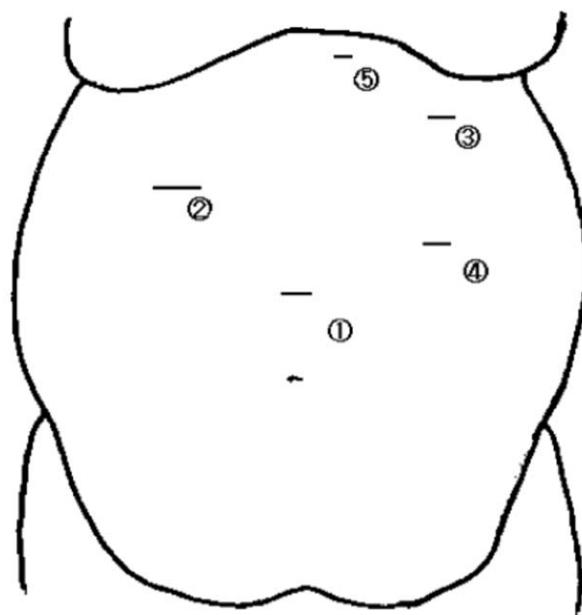
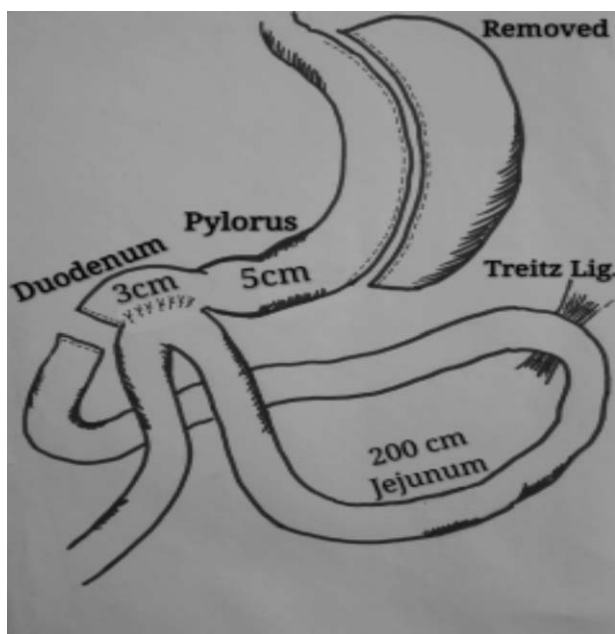


Figure 1. Five ports used in surgery.

using a pressure of 12 mm Hg. Then, 10-mm Trocar was placed, and 12-mm Trocar was placed at 5 cm below the right rib at the right clavicular midline as the operation port (port 2). Around 5-mm Trocar was placed below the left rib at the clavicular midline below the xiphoid as an adjunctive port (ports 4 and 5). Around 5-mm Trocar was placed at left upper abdomen (port 3).

**LDJB-LSG:** After abdominal exploration, the left lateral lobe of liver was elevated to expose the stomach, and the omentum majus was separated beginning at 2 to 6 cm away from pylorus, along the greater curvature and until the His angle. The gastrosplenic ligament was cut. A 42-Fr Bougie was inserted to the distal pylorus, and Endo-GIA linear staplers (green and blue) were employed for sleeve gastrectomy towards the His angle. The pylorus was preserved, and a tube-like stomach sac was formed. The Bougie was withdrawn. The duodenum was separated about 3 cm at the duodenal bulb and then cut with Endo-GIA linear staplers (white). The intestine before the colon was lifted at 200 cm distal to Treitz ligament. Then, the proximal end of the duodenum was manually anastomosed to the jejunum forming a 3-cm anastomosis.<sup>[5]</sup> (Figs. 2 and 3).

