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ORIGINAL CONTRIBUTIONS

Short-Term Outcomes of Sleeve Gastrectomy plus Jejunojejunal Bypass: a Retrospective Comparative Study with Sleeve Gastrectomy and Roux-en-Y Gastric Bypass in Chinese Patients with BMI ≥ 35 kg/m²

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Abstract

Background Bariatric surgery represents the most effective treatment for obesity and its related comorbidities. The present study aims to evaluate the efficacy and safety of sleeve gastrectomy plus jejunojejunal bypass (SG + JJB).

Methods This retrospective study included 244 obese patients with BMI ≥ 35 kg/m² undergoing SG + JJB ($n = 83$), SG ($n = 82$), and Roux-en-Y gastric bypass (RYGB) ($n = 79$). Postoperative weight loss, metabolic outcomes, nutrition status, and patients' complaints at 1-year follow-up were compared. Subgroup analyses (36 pairs of SG + JJB/SG and 37 pairs of SG + JJB/RYGB) were performed to compare weight loss and lipid profiles after matching with gender, age, and BMI.

Results In subgroup case-matched study, SG + JJB exhibited superior weight loss effect to SG regarding total weight loss (38.8 ± 8.7% vs 35.0 ± 6.1%, $P = 0.011$) and excessive weight loss (95.3 ± 20.4% vs 86.9 ± 13.7%, $P = 0.033$) at 1-year follow-up. The postoperative metabolic outcomes, nutritional status, and patients' complaints were similar between SG + JJB and SG. SG + JJB yielded similar weight loss, T2DM remission, and hypertension resolution to RYGB at 1-year follow-up, but less postoperative complications than RYGB regarding anemia (4.8% vs 22.8%), vitamin D deficiency (47.0% vs 65.8%), vitamin B12 deficiency (8.4% vs 25.3%), hypoalbuminemia (1.2% vs 8.9%), diarrhea (6.0% vs 21.5%), dumping syndrome (0 vs 7.6%), and fatigue (25.3% vs 40.5%) ($P < 0.05$). In subgroup case-matched study, RYGB improved total cholesterol and low-density lipoprotein better than SG + JJB ($P < 0.05$).

Conclusions In short-term follow-up, SG + JJB offered better weight loss than SG and similar weight loss to RYGB. SG + JJB resulted in less postoperative nutritional deficiency and complications than RYGB except for lipid and hypertension improvement.

Keywords Obesity · Sleeve gastrectomy · Jejunojejunal bypass · Weight loss · Complication · Roux-en-Y gastric bypass

Introduction

Bariatric surgery represents the most effective therapy for obesity and its related comorbidities compared to non-surgical treatments [1, 2]. Among various bariatric procedures, sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) are the most frequently performed procedures worldwide [3]. Though SG provides similar weight loss effect to RYGB in short-term follow-up, its long-term and very long-term weight loss effect was reported to be inferior to RYGB [4, 5]. Nevertheless, postoperative nutritional deficiencies, gastrointestinal discomfort, and the concern of delayed diagnosis of gastric cancer within the bypassed stomach impair the acceptance of RYGB in Chinese population [6–9].

Weight regain after SG remains the major concern after 2-year follow-up in Chinese population due to gradual loss of appetite suppression and lack of malabsorption function [10, 11]. There are various methods regarding adding the malabsorptive procedure to SG. Though SG combined with duodenum exclusion offers better weight loss and comorbidity resolution, the duodenojejunal anastomosis is inreversible and difficult to perform [12, 13]. SG with jejunal bypass is technically simple and reversible with effective weight loss and diabetes remission in patients with BMI < 35 kg/m² [14, 15]. However, whether or not SG with jejunal bypass is superior to SG alone or RYGB regarding the weight loss and comorbidity resolution remains unclear in patients with BMI ≥ 35 kg/m².

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The aim of this study is to evaluate the therapeutic effect and safety of SG plus jejunojejunal bypass (SG + JJB) compared to SG alone and RYGB in patients with BMI ≥ 35 kg/m^2.

