RESEARCH ARTICLE

Safety and Feasibility of Laparoscopic Sleeve Gastrectomy with Loop Duodenal Switch Surgery for Obesity in Indian Patients

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ABSTRACT

Aim: Laparoscopic sleeve gastrectomy with loop duodenal switch (SLDS) surgery is a loop modification of biliopancreatic diversion with duodenal switch (BPD-DS) aimed at reducing malabsorption without compromising on the efficacy. This study aimed to analyze the safety and feasibility of SLDS surgery in Indians suffering from obesity.

Materials and methods: This was a retrospective study analyzing 169 patients who underwent SLDS surgery between November 2013 and June 2020. The cohort was divided into two subgroups based on the common channel length—2.5 and $\geq$3 m. Weight-loss parameters, diabetes remission, and investigations at 6 months and 1 year follow-up were analyzed in the total cohort and common channel subgroups. The percentage of total weight loss (%TWL) $\geq$25% was considered as a successful weight-loss outcome. HbA1C <6% without the need for antidiabetic medications was considered as complete diabetes remission. Safety was analyzed in terms of intraoperative and postoperative complications.

Results: Mean preoperative body mass index was 45.39 $\pm$ 7.6 kg/m^2. 48.52% of the patients were suffering from type II diabetes. Mean %TWL was 30.91 $\pm$ 4.98 and 41.86 $\pm$ 7.63% and complete diabetes remission was 81.82 and 89.06% at 6 months and 1 year follow-up, respectively. The percentage of total weight loss was inversely proportional to the common channel length. Complete diabetes remission was not significantly affected by the common channel length. Serum albumin <3 gm/dL was significantly high in patients with a common channel length of 2.5 vs $\geq$3 m—25 vs 4.65% at 6 months and 40 vs 7.14% at 1 year follow-up, respectively. Thirty-day mortality was zero.

Conclusion: Sleeve gastrectomy with loop duodenal switch surgery appears to be effective and safe in Indian patients. Malabsorption risk is greatly reduced when the common channel length is $\geq$3 m.

Clinical significance: Sleeve gastrectomy with loop duodenal switch surgery with the common channel length $\geq$3 m simplifies BPD-DS, gives excellent weight loss and diabetes remission with minimal malabsorption. Restricting the biliopancreatic limb to $\leq$55% prevents adverse malabsorptive consequences.

Keywords: Bariatric surgery, Biliopancreatic diversion with duodenal switch, Diabetes, Diabetes remission, Metabolic surgery, Obesity, One anastomosis gastric bypass, Single anastomosis duodenoileal bypass with sleeve, Sleeve gastrectomy, Weight loss.

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INTRODUCTION

Bariatric surgery offers durable weight loss and diabetes remission with minimal complications. Hormonal and physiological alterations are mainly responsible for the metabolic effects after bariatric surgery.[1] Metabolic outcomes are significantly better after laparoscopic biliopancreatic diversion with duodenal switch (BPD-DS) compared to standard surgeries like laparoscopic Roux-en-Y gastric bypass (RYGB). But nutritional deficiencies are also higher after BPD-DS.[2] It is not widely performed because of its technical complexity and increased risk of severe malabsorption.

Single anastomosis duodenoileal bypass with sleeve (SADI-S) is a loop modification of duodenal switch with a 2–2.5 m common channel.[3] It simplifies the procedure and reduces malabsorption to some extent. But even with 2.5 m common channel malabsorption can be significant in SADI-S. Increasing common channel length to 3 m can effectively reduce malabsorption.[4] Several loop duodenal switch (LDS) surgeries were described in the literature with different common channel lengths.[5]

Sleeve gastrectomy with loop duodenal switch (SLDS) is a loop modification of BPD-DS (Fig. 1).[6] It is technically simple with only one anastomosis, compared to BPD-DS. One main advantage

