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ORIGINAL ARTICLE

Metabolic Efficacy and Diabetes Remission Predictors Following 'Sleeve Gastrectomy with Loop Duodenojejunal Bypass' Surgery

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Purpose: Laparoscopic sleeve gastrectomy with loop duodenojejunal bypass (SLDJB) is a novel metabolic surgery that is a modification of the single anastomosis duodenoileal bypass with sleeve. Compared to conventional surgeries, SLDJB is highly effective in inducing diabetes remission. This study analyzed the metabolic efficacy of SLDJB. **Materials and Methods:** Seventy-eight patients with obesity and diabetes who underwent SLDJB between May 2013 and October 2017 were retrospectively analyzed to investigate the efficacy of their surgery and diabetes remission predictors. Complete diabetes remission was defined as an $HbA1_C$ level $<6\%$ with cessation of insulin and oral hypoglycemic agents. **Results:** Complete diabetes remission occurred in 80.52% and 76.71% of patients at 1- and 3-year follow-ups, respectively. There was no significant difference in the rates of complete diabetes remission between the groups based on gender, preoperative body mass index (BMI), diabetes duration or preoperative insulin use. There was a significantly higher rate of complete remission in patients <50 years of age at the 1-year follow-up. Additionally, the rate of complete remission was significantly less when preoperative glycemic control was poor. Preoperative $HbA1_C$ levels negatively predicted complete remission, but was significant only at the 3-year follow-up. **Conclusion:** SLDJB is highly effective in treating obesity with type 2 diabetes, and preoperative glycemic control was found to predict complete remission. Patients under 50 years of age had a better short-term response rate; however, the surgery was effective regardless of gender, preoperative BMI, duration of diabetes or preoperative insulin use.

Key Words: Diabetes remission, Loop duodenojejunal bypass, Metabolic surgery, Bariatric surgery, Obesity, Diabetes

INTRODUCTION

Obesity is considered to be major global health problem [1], and it increases the risk of other diseases such as type 2 diabetes, hypertension, dyslipidemia, and obstructive sleep apnea [2]. Currently, the prevalence of diabetes is increasing, and it affects more than 400 million people worldwide [3]. Furthermore, the risk of diabetes-related complications is overwhelmingly high in diabetic patients with obesity. The objectives of diabetes management include the maintenance of an ideal body weight, good glycemic control, and the prevention or reduction of the incidence of complications [2]. In addition to long-term effective weight loss, metabolic surgery also results in

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diabetes remission. Metabolic surgery has been shown to be more effective than conventional methods in achieving glycemic control and reducing medications and cardiovascular risk factors [4]. Following metabolic surgery, several factors are thought to be responsible for diabetes remission, which include increased insulin secretion and sensitivity, improvement in intestinal gluconeogenesis, changes in glucose utilization and intestinal absorption, and changes in the morphology and physiology of adipose tissue [4].

In June 2009, the American Diabetes Association consensus statement defined diabetes remission as achieving euglycemia for 1 year in the absence of active pharmacological or surgical therapy. Partial diabetes remission was defined as subdiabetic hyperglycemia ($HbA1_C$ <6.5% and a fasting glucose of 100–125 mg/dl) for at least 1 year in the absence of active pharmacological therapy or ongoing procedures [5]. However, among authors reporting diabetes remission rates after medical or surgical interventions, there is a substantial lack of agreement regarding the criteria used to define remission, with various studies taking different $HbA1_C$ cut-off values such as <6% and <6.5% to define remission [6]. A meta-analysis by Buchwald et al. [7] reported a diabetes remission rate ($HbA1_C$<6%) of 78.1% after bariatric surgery. Remission was found to be highest in patients undergoing biliopancreatic diversion with duodenal switch (BPD-DS) (95.1%), followed by gastric bypass (80.3%), gastroplasty (79.7%), and gastric banding (56.7%). While laparoscopic Roux-en-Y gastric bypass (RYGB) is a widely accepted bariatric surgery, it has complications such as marginal ulcers, internal hernias, dumping syndrome, malnutrition and vitamin deficiencies, which can result in a lower quality of life and reduced acceptance of surgery [8].