Methods

Patient Selection

This retrospective study was approved by the ethics committee of the First Affiliated Hospital of Nanjing Medical University (2018-SR-054). Patients who received bariatric surgery from May 2010 to February 2017 were screened. The inclusion and exclusion criteria for bariatric surgery were based on the Chinese Society for Metabolic and Bariatric Surgery (CSMBS) guideline [16]. In addition to CSMBS criteria, patients with severe symptomatic gastroesophageal reflux disease (GERD) were excluded from receiving SG or SG + JJB, and patients with severe gastritis, gastric polyp, gastric ulcer, or family history of gastric cancer were excluded from receiving RYGB. SG, SG + JJB, or RYGB patients with preoperative BMI ≥ 35 kg/m^2 were included in the study. The exclusion criteria of the study were: patients lost at 1-year follow-up, received revisional surgery or converted to other bariatric procedure. Two hundred forty-four patients (82 SG patients, 83 SG + JJB patients, and 79 RYGB patients) were qualified for the study. The follow-up rates of SG, SG + JJB, and RYGB at 1-year mark were 53.2%, 85.6%, and 59.8%.

Surgical Techniques

All the operations were performed laparoscopically. For SG (Fig. 1), the stomach was transected with 60-mm linear stapler from antrum to His angle over a 38F boogie after great omentum mobilization. The staple line was reinforced. The gastric sleeve was fixed to the surrounding tissue. For SG + JJB (Fig. 2), the JJB was performed after SG. Briefly, the jejunum was transected 20-cm distal to Treiz ligament. After that, another 200-cm jejunum was measured and side-to-side jejunojejunal anastomosis was made. The anastomotic and mesenteric defects were closed by hand suture. For RYGB (Fig. 3), the gastric pouch (20–30 mL) was firstly created with 60-mm linear stapler. One hundred centimeter jejunum distal to Treiz ligament (biliopancreatic limb) was measured, and gastrointestinal anastomosis (GIA) was made with 60-mm linear stapler. The anastomotic defect was closed by hand suture. After transecting the biliopancreatic limb (1 cm to GIA), another 100-cm jejunum (Roux limb) was measured and side-to-side jejunojejunal anastomosis was made with 60-mm linear stapler. The mesenteric and Petersen defects were closed. Drainage was placed as the routine procedure.

Fig. 1 Sleeve gastrectomy

Data Collection

Preoperative data were prospectively collected after admission. Postoperatively, all patients were scheduled to the follow-up at 1, 3, 6, 9, 12 months, and annually thereafter through outpatient clinic or telephone interview. T2DM remission was defined as fasting blood glucose (FBG) < 7 mmol/L and HbA1c < 6.5% for 1 year without pharmacological intervention. Fatigue was defined a persistent, distressing, subjective sense of physical, emotional, and/or cognitive tiredness or exhaustion after surgery that was not proportional to recent activity and interfered with usual functioning [17]. Diarrhea was defined as the passage of three or more loose or liquid stools per day.