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is common channel length can be tailored according to the individual requirement and depending on the total bowel length. There is no literature available from the Indian subcontinent about this procedure. We analyzed our experience with this surgical technique in Indian patients suffering from obesity to ascertain its safety, feasibility, and efficacy.
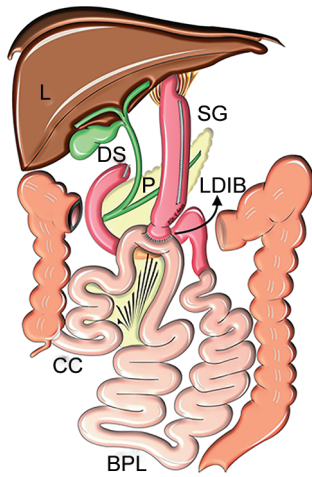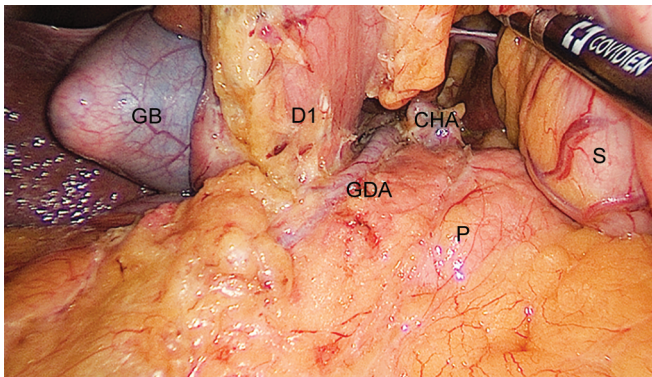
Fig. 1: Schematic diagram of sleeve gastrectomy with loop duodenal switch: BPL (biliopancreatic limb); CC (common channel); DS (duodenal stump); L (liver); P (pancreas); LDIB (loop duodenoileal bypass); SG (sleeve gastrectomy)

Institutional ethics committee approval was obtained and detailed written informed consent was taken from all the participants in this study. Our study complied with the ethical norms proposed by the Helsinki declaration for research involving humans.

Technique

Four ports were used in all the patients. Devascularization of greater curvature was performed starting opposite to angular incisure. Dissection was continued up to 5 cm beyond the pylorus and behind the first part of the duodenum until the gastroduodenal artery was identified (Fig. 2). The lesser omental layer over the caudate lobe was divided from behind the stomach to create a window. The right gastric artery (RGA) was divided at its origin using a vessel sealer. This step was a modification compared to the classical SADI-S described by Sánchez-Pernaute et al.[7,8] This step ensured free mobility of gastric sleeve, pylorus, and the first part of the duodenum as a single unit after the duodenal transection.[9] A lax sleeve gastrectomy (SG) was performed around a 38 French calibration tube starting 4 cm proximal to the pylorus. After completion of SG, the duodenum was transected using staplers (Fig. 3 and 4). The divided first part of the duodenum was
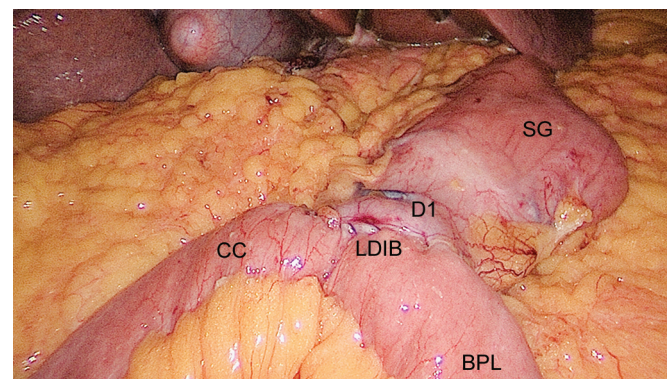

Fig. 2: Operative photograph of the duodenal dissection: CHA (common hepatic artery); D1 (part of the duodenum); GB (gallbladder); GDA (gastroduodenal artery); P (pancreas); S (stomach)
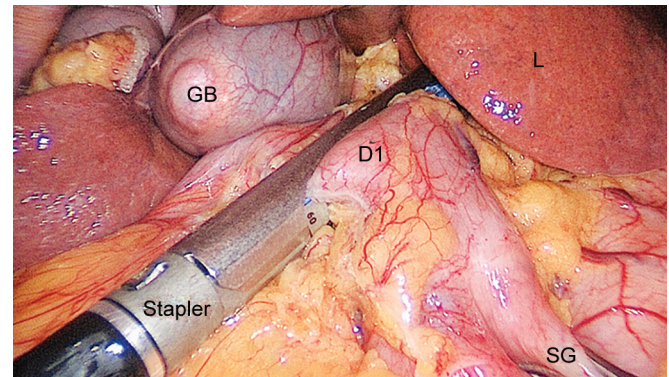
Fig. 3: Operative photograph of the duodenal transection: D1 (part of the duodenum); GB (gallbladder); L (liver); SG (sleeve gastrectomy)
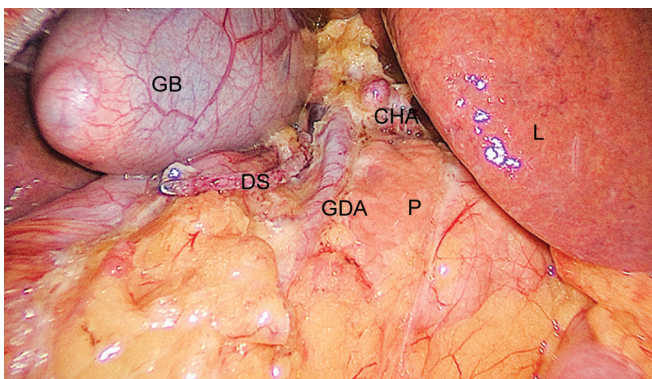
Fig. 4: Operative photograph of the duodenal stump: CHA (common hepatic artery); DS (duodenal stump); GB (gallbladder); GDA (gastroduodenal artery); L (liver); P (pancreas)