Laparoscopic single anastomosis duodenoileal bypass with sleeve (SADI-S) is a loop modification of BPD-DS, with a 200–250 cm common channel. SADI-S is highly effective in terms of diabetes remission and weight loss. However, even a 200–250 cm common channel may result in significant malabsorption [9]. Laparoscopic sleeve gastrectomy with loop duodenojejunal bypass (SLDJB) is similar to SADI-S, but with a proximal anastomosis [10]. SLDJB gives patients the benefits of pyloric preservation, which include a reduced incidence of marginal ulcers, dumping syndrome and bile reflux. This technique also allows for endoscopic gastric surveillance, unlike gastric bypass surgeries for which gastric endoscopy is not possible. It also has the benefits underlying the different mechanisms of glucose homeostasis, including the foregut and hindgut hypotheses [8]. Preliminary results have shown that SLDJB is safe, feasible and provides efficient glycemic control [11]. Moreover, SLDJB is effective in terms of diabetes remission. However, there is limited available literature concerning this surgery. Therefore, this study aimed to analyze the efficacy of SLDJB and the various factors that may predict diabetes remission following this treatment.

MATERIALS AND METHODS

This was a retrospective study carried out in 78 patients who underwent SLDJB between May 2013 and October 2017. Patients suffering from diabetes and obesity with a body mass index (BMI) ≥30 kg/m^2 who underwent SLDJB were included in the study. Nondiabetic and prediabetic patients who underwent SLDJB were excluded. Patient data was retrieved from the master data sheet of the hospital and factors that may predict diabetes remission were analyzed. The primary outcomes were complete diabetes remission, partial diabetes remission and diabetes improvement at 1- and 3-year follow-ups. Secondary outcomes were weight-loss parameters including percent total weight loss (%TWL) and percent excess weight loss (%EWL) and protein energy malnutrition evaluated using the percentage of hypoalbuminemia at 1- and 3-year follow-ups. This study complied with international ethical norms according to the Helsinki declaration. Institutional review board approval (IRB No-ABMC/AH/2020/004) was received and detailed informed consent was obtained from all of the patients included in the study.

Sleeve gastrectomy was performed using 38 Fr calibration tube. The first part of the duodenum was mobilized and divided using staplers. This divided part was then anastomosed to the jejunum in an end-to-side

loop fashion and 200 to 250 cm distal to the duodeno-jejunal flexure (Fig. 1). Anastomosis was hand sewn. The length of the small intestine was measured beyond the anastomosis to ensure that at least a 400 cm common channel remained.

Patient data at the 1- and 3-year follow-up periods was collected and analyzed. Complete diabetes remission was defined as $HbA1_C$ <6% in the absence of antidiabetic medications. Partial diabetes remission was defined as $HbA1_C$ ≥6% and<6.5% in the absence of antidiabetic medications. Diabetes improvement was defined as a statistically significant reduction in $HbA1_C$ that did not meet the criteria for complete or partial remission, or a decrease in the requirements for antidiabetic medications (by discontinuing insulin or one oral agent, or a reduction by half of the dose) [12]. Deterioration was considered if the $HbA1_C$ percentage increased compared to the preoperative value despite using the same or an increased dosage of medications compared to the preoperative dosage. The recurrence of diabetes was defined as an increase in $HbA1_C$ to ≥6.5% or the need to restart medications for blood glucose control if the patient had achieved diabetes remission in the previous follow-up [12].