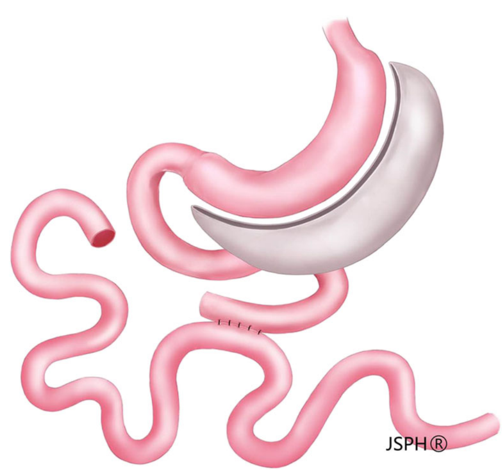

Fig. 2 Sleeve gastrectomy with jejunojejunal bypass

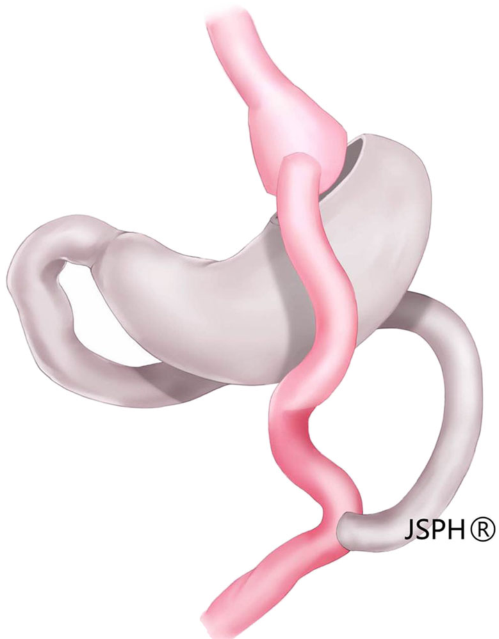

Fig. 3 Roux-en-Y gastric bypass

Statistical Analysis

Data was analyzed by SPSS 22.0. Continuous variables were shown as mean ± standard deviation (SD). Categorical variables were shown as frequencies. Statistical difference was assessed by two-sided *t* test or Fisher's exact test as appropriate. A subgroup case-matched analysis (1:1) was performed to compare weight loss and lipid profiles between SG + JJB/SG and SG + JJB/RYGB. The patients were matched with gender, age (± 2 years), and BMI (± 2 kg/m^2). The statistical significance was defined as $P < 0.05$.

Results

A total of 244 patients, who underwent bariatric surgery of SG ($n = 82$), SG + JJB ($n = 83$), or RYGB ($n = 79$), were included in the study based on the inclusion and exclusion criteria. Patients' preoperative characteristics and perioperative data are shown in Table 1. Compared to patients who underwent SG + JJB, patients who underwent SG had younger age and shorter operation time, while patients who underwent RYGB had lower preoperative weight and BMI. There was no statistical difference regarding the length of postoperative hospital stay within three groups. A total of four patients developed major postoperative complications, including one patient of massive bleeding in SG group, one patient of massive bleeding and one patient of gastric sleeve leak in SG + JJB group, one patient of gastrojejunal anastomosis stenosis and one patient of Petersen hernia in RYGB group (Table 1). The patients with postoperative massive bleeding and Petersen hernia were treated by emergency laparotomy. Leak of the gastric sleeve was treated by percutaneous abdominal drainage and recovered. Stenosis of the gastrojejunal anastomosis was treated by endoscopic dilation and recovered. There was no postoperative mortality.

Weight Loss

To compare the effect of different surgical procedure on weight loss, patients' weight was collected at 1-year follow-up after surgery. As shown in Table 2, patients in SG, SG + JJB, and RYGB group had almost similar weight and BMI at 1-year follow-up after surgery ($P > 0.05$). SG + JJB yielded more total weight loss (TWL) (36.9 ± 8.5%) compared to SG (33.6 ± 7.6%) and RYGB (33.2 ± 9.6%) ($P < 0.05$). It was worth noting that patients in SG + JJB group had older age compared to SG group and higher preoperative weight and BMI compared to RYGB group. To exclude bias of age and preoperative BMI on weight loss, we further performed a case-matched study (1:1 proportion) based on gender, age (± 2 years), and BMI (± 2 kg/m^2). A total of 36 pairs of SG/SG + JJB and 37 pairs of SG + JJB/RYGB were identified and further analyzed. As shown in Table 3, patients in SG + JJB group had higher TWL (38.8 ± 8.7% vs 35.0 ± 6.1%, $P = 0.011$) and excessive weight loss (EWL) (95.3 ± 20.4% vs 86.9 ± 13.7%, $P = 0.033$) compared to SG group at 1-year follow-up. However, there was no statistical difference regarding TWL and EWL at 1-year follow-up after surgery between SG + JJB and RYGB ($P > 0.05$) (Table 4). These data indicated that SG + JJB exhibited superior effect on weight loss comparing to SG alone.

Metabolic Disorders

As shown in Table 2, the remission of T2DM was 86.9% for SG (11/13), 94.1% for SG + JJB (32/34), and 85.3% for RYGB (35/41) ($P > 0.05$) at 1-year follow-up after operation. There was no statistical difference regarding the preoperative and postoperative HbA1C and FBG.

Lipid profiles, including total cholesterol (TC), triglyceride (TG), high-density lipoprotein (HDL), and low-density lipoprotein (LDL), were analyzed within the pairs SG/SG + JJB and SG + JJB/RYGB which were matched with gender, age, and BMI (Tables 3 and 4). The baseline lipid profiles were comparable for the pairs SG/SG + JJB and SG + JJB/RYGB. At 1-year follow-up after surgery, SG decreased the TG ($P < 0.05$) and increased HDL ($P < 0.05$), while SG + JJB improved all the lipid profiles including TC, TG, HDL, and LDL ($P < 0.05$). However, the postoperative lipid profiles were not statistically different between SG and SG + JJB. RYGB also improved all the lipid profiles ($P < 0.05$), but the effects of RYGB on TC and LDL improvement were better than SG + JJB ($P < 0.05$).