Fig. 5: Operative photograph of loop duodenoileal bypass: BPL (biliopancreatic limb); CC (common channel); D1 (part of the duodenum); LDIB (loop duodenoileal bypass); SG (sleeve gastrectomy)

Materials and Methods

It was a retrospective study of 169 patients who underwent SLDS surgery between November 2013 and June 2020. Patients with body mass index (BMI) ≥30 kg/m^2, those in whom surgery was performed as a primary surgery were included in this study. Those who underwent LDS as a revision surgery were excluded from this study.

anastomosed to distal ileum, in the antecolic end to side fashion using 3-0 continuous absorbable sutures in two layers (Fig. 5). In the fixed common channel (FCC) variant of SLDS surgery, the common channel length was fixed at 2.5, 3, or 3.5 m proximal to the ileocecal junction. In the fixed ratio bypass (FRB) variant of SLDS surgery, a fixed percentage of the jejunoileal length was bypassed.

Patients were discharged on the second postoperative day. Contrast X-ray and an abdominal sonography were performed 1 week and 1 month postoperatively to screen for leak and bleeding. Patients were prescribed lifelong bariatric multivitamin, mineral supplements, and ursodeoxycholic acid for 18 months.

Weight and BMI were documented at 6 months and 1 year follow-up and percentage of excess weight loss (%EWL) with BMI reference point of 25 kg/m^2 and percentage of total weight loss (%TWL) were calculated. The percentage of total weight loss ≥25% was considered as a successful weight-loss outcome. The percentage of excess weight loss ≥50% was taken as an alternative reference point to define a successful outcome. Complete diabetes remission was defined as HbA1C <6% with no antidiabetic medications needed for glycemic control. Partial diabetes remission was defined as HbA1C ≥6% but <6.5% in the absence of antidiabetic medications. Diabetes improvement was defined as a statistically significant reduction in HbA1C not meeting the criteria for complete or partial remission or decrease in requirement for antidiabetic medications. Differences in %TWL, %EWL, and HbA1C at 6 months and 1 year follow-up in subgroups based on the common channel were calculated using independent samples t test. The effect of common channel length on the weight-loss parameters was analyzed using simple linear regression and multiple regression analysis. The effect of common channel length on the weight-loss success rates and diabetes remission rates was calculated using logistic regression analysis. IBM SPSS version 26 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. *p* value of <0.05 was considered significant in various statistical tests.

Major complications, such as, internal bleeding and leak, were documented. Nutritional parameters including total protein and serum albumin at 6 months and 1 year follow-up were documented.

RESULTS

A total of 171 patients underwent SLDS surgery between November 2013 and June 2020. One hundred and sixty-nine patients who met the inclusion criteria were analyzed. The mean age was 40.53 ± 10.07 years (16–68). Male:female ratio was 87:82. BMI of 24.85% (42/169) patients was ≥50 kg/m^2. 48.52% (82/169) patients were suffering from type II diabetes. 30.18% (51/169) patients had prediabetes. The average common channel length was 3.33 ± 0.41 (2.5–4.32) m. A fixed common channel variant was performed in 144 patients (the common channel was fixed at 2.5, 3, and 3.5 m in 26, 16, and 102 patients, respectively). Fixed ratio bypass variant was performed in 25 patients (the common channel length was 55% in 1, 50% in 13, 45% in 8, and 40% in 3 patients). 98.7% (152/154) and 91.24% (125/137) patients were available at the 6 months and 1 year follow-up, respectively.