An analysis of complete diabetes remission was carried out using the Pearson Chi Square test with respect to age (<50 vs. ≥50 years), gender, BMI (<40 vs. ≥40 kg/m^2), diabetes duration (<5 vs. ≥5 years), preoperative glycemic control ($HbA1_C$ <8% vs. ≥8%) and preoperative insulin use. Preoperative glycemic control was considered to be poor if the preoperative $HbA1_C$ was ≥8%. Patients were divided into insulin users and insulin non-users based on their preoperative insulin use. Univariate and multivariate logistic regression analyses were performed to analyze the effect of age, gender, preoperative weight, preoperative BMI, weight loss, BMI loss, diabetes duration, preoperative $HbA1_C$ value, and preoperative insulin usage on diabetes remission. An ABCD score was calculated for each patient, and remission rates with respect to this score were documented at each follow-up and analyzed.

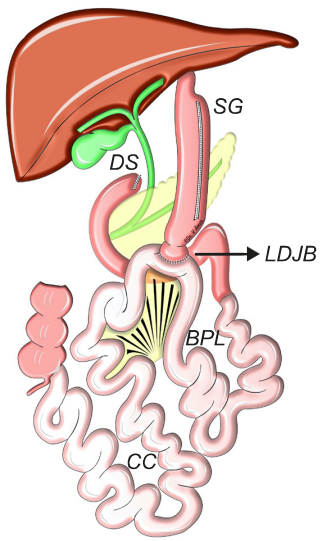

Fig. 1. Schematic diagram of 'Sleeve gastrectomy with loop duodenojejunal bypass'. BPL = Biliopancreatic limb, CC = Common channel, DS = Duodenal stump, LDJB = Loop duodenojejunal bypass, SG = Sleeve gastrectomy.

Weight and BMI were measured at the 1- and 3-year follow-ups. Weight loss, BMI loss, %TWL, and %EWL were calculated at these follow-ups. The correlation between weight loss, BMI loss, and a decrease in $HbA1_C$ was calculated using the Pearson correlation coefficient at the 1- and 3-year follow-ups. Serum albumin levels were analyzed at the 1- and 3- year follow-ups and the percentage of patients who developed hypoalbuminemia with a serum albumin level of <3.5 g/dl was calculated and documented. SPSS version 23 statistical software (IBM Corp., Armonk, NY, USA) was used to perform the statistical analyses. All P-values <0.05 in various statistical tests were considered statistically significant.

RESULTS

SLDJB was performed in 126 patients with obesity between May 2013 and December 2017. Of these patients, 78 with type 2 diabetes and obesity who underwent this surgery between May 2013 and October 2017 were included in this study. Their demographic and perioperative data is summarized in Table 1. Twenty-four of the 78 patients (30.77%) took insulin preoperatively. Twenty-one of these patients stopped using insulin within 1-month post-surgery and 3 stopped using insulin within 3-months post-surgery. One patient was lost to follow-up after 6 months. Five of the 77 patients (6.49%) were still taking oral hypoglycemic agents at the 1-year follow-up period,

Table 1. Demographic and the perioperative data

Parameter	Value (n=78)[a]
Age (years)	44.45±10.52 (27–63)
Age (<50 : ≥50 years)	53:25 (67.95:32.05)
Gender (Male : Female)	55:23 (70.51:29.49)
Weight (kg)	112.64±16.64 (79.2–158)
BMI (kg/m^2)	40.87±6.54 (30.08–55.11)
BMI (<40 : ≥40 kg/m^2)	40:38 (51.28:48.72)
Preoperative HbA1$_C$ (%)	7.76±1.51 (6.1–14.6)
Duration of diabetes (years)	4.85±4.38 (0.25–20)
Preoperative poor glycemic control % (HbA1$_C$ ≥8%)	27 (34.62)
Preoperative insulin usage (%)	24 (30.77)
Duration of surgery (minutes)	199.1±65.89 (120–360)
Intraoperative blood loss (ml)	41.22±22.62 (0–100)
Major intra-/post-operative bleeding (%)	0
Leak from the upper end of the sleeve (%)[b]	1 (1.28)
Leak from the anastomosis (%)	0

[a]Values are mentioned as mean±standard deviation (Minimum–Maximum) or number (%), [b]Required laparoscopic drainage–Recovered well.