Table 1 Preoperative characteristics and perioperative outcomes

	SG ($n = 82$)	SG + JJB ($n = 83$)	RYGB ($n = 79$)
Gender (female/male)	41/41	44/39	42/37
Age (years)	26 ± 6.8	31.5 ± 9.9*	34.8 ± 12.3
Preop weight (kg)	124.0 ± 25.1	131.1 ± 27.7**	121.8 ± 20.3
Preop BMI (kg/m^2)	42.5 ± 6.9	44.7 ± 7.6**	42.4 ± 5.3
Operation time (min)	95.8 ± 27.8	122.1 ± 29.6*	126.6 ± 26.6
Length of postoperative hospital stay (days)	3.9 ± 1.4	4.0 ± 2.5	4.5 ± 1.6
Major complications	Massive bleeding $n = 1$	Massive bleeding $n = 1$ Gastric sleeve leak $n = 1$	Stenosis $n = 1$ Petersen hernia $n = 1$

*$P < 0.05$ compared to SG; **$P < 0.05$ compared to RYGB

The resolution of hypertension was 48.6% for SG, 51.3% for SG + JJB, and 53.1% for RYGB with no statistical difference (Table 2). However, the systolic and diastolic pressure was lower after RYGB compared with SG or SG + JJB ($P < 0.05$).

Nutritional Deficiencies

The nutritional status, including hemoglobin, vitamin D, vitamin B12, folate, and albumin, was evaluated at 1-year follow-up after surgery. As shown in Table 5, SG + JJB patients exhibited similar nutritional status compared to SG alone. However, RYGB patients had higher rates of anemia (22.8% vs 4.8%), vitamin D deficiency (65.8% vs 47.0%), vitamin B12 deficiency (25.3% vs 8.4%), and hypoalbuminemia (8.9% vs 1.2%) than SG + JJB patients ($P < 0.05$). Out of 26 patients who had postoperative anemia, 24 (92.3%) were female.

Major Complaints After Surgery

We collected the major complaints that affected the patients' quality of life at 1-year mark after surgery. As shown in Table 5, SG + JJB only increased the incidence of malodorous flatus compared to SG alone (34.9% vs 2.4%, $P < 0.05$).

Table 2 Weight loss, T2DM remission, and hypertension resolution after bariatric surgery

	SG ($n = 82$)	SG + JJB ($n = 83$)	RYGB ($n = 79$)
Preop weight (kg)	124.0 ± 25.1	131.1 ± 27.7**	121.8 ± 20.3
1-year weight (kg)	81.3 ± 13.6	81.6 ± 14.8	80.8 ± 14.7
ΔWeight (kg)	42.7 ± 16.7	49.5 ± 20.1*,**	40.9 ± 15.6
Preop BMI (kg/m^2)	42.5 ± 6.9	44.7 ± 7.6**	42.4 ± 5.3
1-year BMI (kg/m^2)	28.0 ± 4.2	28.0 ± 4.4	28.2 ± 4.3
ΔBMI (kg/m^2)	14.5 ± 5.1	16.8 ± 6.0*,**	14.2 ± 5.1
1-year %TWL	33.6 ± 7.6	36.9 ± 8.5*,**	33.2 ± 9.6
1-year %EWL	85.4 ± 17.1	87.9 ± 17.7	83.9 ± 25.9
T2DM (n)	13	34	41
T2DM remission	11	32	35
Preop HbA1C (%)	7.5 ± 1.2	7.3 ± 1.9	8.1 ± 1.6
1-year HbA1C (%)	5.5 ± 0.3	5.4 ± 0.4	5.7 ± 0.9
Preop FBG (mmol/L)	8.3 ± 2.0	8.7 ± 3.2	9.5 ± 3.1
1-year FBG (mmol/L)	5.7 ± 0.8	5.6 ± 0.6	5.9 ± 0.5
Hypertension (n)	37	37	32
Hypertension resolution (n)	18	19	17
Preop SP (mmHg)	148.6 ± 9.9	151.3 ± 11.1	150.3 ± 12.3
1-year SP (mmHg)	126.4 ± 14.2	125.5 ± 10.2**	119.8 ± 9.5
Preop DP (mmHg)	89.9 ± 8.3	90.4 ± 9.5	93.7 ± 12.2
1-year DP (mmHg)	78.3 ± 12.7	76.9 ± 9.6**	71.8 ± 10.9