Weight and BMI parameters of patients at different time intervals are summarized in Table 1. Overall weight and BMI were significantly less at 6 months and 1 year follow-up compared to preoperative values (Table 1). The percentage of total weight loss and %EWL with BMI reference point of 25 kg/m^2 in the total cohort and common channel subgroups at 6 months and 1 year follow-up after surgery are summarized in Table 1. Independent samples t test showed significantly more %TWL in patients with 2.5 m common channel compared to those with ≥3 m. Simple linear regression and multiple regression analysis showed that %TWL was inversely proportional to the common channel length at 6 months and 1 year follow-up. The percentage of excess weight loss was similar between the subgroups and the common channel length effect

on %EWL was found to be insignificant (Table 1). The weight-loss success rate was 91.45% (139/152) and 99.2% (124/125) at 6 months and 1 year follow-up when %TWL ≥25% was taken as a reference point. These values were 97.37% (148/152) and 100% (125/125) at 6 months and 1 year follow-up when %EWL ≥50% was taken as a reference point. There was no significant difference in the weight-loss success rates between the common channel subgroups.

HbA1C in the total cohort and common channel subgroups at 6 months and 1 year follow-up are summarized in Table 2. HbA1C was significantly low at 6 months and 1 year follow-up compared to preoperative values. There was no significant difference in HbA1C between the common channel subgroups at 6 months follow-up. But HbA1C was significantly low in patients with common channel length 2.5 vs ≥3 m at 1 year follow-up.

Complete diabetes remission, partial diabetes remission, and diabetes improvement with HbA1C <6% reference point in the total cohort and common channel subgroups at 6 months and 1 year follow-up are summarized in Table 2. There was no significant difference in the percentage of complete diabetes remission between common channel subgroups. There were no symptoms of hypoglycemia or dumping syndrome in any of our patients. Responses of different comorbid conditions to SLDS surgery are summarized in Table 3.

Indicators of nutritional status are detailed in Table 4. Protein-energy malnutrition with serum albumin levels <3 gm/dL was significantly high in patients with a common channel length of 2.5 vs ≥3 m—25 vs 4.65% at 6 months and 40 vs 7.14% at 1 year follow-up, respectively. In patients with common channel length ≥3 m, all the patients with serum albumin <3 gm/dL at 6 months and 1 year follow-up had biliopancreatic limb length of >55%. Poor nutritional intake coupled with malabsorption was responsible for protein-energy malnutrition in these patients. Marked hypoalbuminemia (<2.5 g/dL) with clinical manifestations in eight patients (5 and 3 from 2.5 m and ≥3 m common channel subgroups, respectively) was corrected using intravenous amino acid injections, a high protein diet, and regular exercises. Hypoalbuminemia improved in all these patients except in two of them, one from each subgroup, who lost life >1 year after surgery. All patients who developed mild vitamin and mineral deficiencies responded well to oral supplements.

Concomitant cholecystectomy was performed in 10 patients, adhesiolysis in 21, and different types of hernia repairs in 11 patients. The mean duration of surgery was 191.49 minutes. Intraoperative injury to RGA with 250 mL blood loss occurred in one patient. Bleeding was controlled with a vessel sealer. 1.18% (2/169) patients developed postoperative bleeding on the first postoperative day, requiring diagnostic laparoscopy and lavage. All these patients recovered without any adverse postoperative events. One patient developed a localized leak 10 days after surgery but recovered with conservative treatment. 28.18 and 27.08% patients complained of diarrhea, 80 and 66.67% steatorrhea, 74.55 and 65.63% foul-smelling gas, and 11.82 and 8.33% incontinence at 6 months and 1 year follow-up after surgery, respectively, when their diet contained oil, spice, or chilly. 4.55 and 3.13% of patients complained of constipation at 6 months and 1 year follow-up after surgery, respectively. Thirty-day mortality was zero. None of the patients had gastroesophageal reflux, marginal ulcers, or internal herniation.