**LRYGB:** After abdominal exploration, the hepatogastric ligament was cut at lesser curvature 3 cm below the cardia and the lesser omental bursa was opened. A 36 Fr Bougie was inserted through the mouth to the lesser curvature, and 20 mL of gas was injected through the side airbag of the Bougie. The lesser curvature was cut and closed with Endo-GIA linear staplers (blue). Then, it was cut at the cardiac notch, and a 20-mL small gastric sac was formed. The jejunum was cut at 100 cm distal to Treitz ligament with Endo-GIA linear staplers (white). The distal jejunum after the colon was lifted, and 2 small incisions were made at the small gastric sac and distal jejunum, respectively. Then, gastric-jejunal anastomosis was performed between small gastric sac and distal jejunum with Endo-GIA linear staplers (blue) with the anastomotic site of 1.0 to 2.0 cm. The stomach tube was inserted to the jejunum, and 3–0 suture was used to close the incision and complete gastric-jejunal anastomosis. A marker was made with a suture at 100 cm below the



**Figure 2.** Loop duodeno-jejunal bypass with laparoscopic sleeve gastrectomy (LDJB-LSG). LDJB-LSG=loop duodeno-jejunal bypass with laparoscopic sleeve gastrectomy.

gastric-jejunal anastomotic site. Two incisions were made at distal jejunum (marker) and proximal jejunum, respectively, and side-to-side anastomosis was performed with Endo-GIA linear staplers (anastomotic site was 6 cm in length). Around 3–0 suture was used to close the incision, followed by mesenteric hiatal closure<sup>[31]</sup> (Fig. 4).

### 2.7. Postoperative management

After surgery, prophylactic antibiotics, antacid drugs, and fluid were administered; on the second day, the urinary catheter was removed; patients were asked to get off the bed for more activity and take a small amount of water; since the third day, patients took fluid food. The mean hospital stay after surgery was  $6.28 \pm 1.97$  days in LRYGB group and  $7.11 \pm 1.54$  days in LDJB-LSG group.

### 2.8. Observations

All the patients were followed-up at 1, 6, and 12 months after surgery by the clinicians in our department. The following information was recorded: operation time, intraoperative blood loss, time to postoperative peristalsis, postoperative hospital stay, number of patients with repeated vomiting, complications and number of patients receiving open surgery. The EWL% was calculated as follow:  $\text{EWL\%} = \text{body weight loss} / (\text{original body weight} - \text{ideal body weight}) \times 100\%$  (ideal body weight = height (cm) – 105). HOMA-IR and HOMA- $\beta$  were calculated as follows:  $\text{HOMA-IR} = \text{fasting blood glucose (FBG) (mmol/L)} \times \text{fasting insulin (FINS) (uIU/mL)} / 22.5$ ;  $\text{HOMA-}\beta = 20 \times \text{FINS} (\mu\text{IU/mL}) / (\text{FBG} - 3.5) (\%)$ .

### 2.9. Statistical analysis

Statistical analysis was performed with SPSS version 20.0. Data are expressed as mean  $\pm$  standard deviation. Quantitative data

with normal distribution were compared with *t* test and those with abnormal distribution with nonparametric test. Qualitative data were compared with Fisher exact test. A value of 2 tailed  $P < .05$  was considered statistically significant.

## 3. Results

### 3.1. General characteristics at baseline

The glycated hemoglobin level in LDJB-LSG group was significantly higher than in LRYGB group before surgery ( $P < .05$ ), but there were no marked differences in remaining parameters between the 2 groups before surgery ( $P > .05$ ) (Table 1).