Table 2. Analysis of HbA1$_C$ and diabetes remission at the 1-year and 3-year follow-ups

Variable	1-year follow-up (n=77, 98.72%)	3-year follow-up (n=73, 93.59%)
HbA1C (%)	5.51±0.67, *P<0.001[a]	5.52±0.56, *P=0.368[b]
Complete remission %	62 (80.52)	56 (76.71)
Partial remission %	8 (10.39)	10 (13.70)
Improvement %	7 (9.09)	7 (9.59)
Deterioration %	0 (0)	0 (0)
Recurrence %	0 (0)	3/67[c] (4.48[d])

Values are mentioned as mean±standard deviation (Minimum–Maximum) or number (%).
[a]Paired samples t-test (Preoperative-1-year), [b]Paired samples t-test (1-year-3-year), [c]67/70 patients who achieved remission at 1 year either reached or were available for follow-up at 3 years, [d]Patients were in improvement category compared to preoperative status.

and 5 of 73 patients (6.85%) were on these agents at the 3-year follow-up period.

HbA1$_C$ levels at the different follow-ups are shown in Table 2 and Fig. 2. There was a significant decrease in HbA1$_C$ at the 1-year follow-up compared to the preoperative values. There was no significant difference in the HbA1$_C$ levels at the 1- vs. 3-year follow-up. None of the patients developed hypoglycemia.

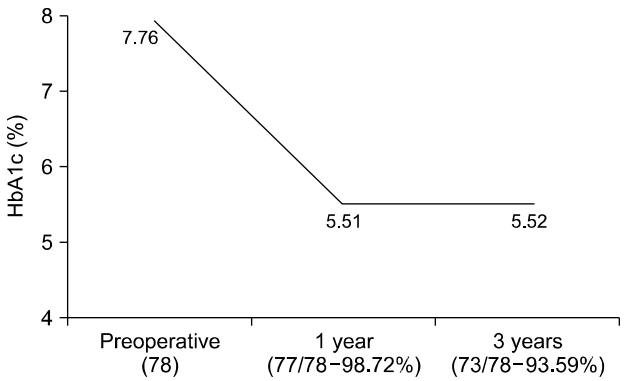

Fig. 2. Chart of HbA1$_C$ values at different time intervals.

The proportion of patients with complete diabetes remission, partial diabetes remission, diabetes improvement, deterioration, and recurrence is listed in Table 2. The variance in complete diabetes remission in the different groups at the 1- and 3-year follow-ups is shown in Table 3. The results of the univariate and multivariate logistic regression analyses showing the effect of different variables on diabetes remission at the 1- and 3-year follow-ups are also shown in Table 3. The rate of complete remission was significantly higher in patients <50 years of age compared to those ≥50 years at the 1-year follow-up. While the univariate logistic regression analysis indicated that age significantly negatively predicted complete remission at the 1-year follow-up, it was not found to be an independent predictor of complete remission. The rate of complete diabetes remission was significantly lower in patients who had poor preoperative glycemic control (HbA1$_C$ ≥8%). Both the univariate and multivariate logistic regression analyses showed that preoperative HbA1$_C$ levels negatively predicted complete remission at the 1- and 3-year follow-ups, but this was statically significant only at the 3-year follow-up. There was no significant difference in complete remission between groups based on gender and preoperative BMI <40 vs. ≥40 kg/m^2. Logistic regression analysis indicated that preoperative weight and BMI did not predict complete remission following surgery. The effect of weight loss, BMI loss and %TWL on complete remission at the 1- and 3-year follow-ups was less evident in the regression analysis. Similarly, correlations between weight loss, BMI loss and a decrease in HbA1$_C$, calculated using Pearson's

Table 3. Significance of the factors influencing the diabetes response at the 1-year and 3-year follow-ups