DISCUSSION

Laparoscopic SG has gained a lot of popularity and became the most commonly performed surgery worldwide.[10] Its technical simplicity,

Table 1: Weight parameters

Parameter		Preoperative		6 months follow-up		1 year follow-up	
		N	Mean ± SD	N	Mean ± SD	N	Mean ± SD
Weight (kg)		169	125.46 ± 24.7	152	85.72 ± 15.68	125	71.23 ± 11.83
[a]Significance					p < 0.001 (A–B)		p < 0.001 (A–C)
BMI (kg/m²)		169	45.39 ± 7.6	152	31.12 ± 4.77	125	26.01 ± 3.59
[a]Significance					p < 0.001 (A–B)		p < 0.001 (A–C)
% Excess weight loss							
Overall		—	—	152	74.53 ± 19.21	125	99.24 ± 20.62
[a]Significance							p < 0.001 (B–C)
Common channel length	2.5 m	—	—	26	70.9 ± 8.45	23	101.87 ± 8.45
	≥3 m	—	—	126	75.28 ± 20.69	102	98.64 ± 22.46
[b]Significance					p = 0.081		p = 0.258
[c]Simple linear regression					p = 0.78 (B = 0.011)		p = 0.272 (B = −0.051)
% Total weight loss							
Overall		—	—	152	30.91 ± 4.98	125	41.86 ± 7.63
[a]Significance							p < 0.001 (A–C)
Common channel length	2.5 m	—	—	26	35.98 ± 5.49	23	51.23 ± 6.55
	≥3 m	—	—	126	29.87 ± 4.18	102	39.75 ± 6.13
[b]Significance					p < 0.001		p < 0.001
[c]Simple linear regression					p < 0.001 (B = −0.052)		p < 0.001 (B = −0.087)
[c]Multiple regression analysis					p < 0.001 (B = −0.045)		p < 0.001 (B = −0.068)

[a]Paired samples t test
[b]Independent samples t test
[c]Significance when the common channel length was taken as an independent variable

easy reproducibility, and low complication profile made it the most popular bariatric surgery. But its main drawback is increased risk of long-term weight regain and recurrence of comorbid conditions.[11] Several of these patients require revision surgery.[12]

Roux-en-Y gastric bypass and its loop variation, one anastomosis gastric bypass (OAGB), lead to more durable weight loss and diabetes remission.[13–15] Roux-en-Y gastric bypass has limitations, such as, inability to monitor remnant stomach endoscopically, increased risk of calcium, and iron deficiencies due to complete duodenal bypass, dumping due to bypass of the pylorus, lack of endoscopic access to the biliary tract, marginal ulcer risk due to unopposed exposure of the jejunum to gastric juice and internal hernias due to mesenteric defects.[16] One anastomosis gastric bypass became more popular because of technical simplicity and an easy learning curve.[17] It can address marginal ulcers and internal hernias to some extent but other problems persist. The risk of calcium and iron deficiencies is relatively more in OAGB.[18] Even though these complications are outweighed by their advantages, novel surgeries to obviate those problems were attempted.[19]

BPD-DS is the most effective surgery in terms of the durability of weight loss and diabetes remission.[20] Preservation of the pylorus and the first part of the duodenum can address calcium and iron deficiencies to some extent but extensive intestinal bypass leaving only 1 m for absorption, increases the risk of severe protein-energy malnutrition, severe nutritional deficiencies, and renal stones.[21]

To reduce malabsorption and simplify the BPD-DS procedure, Sánchez-Pernaute et al. proposed a loop modification of the duodenal switch in 2007, by anastomosing the duodenum directly to a loop of ileum 2 m proximal to the ileocecal junction.[7] Increasing common channel from 1 m in BPD-DS to 2 m in SADI-S

addressed malabsorption to some extent. But it was still a concern. To address this malabsorption issue, later they increased the common channel from 2 to 2.5 m.[22] Mitzman et al. proposed increasing common channel to >2.5 m in LDS surgeries. They published their experience with 3 m common channels in LDS surgeries which showed excellent metabolic outcomes and reduced risk of malabsorption.[23] Theoretical benefits of LDS surgeries over BPD-DS include a reduced risk of complications with similar weight loss and health benefits.[5]

Sleeve gastrectomy with loop duodenal switch is a loop modification of BPD-DS. The advantage of LDS surgery is the scope of adjusting limb lengths to suit individual requirements. Our results showed that SLDS surgery was a very effective surgery to induce significant weight loss. Moon et al. showed %TWL of 23.1% at 6 months and 37.1% at 12 months after LDS surgeries. The percentage of excess BMI loss was 41.9% at 6 months and 68.1% at 12 months follow-up.[24] Cottam et al. showed that there was a significant reduction of BMI from baseline 46.8 ± 5.8 to 29.8 ± 4.4 kg/m² at 1 year follow-up after LDS surgeries.[25] Weight-loss response in our patients was similar to the results shown in these studies. Studies have shown similar %TWL after LDS surgeries and BPD-DS.[4,24] In our patients, increasing common channels from 2.5 to ≥3 m, reduced efficacy of surgery in terms of weight-loss response but the success rate remained unaltered. So, our results showed that the common channel can be increased from 2.5 to ≥3 m without altering the efficacy of surgery.

