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Original article

Comparative analysis of the single-anastomosis duodenal-ileal bypass with sleeve gastrectomy (SADI-S) to established bariatric procedures: an assessment of 2-year postoperative data illustrating weight loss, type 2 diabetes, and nutritional status in a single US center

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Abstract

Background: The sleeve gastrectomy (SG), Roux-en-Y gastric bypass (RYGB), and single-anastomosis duodenal-ileal bypass with SG (SADI-S) are recognized bariatric procedures. A comparison has never been made between these 3 procedures and especially in different body mass index (BMI) categories.
Objective: The study aimed to analyze a large cohort of patients undergoing either laparoscopic (L) SG, LRYGB, or LSADI-S to evaluate and compare weight loss and glycosylated hemoglobin level. The secondary aim was to compare the nutritional outcomes between LRYGB and LSADI-S.
Setting: Private practice, United States.
Methods: This is a retrospective review of 878 patients who underwent LSG, LRYGB, or LSADI-S from April 2014 through October 2015 by 5 surgeons in a single institution. For weight loss analysis, the patients were categorized into 4 different categories as follows: patients regardless of their preoperative BMI, patients with preoperative BMI <45 kg/m^2, patients with preoperative BMI 45 to 55 kg/m^2, and patients with preoperative BMI >55 kg/m^2.
Results: A total of 878 patients were identified for analysis. Of 878 patients, 448 patients, 270 patients, and 160 patients underwent LSG, LRYGB, and LSADI-S, respectively. Overall, at 12 and 24 months, the weight loss was highest with LSADI-S, followed by LRYGB and LSG in all 4 categories. At 2 years, the patients lost 19.5, 16.1, and 11.3 BMI points after LSADI-S, LRYGB, and LSG, respectively. In addition, the weight loss was highest in patients with preoperative BMI <45 kg/m^2 and lowest in patients with preoperative BMI >55 kg/m^2 at 12 and 24 months. Also, there were no statistically significant differences between the nutritional outcomes between LRYGB and LSADI-S. The LSADI-S had significantly lower rates of abnormal glycosylated hemoglobin than LRYGB and LSG at 12 months ($P < .001$).
Conclusions: The weight loss outcomes and glycosylated hemoglobin rates were better with LSADI-S than LRYGB or LSG. The nutritional outcomes between LRYGB and LSADI-S were similar. (Surg Obes Relat Dis 2020;16:24–33.) © 2019 American Society for Bariatric Surgery. Published by Elsevier Inc. All rights reserved.

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Key words: Single-anastomosis duodenal-ileal bypass with sleeve gastrectomy; LSADI-S, Sleeve gastrectomy; Roux-en-Y gastric bypass; LRYGB; Weight loss outcomes; Nutritional outcomes; T2D; Comparison

Obesity is a major public health issue worldwide and is closely linked to the development of type 2 diabetes (T2D). People with obesity, compared with those with a normal or healthy weight, are at an increased risk for many other serious diseases and health conditions. Bariatric surgery is currently the only effective treatment for severe obesity. Although being most effective, the established bariatric procedures fail in 6% to 20% of patients at 2 years [1]. In addition, the failed bariatric procedures are associated with a greater likelihood of T2D relapse to 2 or 3 years [2–4].

The Roux-en-Y gastric bypass (RYGB) has been shown to produce significant weight loss in patients with morbid obesity. However, weight loss failure or weight regain or recurrence of metabolic syndrome has been reported in 15% to 35% of patients [5,6]. Of all the performed bariatric procedures, the sleeve gastrectomy (SG) continues to be the most common procedure (59.3%) [7]. Perhaps, 1 of the biggest problems with SG is weight regain over time [8–11]. Moreover, patients with super obesity do not lose enough weight with this procedure [12,13]. The single-anastomosis duodenal-ileal bypass with SG (SADI-S) is a modification of the standard biliopancreatic diversion. Based on clinical knowledge, expert opinion, and published peer-reviewed scientific evidence, the International Federation for the Surgery of Obesity and Metabolic Disorders considered the SADI-S (and its variant [stomach intestinal pylorus-sparing surgery]) an established bariatric procedure [14]. In recent years, there have been few reports on the short- and mid-term outcomes of this procedure [15–30]. In terms of weight loss, the SADI-S and RYGB had statistically similar weight loss; however, the weight loss was statistically higher in patients undergoing SADI-S procedure than SG [21,30]. In these reports, the comparison was made between either the SADI-S and RYGB or SG. None have compared all 3 procedures together.

The primary aim of the study was to analyze a large cohort of patients undergoing either laparoscopic (L) SG, LRYGB, or LSADI-S to evaluate and compare weight loss outcomes and glycosylated hemoglobin (HbA1C) rates. The secondary aim was to compare the nutritional outcomes between LRYGB and LSADI-S.

Methods

Eight hundred seventy-eight patients with morbid obesity underwent a bariatric procedure at a single, nonacademic, private institute from April 2014 through October 2015. All surgeries were performed by 5 surgeons. Exclusion criteria included any previous bariatric procedure. Patients were selected for each surgery based on when they came in and the surgeon they chose. All the patients were required to provide written informed consent specific to the procedure that included a diagram of the proposed operation. Preoperative and postoperative outcome data included weight loss, co-morbidity resolution, and nutritional parameters.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Because this is a retrospective study, formal consent is not required for this type of study.