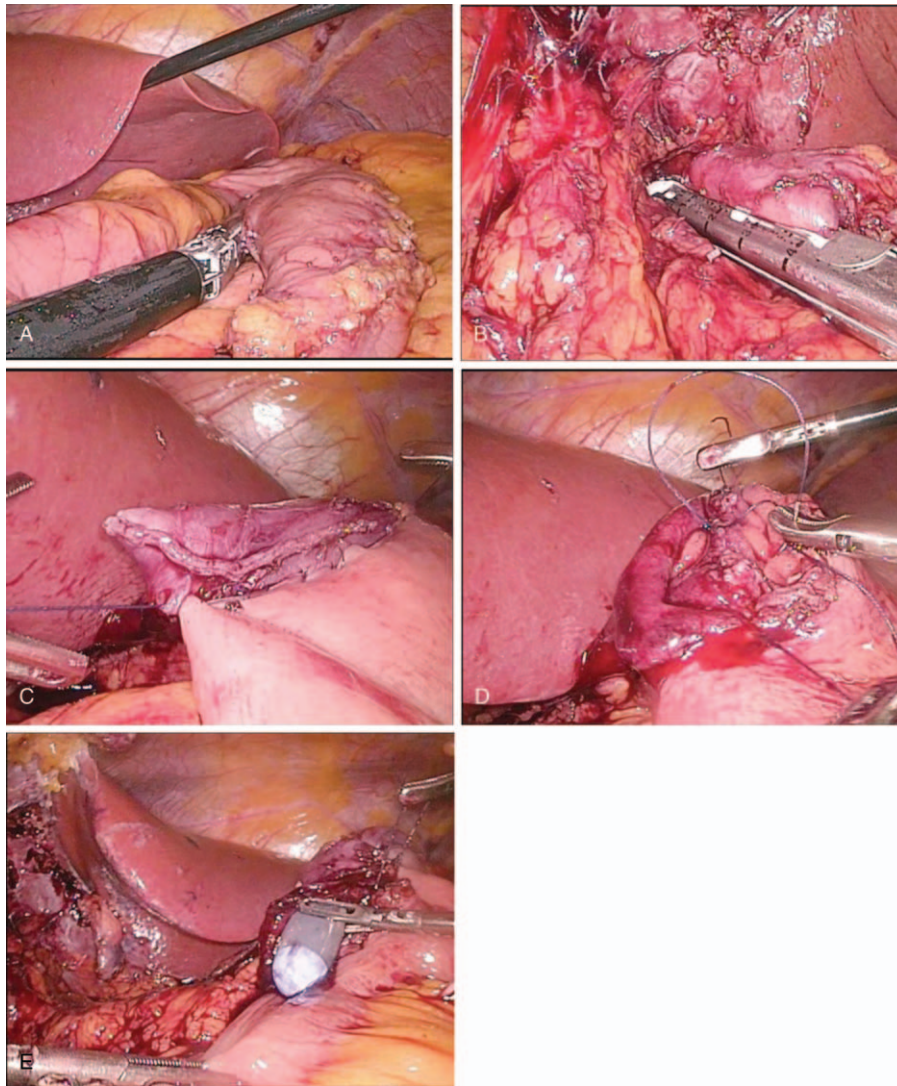
### 3.2. Surgery and follow-up

All the patients received the surgery by the same group of surgeons, open surgery due to heavy intraoperative bleeding and spleen rupture was not observed in these patients, and there were no severe complications after surgery (such as anastomotic leakage, anastomotic stenosis and stomach leakage). Around 34 patients received postoperative follow-up by the same group of clinicians and none were lost to follow-up. There was one more anastomotic site in LRYGB than in LDJB-LSG; LDJB-LSG did not need closure of mesenteric hiatus and therefore the operation time in LDJB-LSG group was significantly shorter than in LRYGB group ( $P < .05$ ). There was only single duodenal-jejunal anastomosis in LDJB-LSG group, and therefore there were no severe symptoms of anastomotic leakage such as abdominal distension, severe abdominal pain, and peritonitis. Since the second day, patients were asked to take a small amount of water in LDJB-LSG group. In LRYGB group, there was gastric-jejunal anastomosis, and jejunal-jejunal Roux-en-Y anastomosis, and therefore patients took food and water since 3 days after surgery. In LDJB-LSG group, the pylorus was preserved, postoperative gastric pressure increased, gastric empty delayed, and short-term vomiting and nausea were present after surgery. In LRYGB group, pyloric exclusion was introduced, there was only gastric-jejunal anastomosis, there was no valve-mediated control of digestive fluid and food in the stomach and therefore they were expelled directly into the intestine.<sup>[6]</sup> Thus, the incidence of vomiting and nausea reduced significantly in LDJB-LSG group ( $P < .05$ ). In addition, Elrazek AEMAA et al<sup>[7]</sup> reported that the post-operative nausea and vomiting after bariatric surgery was closely related to the long operation time, and females, nonsmokers, and patients susceptible to motion sickness were more likely to develop postoperative vomiting. In addition, 6 to 7 staple cartridges were used in LDJB-LSG and 7 staple cartridges in LRYGB, and therefore the medical cost in LRYGB group was significantly higher than in LDJB-LSG group ( $P < .05$ ). There were no marked differences in the intraoperative blood loss, time to postoperative peristalsis and postoperative hospital stay between 2 groups ( $P > .05$ ) (Table 2).