Our results indicate that SLDS surgery is a very powerful metabolic surgery for diabetes remission. Cottam et al. showed diabetes remission of 96.3% at a 1 year follow-up after the single anastomosis duodenal switch (SADS).[25] Diabetes remission was

Table 2: Variance in HbA1C and diabetes remission

Category	Subgroups	Preoperative		6 months follow-up		1 year follow-up	
		Mean ± SD	N	Mean ± SD	N	Mean ± SD	N
Variance in HbA1C							
Overall		8.71 ± 1.82 (5–12.1)	82	5.47 ± 0.81 (3.9–10)	77	5.08 ± 0.76 (4–8.9)	64
[a]Significance				p < 0.001		p < 0.001	
Common channel length	2.5 m	8.91 ± 2.07 (6.1–11.8)	11	5.28 ± 0.59 (4.6–6.5)	11	4.63 ± 0.6 (4–6.2)	11
	≥3 m	8.67 ± 1.79 (5–12.1)	71	5.5 ± 0.85 (3.9–10)	66	5.18 ± 0.76 (4–8.9)	53
[b]Significance		p = 0.694		p = 0.41		p = 0.029	

Category	Subgroups	Preoperative			6 months follow-up			1 year follow-up		
		N	CR%	PR and DI%	N	CR%	PR and DI%	N	CR%	PR and DI%
Diabetes response										
Overall		—	—	—	77	81.82%	18.18%	64	89.06%	10.94%
Common channel length	2.5 m	—	—	—	11	81.82%	18.18%	11	90.91%	9.09%
	≥3 m	—	—	—	66	81.82%	18.18%	53	88.68%	11.32%
[c]Significance					p = 1			p = 0.829		
[d]Univariate logistic regression					p = 0.186			p = 0.178		

[a]Paired samples t test
[b]Independent samples t test
[c]Pearson's chi-square test
[d]Common channel length was taken as an independent variable
CR, complete diabetes remission, PR and DI, partial diabetes remission and diabetes improvement

similar in the common channel subgroups in our study indicating that the common channel length can be increased from 2.5 to ≥3 m in LDS surgeries, without altering metabolic efficacy. The anastomosis is placed distally in the ileum in LDS surgeries, and this probably correlates with a potent ileal brake mediated by an enhanced secretion of Peptide YY and GLP1 which stimulate early satiety.[3]

The resolution of hypertension, hyperlipidemia, and obstructive sleep apnea was significant in our patients. Surve et al. showed hypertension resolution of 75% and hyperlipidemia resolution of 94% following the SADS procedure.[26] While Shoar et al. showed hypertension resolution of 96.3% and hyperlipidemia resolution of 68.3% and obstructive sleep apnea resolution of 63.3% after LDS surgeries.[27]

Major intraoperative complications were <1% and postoperative complications requiring surgical intervention were <2% in our patients. Surve et al. showed the short-term and long-term complication rates of 4.3 and 0%, respectively, and zero mortality rate.[26]

The presence of loop anastomosis in LDS surgeries reduces the chances of anastomotic leak and internal herniation by minimizing the number of anastomoses and mesenteric gaps. To facilitate tension-free anastomosis and make it technically simple, we modified LDS surgery by dividing RGA at its origin and creating a window in the lesser sac. This modification allows bringing the duodenum down toward the ileum for the anastomosis, rather than taking ileum to the first part of the duodenum into the right subhepatic space. This modification results in a freely mobile sleeve, pylorus, and the first part of the duodenum, facilitating tension-free anastomosis and avoids the need to divide greater omentum to facilitate the same. None of our patents required division of greater omentum. Sánchez-Pernaute et al. in their proposed SADI-S technique did not divide RGA.[7] Dallegrave proposed division of RGA while performing LDS surgeries.[8] He suggested that the division of RGA reduces the risk of marginal ulcers and bile reflux. A large gap is left behind anastomosis in our modification. This large gap perhaps allows free movement of intestinal loops behind without causing an obstruction. None of our patients developed obstruction or strangulation due to internal herniation. Gebelli et al. showed that LDS surgeries with RGA ligation can be performed safely.[9]