FBG fasting blood glucose, *SP* systolic pressure, *DP* diastolic pressure

*$P < 0.05$ compared to SG; **$P < 0.05$ compared to RYGB

Table 3 Case-matched study of weight loss and lipid profiles between SG and SG + JJB

	SG (*n* = 36)	SG + JJB (*n* = 36)	*P* value
Gender (female/male)	19/17	19/17	1.000
Age (years)	27.7 ± 4.7	28.1 ± 4.5	0.085
Preop BMI (kg/m^2)	42.7 ± 5.7	43.1 ± 5.6	0.058
1-year BMI (kg/m^2)	27.6 ± 3.1	26.1 ± 3.6	0.035
1-year %TWL	35.0 ± 6.1	38.8 ± 8.7	0.011
1-year %EWL	86.9 ± 13.7	95.3 ± 20.4	0.033
Lipid profiles (mmol/L)			
Preop TC	4.65 ± 0.79	4.81 ± 0.62	0.34
1-year TC	4.38 ± 0.72	4.48 ± 0.74*	0.56
Preop TG	1.57 ± 0.80	1.89 ± 1.57	0.28
1-year TG	0.89 ± 0.41*	0.91 ± 0.40*	0.83
Preop HDL	1.00 ± 0.20	1.06 ± 0.18	0.19
1-year HDL	1.38 ± 0.29*	1.39 ± 0.24*	0.87
Preop LDL	3.37 ± 0.75	3.53 ± 0.77	0.37
1-year LDL	3.06 ± 0.66	3.10 ± 0.68*	0.80

TC total cholesterol, *TG* triglyceride, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein

*$P < 0.05$ compared to preoperative data

Compared to RYGB, SG + JJB patients were more likely to complain of de novo GERD (9.6% vs 0) after surgery ($P < 0.05$). However, RYGB resulted in higher incidence of diarrhea (21.5% vs 6.0%), dumping syndrome (7.6% vs 0), and fatigue (40.5% vs 25.3%) than SG + JJB ($P < 0.05$).

Table 4 Case-matched study of weight loss and lipid profiles between SG + JJB and RYGB

	RYGB (*n* = 37)	SG + JJB (*n* = 37)	*P* value
Gender (female/male)	22/15	22/15	1.000
Age (years)	30.1 ± 9.0	30.1 ± 9.2	0.809
Preop BMI (kg/m^2)	42.6 ± 4.7	42.8 ± 4.4	0.482
1-year BMI (kg/m^2)	27.7 ± 4.3	26.8 ± 4.2	0.234
1-year %TWL	34.9 ± 8.1	37.0 ± 7.6	0.233
1-year %EWL	88.2 ± 22.6	92.5 ± 22.3	0.359
Lipid profiles (mmol/L)			
Preop TC	4.73 ± 0.89	4.75 ± 0.74	0.92
1-year TC	3.57 ± 0.71*	4.29 ± 0.68*	< 0.0001
Preop TG	1.91 ± 0.71	1.66 ± 1.03	0.23
1-year TG	0.85 ± 0.38*	0.82 ± 0.29*	0.70
Preop HDL	0.98 ± 0.18	1.02 ± 0.25	0.43
1-year HDL	1.24 ± 0.49*	1.42 ± 0.32*	0.07
Preop LDL	3.25 ± 0.70	3.41 ± 0.58	0.29
1-year LDL	2.37 ± 0.58*	3.02 ± 0.56*	< 0.0001

TC total cholesterol, *TG* triglyceride, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein

*$P < 0.05$ compared to preoperative data

Discussion

Sufficient weight loss and favorable comorbidity remission are the two major objectives of bariatric surgery. Meanwhile, the risk-to-benefit ratio should be balanced when choosing the bariatric procedure, regarding the therapeutic outcomes and the postoperative complications [18]. The ideal bariatric procedure aims to pursue better therapeutic outcomes, minimize the side effect, and simplify the surgical procedure. The present study provided the preliminary results that SG + JJB yielded better weight loss than SG alone and equivalent weight loss to RYGB in patients with BMI ≥ 35 kg/m^2. Furthermore, SG + JJB resulted in less nutritional deficiencies and postoperative discomforts than RYGB. Thus, SG + JJB may serve as a feasible and safe bariatric procedure for selected patients with obesity.