### 3.3. Improvement of blood glucose

The fasting blood glucose and 2 hours postprandial blood glucose were significantly improved since 1 month after surgery ( $P < .05$  vs before surgery); the fasting C peptide reduced markedly ( $P < .05$ ); HbA1c (%) decreased dramatically as compared to that before surgery, and the reduction in HbA1c (%) in LRYGB group was higher than in LDJB-LSG group at 1 month after surgery (Table 3).





**Figure 3.** Surgical procedures of LDJB-LSG. (A) Sleeve gastrectomy with Endo-GIA linear staplers (green and blue). (B) Complete separation of duodenal bulb and cutting of duodenum at 3 cm distal to pylorus with Endo-GIA linear staplers (white). (C) The jejunum and proximal duodenum were lifted at 200 cm away from the Treitz Ligament, followed by duodenojejunal anastomosis (external layer of posterior wall of the anastomosis). (D) Full-thickness continuous anastomosis was manually performed at the posterior wall of duodenojejunal anastomosis. (E) Bougie was inserted through proximal duodenal bulb to jejunum to support the lumen at the anastomosis site, followed by anterior wall continuous anastomosis. LDJB-LSG=loop duodeno-jejunal bypass with laparoscopic sleeve gastrectomy.

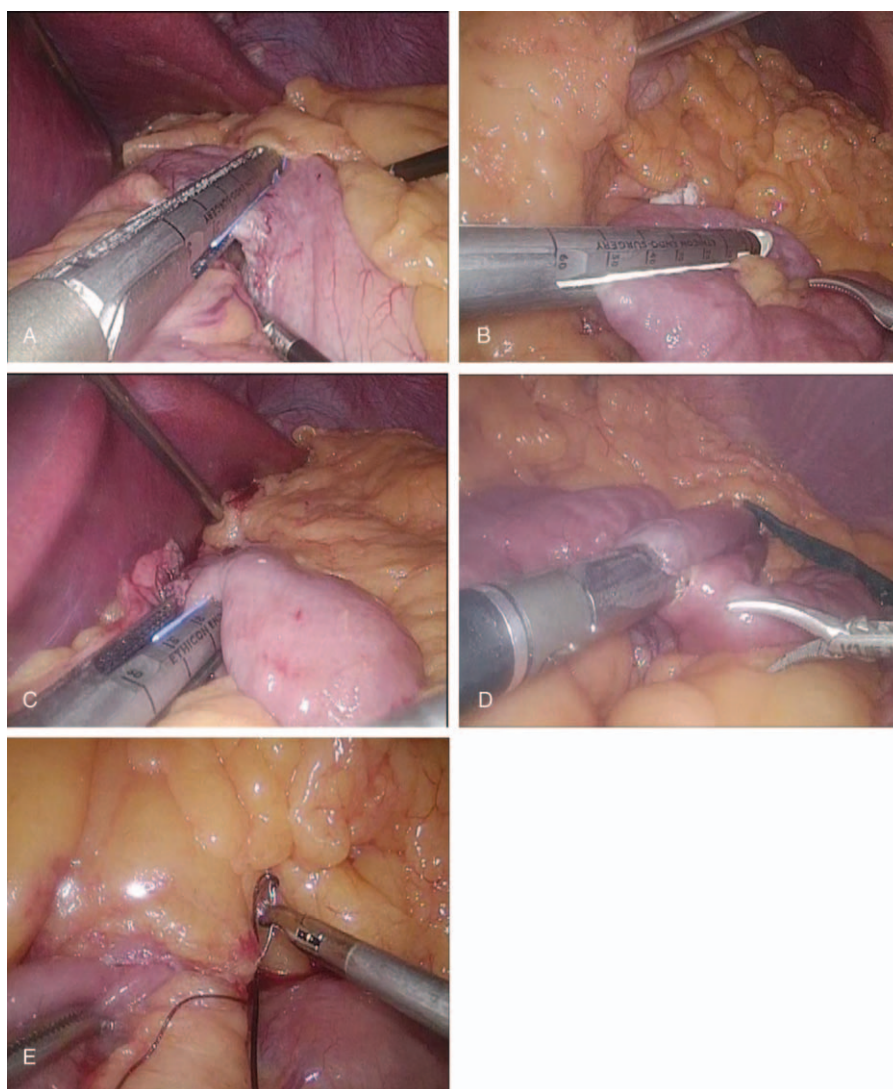
### 3.4. BMI and metabolic parameters

In both groups, the BMI reduced significantly after surgery ( $P < .05$  vs before surgery). The EWL% at 1, 6, and 12 months after surgery increased gradually, there was almost no excessive body weight at 12 months, but there was no marked difference in EWL% between the 2 groups ( $P > .05$ ). Both inter- and intra-assay CVs of low density lipoprotein were  $< 5\%$ . Inter-assay CV of high density lipoprotein was less than 4%, and intra-assay CV of high density lipoprotein was  $< 5\%$ . Interassay CV of triglyceride was  $< 2.5\%$ , and intra-assay CV of triglyceride was  $< 4.3\%$ . The triglycerides level within 6 months after surgery reduced significantly in both groups ( $P < .05$  vs before surgery). In addition, the reduction in LDJB-LSG group was significantly higher than in LRYGB group at 1 and 6 months ( $P < .05$ ). The high-density lipoprotein level remained unchanged in both groups after surgery ( $P > .05$ ). In LDJB-LSG group, the low-density lipoprotein level decreased significantly at 1 and