Variable	1-year follow-up (n=77, 98.72%)				3-year follow-up (n=73, 93.59%)			
	N (CR[a]:No CR[b])	CST[c]	ULR[d]	MLR[e]	N (CR[a]:No CR[b])	CST[c]	ULR[d]	MLR[e]
Age (<50 years)	53 (86.79:13.21)	0.039	0.026	0.099	50 (76:24)	0.832	0.508	0.833
Age (≥50 years)	24 (66.67:33.33)				23 (78.26:21.74)			
Males	54 (79.63:20.37)	0.763	0.763	0.274	51 (74.51:25.49)	0.498	0.500	0.662
Females	23 (82.61:17.39)				22 (81.82:18.18)			
BMI (<40 kg/m^2)	39 (82.05:17.95)	0.731	0.491	0.532	38 (76.32:23.68)	0.933	0.523	0.125
BMI (≥40 kg/m^2)	38 (78.95:21.05)				35 (77.14:22.86)			
Weight	77 (-)	-	0.371	0.558	73 (-)	-	0.918	0.116
Weight loss	77 (-)	-	0.135	0.771	73 (-)	-	0.597	0.097
BMI loss	77 (-)	-	0.202	0.708	73 (-)	-	0.393	0.101
Diabetes duration (<5 years)	43 (88.37:11.63)	0.050	0.334	0.333	40 (75:25)	0.703	0.288	0.512
Diabetes duration (≥5 years)	34 (70.59:29.41)				33 (78.79:21.21)			
$HbA1_C$ (<8%)	50 (90:10)	0.004	0.075	0.088	47 (85.11:14.89)	0.023	0.032	0.026
$HbA1_C$ (≥8 %)	27 (62.96:37.04)				26 (61.54:38.46)			
Insulin use (no)	54 (81.48:18.52)	0.744	0.744	0.375	51 (74.51:25.49)	0.498	0.500	0.633
Insulin use (yes)	23 (78.26:21.74)				22 (81.82:18.18)			

Variables in logistic regression = Age, sex, preoperative BMI, preoperative weight, weight loss, BMI loss, diabetes duration, preoperative $HbA1_C$, preoperative insulin use.
[a]CR = Complete Remission%, [b]No CR = Partial remission and improvement%, [c]CST = P-value in Chi square test, [d]ULR = P-value in univariate logistic regression, [e]MLR = P-value in multivariate logistic regression.

Table 4. Prediction of the complete diabetes remission by ABCD score

ABCD score	1-year follow-up (n=77, 98.72%)	3-year follow-up (n=73, 93.59%)
0	-	-
1	0/1 (0)	0/1 (0)
2	0/2 (0)	0/1 (0)
3	2/3 (66.67)	0/3 (0)
4	5/7 (71.43)	5/7 (71.43)
5	17/22 (77.27)	16/22 (72.73)
6	15/19 (78.95)	16/19 (84.21)
7	9/9 (100)	8/9 (88.89)
8	9/9 (100)	8/8 (100)
9	5/5 (100)	3/3 (100)
10	-	-
BLR[a]	P=0.001	P=0.001

Values are mentioned as number (%).
[a]BLR = Binary logistic regression.

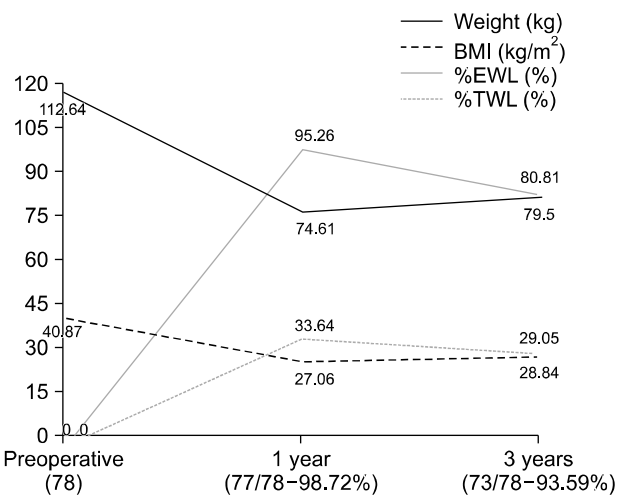

Fig. 3. Weight loss parameters at different time intervals.