Though multiple hypotheses, including hormone changes, were proposed to explain the mechanisms of weight loss after bariatric surgery, meal size restriction and macronutrient malabsorption remained the basis of postoperative weight loss [11, 19]. Jejunoileal bypass (JIB), which typically bypasses 90% of the intestine, is the oldest bariatric procedure for the treatment of obesity with pure malabsorptive function. However, JIB was abandoned due to the higher incidence of severe postoperative complications [20]. Shortening the length of bypassed intestine will decrease the postoperative complications, but compromise the weight loss effect. SG is a mainly restrictive bariatric procedure with marginal malabsorptive effect. The rationale of adding JJB to SG is to enhance the malabsorptive function, increase the weight loss effect, and prevent the postoperative weight regain. The present data confirmed that SG + JJB indeed had superior weight loss effect to SG alone in short-term follow-up, with 8.4% of extra EWL. Meanwhile, we observed that JJB did not increase the nutritional deficiencies and postoperative discomforts with an exception of malodorous flatus compared to SG alone.

RYGB is a bariatric procedure with both restrictive and malabsorptive function. We further compared the weight loss effect between SG + JJB and RYGB. As shown in Table 4, SG + JJB resulted in similar weight loss to RYGB. However, SG + JJB preserved the pylorus function and avoided the duodenal exclusion. With the preservation of pylorus function, SG + JJB did not result in dumping syndrome, compared to 7.6% of RYGB. Duodenal exclusion offers better T2DM control based on foregut theory, but it also excludes the absorptive function of the duodenum and proximal jejunum [13, 21]. Together with the delayed mixture of food and digestive juice, bariatric procedures with duodenal exclusion (e.g., BPD-DS or RYGB) were usually associated with higher incidence of nutritional deficiencies and gastrointestinal disorders [9, 22]. In the present study, SG + JJB resulted in less nutritional deficiencies (anemia, vitamin D deficiency, vitamin B12 deficiency, and hypoproteinemia) and diarrhea than RYGB with an exception

Table 5 Nutritional deficiency and patients' complaints at 1-year follow-up after bariatric surgery

Nutritional deficiency and patient complaints (*n*)	SG (*n* = 82)	SG + JJB (*n* = 83)	RYGB (*n* = 79)
Anemia	4	4**	18
Vitamin D deficiency	35	39**	52
Vitamin B12 deficiency	6	7**	20
Folate deficiency	3	2	2
Hypoproteinemia	1	1**	7
De novo GERD	6	8**	0
Constipation	3	4	1
Malodorous flatus	2	29*	31
Diarrhea	1	5**	17
Hair loss	48	55	62
Dumping syndrome	0	0**	6
Fatigue	12	21**	32

Anemia: hemoglobin < 120 g/L in men or < 110 g/L in women; vitamin D deficiency: vitamin D < 52.5 nmol/L; vitamin B12 deficiency: vitamin B12 < 133 pmol/L; folate deficiency: folate < 2.27 nmol/L; hypoproteinemia: albumin < 40 g/L

GERD gastroesophageal reflux disease

*$P < 0.05$ compared to SG; **$P < 0.05$ compared to RYGB

of de novo GERD (9.6%). These data demonstrated the important role of duodenum in preventing the nutritional and digestive complications. Meanwhile, SG + JJB facilitates the gastroscopy examination and avoids the delayed diagnosis of gastric cancer. Thus, SG + JJB may gain more popularity than RYGB in Chinese patients with severe obesity.