6 months, but increased at 12 months and was comparable to that before surgery at 12 months ( $P > .05$ ). In LRYGB group, the low-density lipoprotein level reduced significantly after surgery ( $P < .05$  vs before surgery). In both groups, the uric acid remained unchanged at 1 month ( $P > .05$  vs before surgery), but it reduced dramatically at 6 and 12 months after surgery ( $P < .05$ ) (Table 4).

### 3.5. Insulin resistance and islet $\beta$ cell function improvement

In LDJB-LSG group, the insulin resistance was significantly improved since 1 month after surgery ( $P < .05$ ). In LRYGB group, the insulin resistance was significantly improved at 6 months after surgery ( $P < .05$ ). Moreover, the improvement of insulin resistance in LDJB-LSG group was better than in LRYGB group at 1 and 6 months. The islet  $\beta$  cell function in LDJB-LSG group was improved as compared to that before surgery although significant difference was not observed ( $P > .05$ ). In LRYGB



**Figure 4.** Surgical procedures of LRYGB. (A) Endo-GIA (blue nail) was used to make a small stomach sac. (B) Endo-GIA (white nail) was used to cut off jejunum at 10 cm after Treitz ligament. (C) Endo-GIA (blue nail) was used to anastomose distal jejunum with the small stomach sac. The diameter of anastomosis was 2 cm. (D) Endo-GIA (white nail) was used to make a side-to-side anastomosis with proximal jejunum at 100 cm after gastric-jejunal anastomosis. The diameter of anastomosis was 6 cm. (E) Mesenteric hiatus was closed. LRYGB=laparoscopic Roux-en-Y gastric bypass.

**Table 1**  
**Characteristics of patients in both groups at baseline.**

Group	n	Age, years	Gender (n)		BMI, kg/m <sup>2</sup>	Fasting blood glucose, mmol/L	2-h postprandial blood glucose, mmol/L	Fasting C peptide, nmol/L	HbA1c (%)	HOMA-IR	HOMA-β
			M	F							
LDJB-LSG	9	41.78±8.56	6	3	29.37±1.14	9.30±1.94	19.21±3.90	1.08±0.55	9.57±1.33	7.32±2.96	69.67±30.89
LRYGB	25	45.12±11.22	15	10	30.10±1.67	10.07±2.54	16.93±3.99	1.34±0.63	7.72±1.49	8.40±4.10	68.95±35.79
Statistic		t=0.810		t=1.453	t=0.822	t=1.493	t=1.101	t=-3.289	t=0.722	t=-0.054	
P		.424	1*	.161	.417	.145	.279	.002	.476	.958	

Notes: \* Fisher exact test.  
 BMI=body mass index, HbA1c=blood glycosylated hemoglobin, HOMA=homeostasis model assessment, LDJB-LSG=loop duodeno-jejunal bypass with laparoscopic sleeve gastrectomy, LRYGB=laparoscopic Roux-en-Y gastric bypass.

group, the islet β cell function was improved significantly at 1 and 6 months after surgery (P < .05 vs before surgery), and especially the improvement at 1 month was better than in LDJB-LSG group (Table 5).