correlation coefficient, was found to be statistically insignificant at the 1- and 3-year follow-ups. Moreover, there was no significant difference in complete remission rates when the duration of diabetes was <5 as opposed to ≥5 years and between preoperative insulin users and non-users.

The recurrence of diabetes among those who achieved diabetes remission in the previous follow-up is shown in Table 2. Complete and partial diabetes remission was achieved in 70 of 77 patients at the 1-year follow-up. Of these 70 patients, 67 were available for follow-up after 3 years. Diabetes recurrence occurred in 3 of these patients at that time. All of the patients who had recurrence were in the diabetes improvement category, and one required oral hypoglycemic agents to control their blood glucose. The other 2 patients were not taking any medications. A logistic regression analysis showed that none of the factors

under investigation were found to predict recurrence in our study. Hence, while there was a weight gain of 6.67±2.52 kg in these 3 patients, this gain did not predict their diabetes recurrence. As the number of patients who developed recurrence was very low, a detailed analysis of predictors could not be performed.

Remission rates with respect to ABCD scores the at 1-year and 3-year follow-ups are summarized in Table 4. Logistic regression analysis indicated that ABCD scores significantly predicted complete diabetes remission at the 1- and 3-year follow-ups. Higher ABCD scores were associated with more complete diabetes remissions.

Mean preoperative weight, BMI, and the weight-loss parameters at the 1- and 3-year follow-ups are shown in Fig. 3. Weight loss was significantly high 1-year after surgery. However, weight gain and a reduction in %TWL was observed at the 3-year follow-up, which was statistically significant.

None of the patients had serum albumin levels <3 g/dl at the 1-year and 3-year follow-ups. Four of the 77 patients (5.19%) at 1-year follow-up and 3 of 73 patients (4.11%) at the 3-year follow-up had serum albumin levels <3.5 g/dl; although, none of them had clinical manifestations of hypoalbuminemia. Moreover, none of them required intravenous albumin injections or a read-justment of the common channel to treat hypoalbuminemia.

DISCUSSION

Metabolic surgery has been shown to be more effective than lifestyle interventions for the treatment of diabetes with obesity. A meta-analysis by Rao et al. [13] examined the effects of gastric bypass surgery on diabetes in patients 1-year post-surgery and found an overall diabetes remission rate of 57% (range, 23%–93%). Recently, a joint statement by International Diabetes Organizations included metabolic surgery in their treatment algorithm for diabetes [14]. SLDJB is a highly effective metabolic surgery for the treatment of diabetes with obesity, with diabetes remission primarily due to physiological and hormonal changes that alter insulin production and sensitivity [4].

Our study showed that $HbA1_C$ dropped significantly to <6% 1 year after SLDJB in a majority of the patients, and this decrease was maintained even at the 3-year follow-up. These results are in accordance with a study by Huang et al. [8] that compared SLDJB and RYGB surgeries in diabetic patients with BMI <35 kg/m^2. Their results showed a significant decrease in $HbA1_C$ levels after both surgeries compared to baseline values. They also demonstrated that both surgeries were comparable in terms of glycemic control and weight loss in their patients.