Obesity is an underlying risk factor for cardiovascular disease (CVD) as it raises hyperglycemia, hypertension, and dyslipidemia [23]. Though it is widely accepted that bariatric surgery could improve the metabolic disorders in patients with obesity, effects of different bariatric procedures on metabolic disorders are different. Praveen Raj et al. reported that RYGB had similar effect on dyslipidemia improvement to SG in short-term follow-up [24]. In long-term follow-up, Salminen et al. reported that RYGB resulted in equivalent T2DM remission to SG, but lower LDL and better hypertension control [25]. Melissas et al. reported that RYGB yielded better resolution of hypertension, T2DM, and dyslipidemia than SG in short-term follow-up, but the difference subsided in long-term follow-up [26]. In present study, we observed that SG + JJB had similar effect on the resolution of metabolic disorders to SG, but RYGB seemed to be more effective in improving hypertension (lower systolic and diastolic pressure) and dyslipidemia (lower TC and LDL) than SG + JJB in short-term follow-up. This data indicated that RYGB might be a better procedure for obese patients with severe metabolic disorders than SG or SG + JJB.

Bacterial overgrowth within the blind limb after JIB was reported to be related with the postoperative liver disease [27]. Lack of bile stimulation within the blind limb may jeopardize the intestinal barrier function and promote the bacterial translocation [28]. Unlike RYGB, SG + JJB retained the blind jejunal limb with no food and bile passage. Whether this blind jejunal limb will develop bacterial overgrowth as well as translocation or not remain unclear. In short-term follow-up, we did not observe any patients who suffered from liver toxicity, infection, or explosive diarrhea related to the bacterial overgrowth and translocation after SG + JJB. Bacterial overgrowth in bypassed intestine is common (40% of all cases) after malabsorptive procedures like RYGB, but its related symptoms are rare [29, 30]. Thus, the bacterial overgrowth within the blind limb may be overestimated. Moreover, the intestine continuity can be easily restored in case of severe symptoms related to the bacterial overgrowth.

Despite favorable weight loss after SG + JJB, lifestyle correction and supplementation of vitamin and mineral remain essential to prevent the postoperative weight regain and malnutrition. Postoperative binge eating was reported to be associated with poor weight loss and more weight regain after bariatric surgery [11]. Excessive food intake will counteract the malabsorptive function of JJB and decrease the weight loss effect. Meanwhile, small intestine has strong adaptive capacity [31]. Whether the common channel will compensate the function of bypassed jejunum or not remains unclear.

In the present study, 2 m of jejunum was bypassed after SG. The length of the bypassed intestine is correlated with strength of malabsorptive function. Longer bypassed intestine may also increase the risk of malnutrition and gastrointestinal disorders. Hassn et al. reported that SG with JIB (75-cm proximal jejunum and 75-cm ileum distal to cecum valve) increased the incidence of gallstone (16%) and intussusception of the blind intestine loop (2.4%) in long-term follow-up [32]. We did not observe these complications, possibly due to the short-term follow-up or short bypassed intestine. However, further investigations are warranted regarding the therapeutic outcome and postoperative complications with different length and location of the bypassed intestine.

The main limitation of this study was the bias of the patient selection as the age and preoperative BMI in three groups were not comparable. Although we performed case-matched analysis, the sample size was small and the evidence lever was further decreased. Moreover, the follow-up duration was short, and the follow-up rates of SG, RYGB, and SG + JJB were different. Despite better weight loss effect when adding JJB to SG, we would not guarantee that this procedure will decrease the weight regain in long-term follow-up. And the higher rate of loss to follow-up in SG or RYGB group may amplify the weight loss effect of SG or RYGB as patients with unsuccessful weight loss have higher rate of non-adherence to follow-up than successful patients [33]. Furthermore, the proportion and severity of T2DM in each group were different and the true effect of these procedures on T2DM remission may be different. Meanwhile, it was worth noting that the patients' complaints were not further validated and graded. Besides the prevalence, the severity of these complaints also exerted direct influence on patients' quality of life and the acceptance of the bariatric procedure. Thus, the results should be interpreted carefully. The follow-up of present cohort continues, and a prospective study with larger sample size is ongoing.

Conclusion

SG + JJB is an effective and safe bariatric procedure with favorable weight loss and metabolic disorder resolution as well as acceptable postoperative gastrointestinal discomfort and nutritional deficiency. SG + JJB may serve as an alternative bariatric procedure for patients with severe obesity. The choice of SG, SG + JJB, or RYGB should base on patient's individual condition. SG + JJB deserves further investigations with longer follow-up and larger sample size to validate its efficacy and safety.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was approved by the ethics committee of the First Affiliated Hospital of Nanjing Medical University (2018-SR-054).

Informed Consent Informed consent was obtained from all individual participants included in the study.

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