**4. Discussion**

Metabolic syndrome (MS) is a disease entity characterized by concentric obesity, overweight, diabetes or impaired glucose regulation, hypertension, and dyslipidemia. The incidence of MS

**Table 2****Intro-operative and postoperative characteristics of patients in 2 groups.**

Group	Operation time, minutes	Intro-operative blood loss, mL	Time to postoperative peristalsis, days	Time to postoperative food intake, days	Postoperative hospital stay, days	Medical cost (10 <sup>4</sup> RMB)	Repeated vomiting (n)
LDJB-LSG	166.7 ± 29.58	106.7 ± 44.2	2.22 ± 0.97	1.56 ± 0.73	7.11 ± 1.54	5.64 ± 0.25	8
LRYGB	202.4 ± 41.46	129.6 ± 56.6	2.44 ± 0.82	3.08 ± 0.70	6.28 ± 1.97	6.06 ± 0.29	6
Statistic	2.367	1.097	0.651	5.535	-1.143	3.802	
P	.024	.281	.520	.000	.261	.001	.001

LDJB-LSG=loop duodeno-jejunal bypass with laparoscopic sleeve gastrectomy, LRYGB=laparoscopic Roux-en-Y gastric bypass.

**Table 3****Glucose metabolism related parameters before and after surgery in 2 groups.**

Group	Fasting blood glucose, mmol/L	2-h postprandial blood glucose, mmol/L	Fasting C peptide, nmol/L	HbA1c (%)
LDJB-LSG (n=9)				
Before surgery	9.30 ± 1.94	16.93 ± 3.99	1.08 ± 0.55	9.57 ± 1.33 <sup>†</sup>
1 months	7.48 ± 0.71*	11.24 ± 1.97*	0.86 ± 0.24*	8.19 ± 1.16 <sup>*,†</sup>
6 months	6.06 ± 0.62*	8.83 ± 1.80*	0.78 ± 0.23*	6.43 ± 0.87*
12 months	5.92 ± 1.13*	8.96 ± 1.25*	0.84 ± 0.20*	6.17 ± 0.41*
LRYGB (n=25)				
Before surgery	10.07 ± 2.54	19.21 ± 3.90	1.34 ± 0.63	7.72 ± 1.49
1 months	7.22 ± 0.80*	10.19 ± 1.63*	0.91 ± 0.33*	6.88 ± 1.13*
6 months	6.36 ± 1.07*	9.45 ± 1.69*	0.84 ± 0.23*	6.12 ± 0.55*
12 months	5.86 ± 0.71*	9.43 ± 1.51*	0.90 ± 0.19*	5.92 ± 0.41*

HbA1c=blood glycosylated hemoglobin, LDJB-LSG=loop duodeno-jejunal bypass with laparoscopic sleeve gastrectomy, LRYGB=laparoscopic Roux-en-Y gastric bypass.

\* P &lt; .05 vs before surgery;

† P &lt; .05 between 2 groups at the same time points.