Preservation of the pylorus reduces the risk of acid exposure to the anastomosis, thereby reducing the risk of marginal ulcers. In their pooled analysis, Surve et al. showed that the anastomotic leak, ulcer, and bile reflux occurred in 0.6% (9/1328), 0.1% (2/1328), and 0.1% (2/1328), respectively. None of their patients had an internal hernia. Loop duodenal switch surgeries may cause fewer anastomotic complications compared with RYGB and BPD-DS.[28,29]

Table 3: Comorbid conditions

Comorbid condition	% of total patients	Percentage of response	
		6 months follow-up	1 year follow-up
Hypertension	46.75% (79/169)	77.03% (57/74)	87.69% (57/65)
Hyperlipidemia	56.21% (95/ 169)	88.64% (78/88)	94.12% (64/68)
Osteoarthritis	10.65% (18/169)	76.47% (13/17)	76.92% (10/13)
Obstructive sleep apnea	22.49% (38/169)	85.29% (29/34)	92% (23/25)

Table 4: Investigations

Investigation	Preoperative (A) N	Preoperative (A) Mean ± SD	6 months follow-up (B) N	6 months follow-up (B) Mean ± SD	6 months follow-up (B) Significance	1 year follow-up (C) N	1 year follow-up (C) Mean ± SD	1 year follow-up (C) Significance
Serum vitamin B$_{12}$ (pg/mL)	109	394.1 ± 278.33	89	584.17 ± 414.02	^{a}p < 0.001 (A–B)	70	699.1 ± 548.85	^{a}p < 0.001 (A–C)
Serum vitamin D total (ng/mL)	102	14.01 ± 9.23	89	26.71 ± 20.47	^{a}p < 0.001 (A–B)	74	27.54 ± 21.15	^{a}p < 0.001 (A–C)
Serum calcium (mg/dL)	110	9.39 ± 0.56	88	9.22 ± 0.47	^{a}p = 0.012 (A–B)	73	9.08 ± 0.52	^{a}p = 0.016 (A–C)
Serum iron (μg/dL)	110	71.71 ± 28.59	90	70.14 ± 28.99	^{a}p = 0.4 (A–B)	74	72.72 ± 31.19	^{a}p = 0.308 (A–C)
Blood hemoglobin (g/dL)	115	13.43 ± 1.82	91	13.01 ± 1.68	^{a}p = 0.043 (A–B)	75	12.17 ± 1.86	^{a}p < 0.001 (A–C)
Total protein (g/dL)	132	7.34 ± 0.55	106	6.67 ± 0.68	^{a}p < 0.001 (A–B)	90	6.46 ± 0.77	^{a}p < 0.001 (A–C)
in 2.5 m common channel subgroup	20	7.33 ± 0.57	20	6.32 ± 0.84	^{b}p = 0.009	20	5.74 ± 0.94	^{b}p < 0.001
in ≥3 m common channel subgroup	112	7.34 ± 0.55	86	6.75 ± 0.61		70	6.66 ± 0.57	
Serum albumin (g/dL)	132	4.03 ± 0.38	106	3.65 ± 0.46	^{a}p < 0.001 (A–B)	90	3.5 ± 0.66	^{a}p < 0.001 (A–C)
in 2.5 m common channel subgroup	20	4 ± 0.34	20	3.4 ± 0.5	^{b}p = 0.006	20	2.93 ± 0.66	^{b}p < 0.001
in ≥ 3 m common channel subgroup	112	4.04 ± 0.39	86	3.71 ± 0.43		70	3.66 ± 0.57	
Albumin deficiency with <3 g/dL cut off	≥3 g/dL		<3 gm/dL	≥3 g/dL		<3 g/dL	≥3 g/dL	
in 2.5 m common channel subgroup	75% (15/20)		25% (5/20)		^{c}p = 0.003	40% (8/20)		^{c}p < 0.001
in ≥3 m common channel subgroup	95.35% (82/86)		4.65% (4/86)		^{d}p = 0.012	7.14% (5/70)	92.86% (65/70)	^{d}p = 0.005

^{a}Paired samples t test
^{b}Independent samples t test
^{c}Pearson's Chi-square test
^{d}Logistic regression with common channel length as an independent variable

None of our patients had an anastomotic leak or marginal ulcers. None of our patients required readmission because of major postoperative complications. Patients who underwent BPD-DS or LDS surgeries have a unique risk of duodenal stump leakage, though incidence is very low. The superior quality of staplers and the presence of anastomosis farther away from the duodenal stump probably reduce risk of stump leak. Nelson et al. reported a duodenal stump leak of 1.45% (1/69).[30] None of our patients had duodenal stump leakage.