Our study showed that more than 90% of the patients achieved either complete or partial diabetes remission after SLDJB at the 1-year follow-up. Although the percentage of complete diabetes remission decreased at the 3-year follow-up, overall diabetes remission was maintained in more than 90% of the patients, indicating that the metabolic effect of SLDJB was sustainable. Huang et al. [11] has also reported encouraging results, with remission rates of 50% and remission or improvement of diabetes in 91% of patients 6 months following SLDJB. Naitoh et al. [15], in their study comparing laparoscopic sleeve gastrectomy (SG) and laparoscopic sleeve gastrectomy with duodenojejunal bypass (SDJB) surgeries, showed diabetes remission occurring in 80.8% of patients after SG and 86% after SDJB at a 1-year follow-up. The diabetes remission rate found in our study is comparable with these results. SDJB is similar to SLDJB, with the exception that the anastomosis in the former is in the Roux-en-Y fashion, while in the later it is in a loop fashion.

None of the patients in our study required insulin to control their blood glucose levels at the 1- and 3-year follow-ups, and the proportion of patients requiring oral hypoglycemic agents was <10%, even at the 3-year follow-up. These results suggest that glycemic control was sustainable with SLDJB and resulted in the discon-tinuation of anti-diabetic medications for the majority of the patients.

Our study also showed that younger patients had better short-term, complete diabetes remission rates, and that SLDJB was equally effective in males and females. Similarly, preoperative BMI had no influence on diabetes remission. We also found no strong correlation between weight or BMI loss with postoperative decrease in $HbA1_C$ levels. In a meta-analysis by Wang et al. [16], the authors claimed that there was a significant negative association between

diabetes remission following metabolic surgery and baseline age and higher baseline BMI in Asian diabetic patients. However, gender and baseline BMI in non-Asian ethnicities could not predict diabetes remission. The results of our study are comparable with several other studies suggesting that gender and BMI had no effect on diabetes remission [6].

However, our results in relation to the effects of preoperative BMI and weight loss on diabetes remission should be interpreted with caution. In the STAMPEDE trial, Schauer et al. [17] compared bariatric surgery with intensive medical therapy for diabetes and found that the percentage of weight loss at the 1-year follow-up was significantly associated with achieving glycemic control at the 5-year follow-up. Moreover, in the DiRECT randomized trial, Lean et al. [18,19] compared a weight management program and best-care practice guidelines and demonstrated that diabetes remission at 1- and 2-year follow-ups was closely linked to weight loss. In addition, in a study comparing laparoscopic SADI-S with RYGB and SG, Enochs et al. [20] suggested that more weight loss may have contributed to higher rates of diabetes remission in the SADI-S group. In our investigation, weight loss, BMI loss, and %TWL were significant at the 1- and 3-year follow-ups. This significant weight loss may have also contributed to the diabetes remission observed in our patients as well. However, the association between weight-loss parameters and diabetes remission was less evident in our cohort, which was likely due to the relatively small number of patients and similar weight-loss responses in the majority of the patients, as well as the significant diabetes remission rates at the 1- and 3-year follow-ups. Therefore, larger, multicenter studies are needed to clarify the effect of weight loss on diabetes remission following SLDJB.

The duration of diabetes and preoperative insulin use did not alter the outcome of the surgery in our patients. This suggests that diabetes remission was effective after SLDJB, regardless of the diabetes duration and preoperative insulin use. Huang et al. [8] has shown that there was a higher rate of diabetes remission in patients with a diabetes duration <5 years as opposed to ≥ 5 years 1-year following SLDJB and RYGB surgeries, but the difference was not statistically significant. Naitoh et al. [15] demonstrated that the absence of insulin use significantly predicted diabetes remission following SDJB and SG surgeries. Similarly, in our study, patients with better preoperative glycemic control responded favorably after surgery. These results suggest that surgery should be considered when diabetes is under control in obese patients. Naitoh et al. [15] also showed that lower preoperative $HbA1_C$ levels significantly predicted diabetes remission after SDJB and SG surgeries. Nautiyal et al. [21] has suggested that the duration of diabetes was the most probable independent predictive factor for relapse owing to reduced β-cell functioning and, therefore, that patients with diabetes and obesity should be treated with metabolic surgery during the earlier course of the disease. In addition, a meta-analysis by Wang et al. [16] showed that disease severity was an important prognostic factor effecting the outcome of metabolic surgery.