**Table 4****Metabolic parameters before and after surgery in 2 groups.**

Group	BMI, kg/m <sup>2</sup>	EWL%	Triglycerides, mmol/L	High-density lipoprotein, mmol/L	Low-density lipoprotein, mmol/L	Uric acid, μmol/L
LDJB-LSG						
Before surgery	29.37 ± 1.14		2.22 ± 1.40	0.90 ± 0.18	2.46 ± 1.07	383.78 ± 72.58
1 months	27.44 ± 1.37*	30.33 ± 5.41	1.18 ± 0.59 <sup>†</sup>	0.96 ± 0.22	1.45 ± 0.58*	369.33 ± 64.67
6 months	22.70 ± 2.25*	94.78 ± 11.49*	1.08 ± 0.47 <sup>*,†</sup>	0.96 ± 0.15	1.24 ± 0.67*	247.33 ± 63.99*
12 months	19.49 ± 1.50 <sup>*,†</sup>	102 ± 12.03*	0.81 ± 0.40*	0.97 ± 0.26	1.50 ± 0.96	274.89 ± 50.46*
LRYGB						
Before surgery	30.10 ± 1.67		2.67 ± 1.47	0.98 ± 0.29	2.51 ± 0.79	409.24 ± 101.29
1 months	28.21 ± 2.38*	27.88 ± 6.29	2.02 ± 1.14	0.93 ± 0.22	1.57 ± 0.62*	379.96 ± 99.18
6 months	23.06 ± 2.50*	83.24 ± 24.10*	1.70 ± 0.83*	0.90 ± 0.23	1.53 ± 0.66*	285.16 ± 86.71*
12 months	20.97 ± 1.94*	92.72 ± 21.51*	1.08 ± 0.45*	0.98 ± 0.17	1.76 ± 0.88*	283.84 ± 70.25*

BMI=body mass index, EWL%=percent of excess weight loss, LDJB-LSG=loop duodeno-jejunal bypass with laparoscopic sleeve gastrectomy, LRYGB=laparoscopic Roux-en-Y gastric bypass.

\* P &lt; .05 vs before surgery;

† P &lt; .05 between 2 groups at the same time points.

**Table 5****Insulin sensitivity evaluated by homeostasis model assessment.**

Group	HOMA-IR	HOMA-β
LDJB-LSG (n=9)		
Before surgery	7.32 ± 2.96	69.67 ± 30.89
1 months	4.77 ± 1.31 <sup>*,†</sup>	89.79 ± 33.55 <sup>†</sup>
6 months	2.42 ± 1.12 <sup>*,†</sup>	78.14 ± 34.97
12 months	2.15 ± 0.85*	129.45 ± 99.60
LRYGB (n=25)		
Before surgery	8.40 ± 4.10	68.95 ± 35.79
1 months	6.75 ± 2.68	130.33 ± 53.82*
6 months	3.57 ± 1.22*	108.26 ± 62.15*
12 months	2.56 ± 1.18*	95.67 ± 67.05

HOMA=homeostasis model assessment, LDJB-LSG=loop duodeno-jejunal bypass with laparoscopic sleeve gastrectomy, LRYGB=laparoscopic Roux-en-Y gastric bypass.

\* P &lt; .05 vs before surgery;

† P &lt; .05 between 2 groups at the same time points.



is increasing significantly with the rapid economic development and the change in diet,<sup>[8]</sup> and therefore increasing attention has been paid to the prevention of MS. A variety of studies<sup>[3,9,10]</sup> has shown that bariatric surgery is superior to internal medicine in the treatment of MS. Especially, bariatric surgery may achieve complete remission in obese patients with concomitant T2DM.<sup>[11]</sup> Currently, LRYGB has become a standard in the treatment of severe obesity and metabolic diseases.<sup>[12]</sup> As a novel surgical technique, LDJB-LSG has just begun in China. The main differences were as follows: there were gastric-jejunal anastomosis and jejunal-jejunal anastomosis in LRYGB, while there was only single duodenum-jejunum anastomosis in LDJB-LSG. Less anastomosis indicated less incidence of anastomotic leakage. LDJB-LSG did not need closure of mesenteric hiatus, only duodenal-jejunal anastomosis was needed before colon. However, LRYGB needed closure of mesenteric hiatus. Thus, LRYGB was more complex than LDJB-LSG, and has more possibility of internal hernia after surgery. The 2 anastomosis of LRYGB was completed under Endo-GIA linear staplers, while LDJB-LSG needed manual anastomosing.