Since all of our patients were kept on regular vitamin and mineral supplements, we noticed significantly increased serum vitamin D total and B12 levels at 6 months and 1 year follow-up. Moon et al. noted low levels of serum vitamin D at 6 and 12 months following SADS.[24] Shoar et al. reported that serum vitamin A, selenium, and iron deficiency were the most common nutritional deficiencies after LDS surgeries with 3 m common channel.[27] Surve et al., in the pooled data analysis of SADS surgeries, did not find any statistically significant difference between most of the pre- and postoperative nutritional data.[28]

In our patients, the extent of hypoalbuminemia significantly reduced from 40 to 7.14%, when the common channel was increased from 2.5 to ≥3 m. Sánchez-Pernaute et al. showed low levels of protein in 34% of patients and albumin in 13.7% of patients after SADI-S with 2 to 2.5 m common channel.[22] Enochs reported protein and albumin deficiency in 7.6 and 3.1% of the SADS patients with 3 m common channels, respectively, at 1 year follow-up.[31] Surve et al. showed that 6.6 and 6.2% of the patients had abnormal protein and albumin levels, respectively, after LDS surgeries with 3 m common channel.[26] Our study showed that Indian patients are at significantly higher risk of protein deficiency after LDS surgeries when the common channel was 2.5 m compared to those with ≥3 m. Since all the patients who had serum albumin levels <3 gm/dL had biliopancreatic limb length of >55%, we recommend measuring total jejunoileal length in all the patients and restrict biliopancreatic limb length to ≤55%, to prevent protein malnutrition.

Increasing biliopancreatic limb beyond 2 m in RYGB or OAGB increases the risk of protein-energy malnutrition, nutrient malabsorption, and diarrhea.[32] Biliopancreatic limb length is directly proportional to the efficacy of surgery.[33] Preservation of pylorus and the first part of the duodenum perhaps play a role in reducing malabsorption in LDS surgeries. Pylorus controls gastric emptying, allowing a greater length of the intestine to be bypassed without malabsorptive consequences.[33] Preservation of pylorus reduces the risk of dumping syndrome. This is again related to the control of gastric emptying.[23] Pylorus also prevents the reflux of ileal contents into the stomach.[33] With our technical modification, once anastomosis is completed — sleeve, pylorus, the first part of the duodenum, and anastomosis lie in a straight vertical line. This theoretically reduces the risk of reflux into the esophagus as well as reflux of ileal contents into the sleeve. We presume this adds extra protection against reflux in addition to the pylorus. None of our patients had postoperative symptoms of esophageal reflux.

One disadvantage of LDS surgeries is the loss of endoscopic access to the biliary tract. If anyone develops cholangitis or choledocholithiasis, the only option is laparoscopic common bile duct exploration. To reduce the incidence of cholelithiasis, all our patients were kept on prophylactic ursodeoxycholic acid. Studies showed that fewer complications like chronic diarrhea, smelly stools, and flatulence were reported in LDS surgeries with

3 m common channel compared to BPD-DS.[4,29] In our study, we observed that these bowel problems were triggered when there was oil, spice, or chilly in the food. So, our patients were advised to avoid these items after surgery.

Conclusion

This study showed that SLDS surgery is safe and feasible. Nutritional complications significantly come down when the common channel is increased to ≥3 m without compromising on the metabolic efficacy of the procedure. More studies with long-term follow-up are needed to determine the ideal common channel length to standardize this promising procedure.

Clinical Significance

Sleeve gastrectomy with loop duodenal switch surgery with common channel length ≥3 m simplifies BPD-DS, gives excellent weight loss and diabetes remission with minimal malabsorption. Restricting biliopancreatic limb to ≤55% prevents adverse malabsorptive consequences.

Disclaimer

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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