There are several scoring systems, such as the ABCD and DiaRem scores, that have been designed to predict diabetes remission following metabolic surgery. ABCD score takes preoperative age (A), preoperative BMI (B), fasting C-peptide level (C), and diabetes duration (D) into consideration [22]. The DiaRem score takes preoperative insulin use, preoperative age, preoperative $HbA1_C$ levels, and the types of preoperative anti-diabetic medications into consideration [23]. Lower DiaRem and higher ABCD scores are associated with higher diabetes remission incidence [22,23]. The ABCD score has better predictive power in comparison to DiaRem score [24] and, in our patients, higher ABCD scores were significantly associated with better diabetes remission likelihoods at the 1-year and 3-year follow-ups.

The results of our study indicate that, while some patients did not achieve diabetes remission, there was an improvement in diabetes status after SLDJB at the 1- and 3-year follow-ups. Moreover, none of the patients experienced diabetes deterioration following SLDJB. The proportion of diabetes recurrence was $<5\%$ at the 3-year follow-up, however, these patients were still in the diabetes improvement category. This suggests that even though diabetes recurred, diabetes improvement can be maintained after SLDJB.

Bariatric surgeries alter several gastrointestinal hormones that result in sustained weight loss and diabetes remission. Ghrelin acts against insulin [25], and the sleeve gastrectomy part of the SLDJB reduces ghrelin, leading to reduced insulin resistance. Longer biliopancreatic limbs also contribute to increased weight loss and diabetes remission [26]. Roslin et al. [27] has suggested that longer biliopancreatic limbs in single anastomosis duodenal switch (SADS) surgeries are associated with greater weight loss and improved metabolic outcomes. SLDJB is a type of SADS, also known as the one anastomosis duodenal switch [28]. The key difference between SLDJB and conventional surgeries is the presence of a longer biliopancreatic limb, and the preservation of the pylorus and the first part of the duodenum in SLDJB. In the majority of the patients treated with SLDJB in our study, the biliopancreatic limb length was 250 cm. As nutrients directly enter the mid-jejunum and bypass 250 cm of the jejunum, they reach the distal ileum more quickly, and probably significantly increase GLP 1 and peptide YY which improve glucose tolerance [29]. Furthermore, anti-incretins, produced in the second part of duodenum, increases insulin resistance [30]. The prevention of food entering into the second part of duodenum after SLDJB likely reduces anti-incretins, thereby increasing insulin sensitivity. Hormonal assays are required at different time intervals to verify the role of these hormones in diabetes remission. However, due to cost constraints, these assays were not performed in this study.

Increasing the biliopancreatic limb to more than 200 cm increases the risk of protein energy malnutrition following gastric bypass surgery [31]. While the length of the biliopancreatic limb in the majority of our patients was >200 cm, none of them experienced protein energy malnutrition. As the pylorus controls gastric emptying, its preservation allows a greater length of intestine to be bypassed, which increases the metabolic efficacy of the surgery and reduces the risk of malabsorption [27]. It also reduces the risk of dumping syndrome, marginal ulcers and bile reflux into the sleeve [27,32]. Furthermore, the presence of only one anastomosis in OADS surgeries reduces the risk of internal herniation [20].

CONCLUSION

This study demonstrates that SLDJB is a highly effective metabolic surgery for the treatment of patients with obesity and type 2 diabetes. Diabetes remission following this surgery was maintained in the majority of our patients over a period of several years. Patients with better preoperative glycemic control responded well after the surgery, suggesting that it is best to consider surgery in obese patients when their diabetes is still under control. Young patients also responded well after the surgery, at least in the short term. SLDJB is effective irrespective of gender, preoperative BMI, the duration of diabetes or preoperative insulin use.

CONFLICT OF INTEREST

We hereby declare that there are no hidden conflicts of interests either financial or plagiarism related or any other related to the clinical content and work of this manuscript.

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