There is significant difference in the body constitution between Chinese and Western people. In China, abdominal obesity is the major type, adipose tissues are mainly found in the subcutaneous space of the abdomen and abdominal viscera, and these people are more susceptible to develop hyperlipidemia, diabetes, cardiovascular, and cerebrovascular diseases.<sup>[13]</sup> It was reported the prevalence of overweight (BMI: 25.0–27.5 kg/m<sup>2</sup>) and obesity (BMI ≥ 27.5 kg/m<sup>2</sup>) was 12.8% and 18.5%, respectively, and the mean BMI was 25.0 kg/m<sup>2</sup> in T2DM patients. Thus, according to the diagnostic criteria of American Diabetes Association in 2016<sup>[12]</sup> that type I obesity is defined as 27.5 kg/m<sup>2</sup> ≤ BMI ≤ 32.5 kg/m<sup>2</sup>, bariatric surgery is considered for Asian patients with T2DM when active lifestyle interventions and pharmacotherapy are ineffective, and therefore a variety of patients will develop islet β cell dysfunction due to long term nonsurgical treatment and lost the chance to bariatric surgery.

In 2008, Rodriguez-Grunert et al<sup>[14]</sup> for the first time performed DJB-SG by laparoscopy which employed duodenal jejunal bypass on the basis of sleeve gastrectomy by laparoscopy. In recent years, Huang et al reported bariatric surgery achieved favorable efficacy in T2DM patients with BMI ≤ 35 kg/m<sup>2</sup>.<sup>[15,16]</sup> This surgery is a type of stomach intestinal pylorus sparing<sup>[17]</sup> and emphasizes the importance of pylorus preservation. This avoids the direct expelling of food in the pylorus into the intestine, therefore the postprandial glucose is more stable and dumping syndrome is avoided. The gastric acid mixed with chyme enters the ileum via the pylorus and then mixes with pancreatic juice, which also reduce the incidence of anastomotic ulcer.<sup>[15]</sup> In the LDJB-LSG, although more time is consumed during the anastomosis, there is one anastomosis as compared to 2 anastomoses in LRYGB. Our results also showed the operation time in LDJB-LSG was shorter than that in LRYGB. Of more important, Asia has a high incidence of gastric cancer,<sup>[12]</sup> and postoperative examination of the stomach is infeasible after LRYGB, which might delay the diagnosis and treatment once gastric cancer is present. After LDJB-LSG, regular gastroscopy is feasible because the distal stomach is not spared, and there is no concern about the misdiagnosis of gastric cancer.

Our results indicated LDJB-LSG and LRYGB had comparable efficacy and safety in the treatment of T2DM patients with 27.5 kg/m<sup>2</sup> ≤ BMI ≤ 32.5 kg/m<sup>2</sup>. Not only body weight reduced in both groups, but also the glucose metabolic parameters,

insulin resistance and insulin function were improved significantly. Not only the food intake is limited after surgery, but also the duodenum and proximal jejunum are spared after gastrointestinal reconstruction in both groups.<sup>[13]</sup> The LDJB-LSG emphasizes the complete resection of the gastric fundus. Of note, the gastric fundus is a major site of ghrelin secretion, and resection of the gastric fundus may reduce blood ghrelin. In diabetes mellitus patients, reduction of blood ghrelin may prevent or delay the progression of obesity and diabetes mellitus.<sup>[18]</sup> In both groups, the efficacy on the hyperlipidemia and hypercholesterolemia was comparable, and both were improved significantly after surgery. However, the reduction in blood uric acid was slow, and significant difference in uric acid was observed only after 6 months following surgery. This might be ascribed to the reabsorption of urate by renal tubules due to urine concentration in case of postoperative reduction in food and water intake, but the blood uric acid begins to reduce significantly with the increase in food intake and reduction in body weight.

The surgical procedures of LDJB-LSG are relatively simple, there is only single duodenum-jejunum anastomosis, and therefore the incidence of severe complications after LDJB-LSG (such as anastomotic leakage, anastomotic stenosis, anastomotic ulcer and internal hernia) is significantly lower than that after LRYGB.<sup>[3]</sup> On the basis of the fact that Asia has a higher incidence of gastric cancer and BMI is higher in T2DM patients, LDJB-LSG is safe and effective and provides a new treatment of type I obesity in T2DM patients. Although the procedures of LDJB-LSG are simple, it requires skills and experience. This study still had some limitations. Due to a relatively small sample size, it still needs more multicenter and long-term follow-up studies with large sample sizes on weight and blood glucose control in T2DM patients with 27.5 kg/m<sup>2</sup> ≤ BMI ≤ 32.5 kg/m<sup>2</sup>.

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