All operations were performed laparoscopically using standardized perioperative and postoperative protocols. The surgical techniques were standardized. According to a standardized protocol, a nutritionist and a surgeon routinely evaluated each patient after surgery. In addition, physician assistants were used as well.

All patients were required to follow-up at 2 weeks and 1, 3, 6, 12, 18 months, and then once annually after the surgery. The presence of co-morbidities was based on oral hypoglycemic or insulin use. The only co-morbidity studied was T2D. The HbA1C results were studied in all 3 procedures at 12 and 18 months in the diabetic group. Every patient was counseled to take bariatric advantage vitamins for their specific procedure. Protein recommendation was 80 to 100 g of protein per day regardless of the procedure. The nutritional outcomes were studied in patients who underwent LRYGB or LSADI-S procedure. The percentage of patients with abnormal lab values were compared pre- and postoperatively for each procedure. In addition, the nutritional outcomes between both procedures were compared at 6, 12, and 24 months.

In both groups, vitamins A, D, E, K, and B12, ferritin, iron, and albumin levels were analyzed, pre- and postoperatively.

The following weight-related parameters were recorded: weight (lbs), body mass index (BMI; kg/m^2), percentage of excess BMI lost with excess $>$25 kg/m^2, and percent total weight loss. For weight loss analysis, the patients were categorized into 4 different categories as follows: patients regardless their preoperative BMI, patients with preoperative BMI $<$45 kg/m^2, patients with preoperative BMI 45 to 55 kg/m^2, and patients with preoperative BMI $>$55 kg/m^2.

Statistical methods

All statistical analysis was conducted with Sigma Plot statistical software (Systat Software, San Jose, CA, USA). Demographic differences were compared using *t* tests and one-way analysis of variance tests.

For comparing the preoperative and postoperative abnormal HbA1C rates, the Holm-Bonferroni correction was used, as we believe, it best minimizes the type one and 2 error rate simultaneously while the classic Bonferroni correction elevates the type 2 error rate more than necessary and is too conservative.

Operative technique

LSADI-S technique

The terminal ileum was identified, 300 cm proximal to the ileocecal valve. The ileum was brought up and tacked to the gastrocolic omentum, just below the pylorus. A 40-Fr bougie was the placed transorally down the esophagus, through the stomach, and into the first portion of the duodenum. The greater curve of the stomach was mobilized with the Ligasure device (Medtronic, Mansfield, MA, USA) all the way up to the diaphragm. Upon doing so, an Endo-gastrointestinal anastomosis (GIA) 60 (Medtronic) with a black tri-staple load was placed across the antrum parallel to the bougie, and this Endo-GIA 60 with a black tri-staple load was reinforced with TRS staple-line reinforcement. Once this was placed around the angularis using an Endo-GIA 60 with a black tri-staple load reinforced with the TRS staple line reinforcement. Several sequential loads of the Endo-GIA 60 with a purple tri-staple load reinforced with TRS staple line reinforcement were placed along the bougie all the way up to the left crus of the diaphragm. The staple line was then secured to the cut edge of the omentum with interrupted 2-0 surgidac stitch. Upon completion of the SG portion of the procedure, attention was then placed on the duodenum. The greater curve of the stomach was then mobilized down past the stomach, past the pylorus, and toward the first portion of the duodenum. Over the level of the gastroduodenal artery, a retroduodenal tunnel was created with a articulating grasper, and an Endo-GIA 60 with a tan Tri-Staple load reinforced with seam guard was placed across the first portion of the duodenum and fired. Once the transection of the duodenum had been completed, the duodenum was mobilized to allow mobility of the duodenum. The ileum was the grasped at the mark 300 cm proximal to the terminal ileum and secured to the staple line of the duodenum with a running 2-0 Polysorb (Medtronic) suture. An enterotomy was made in the small bowel as well as in the duodenum of approximately 1 to 2 cm, and the inner layer of the anastomosis was then completed with a running 3-0 Polysorb suture. Once the anastomosis of the inner layer had been completed, an anterior outer layer was then completed with a 2-0 Polysorb suture. Clamps were then placed across the afferent and efferent limbs of the ileum, and the area was insufflated under saline using the bougie.

LRYGB technique

The omentum was visualized and bisected with the LigaSure device. The ligament of Treitz was identified, and 50 cm distal to the ligament of Treitz the small bowel, the small bowel was taken and secured to the greater curve of the stomach. The LigaSure device was then used to take the lesser curve vessels down to the level of the second gastric vein, and an Endo-GIA 60 with a 3.5-mm Duet load was placed transversely across the stomach at the level of the second gastric vein. Two additional loads were placed toward the left crus of the diaphragm to complete the gastric pouch. A gastrostomy was created in the underside of the gastric pouch. The small bowel was then identified and attached to the greater curve of the stomach. This suture was cut, and the bowel was brought up to the upper abdomen where a 2.5-cm enterotomy was made in bowel and stomach and fired to create the gastrojejunostomy. Once this was done, the common enterotomy was approximated with a 2-0 Polysorb suture. A 34-Fr blunt bougie was placed across the anastomosis. The anastomosis was oversewn with a 2-0 Surgidac stitch. Upon completion of the anastomosis, a defect was made in the mesentery area of the afferent limb, and an Endo-GIA 60 with a 2.5-mm articulating white load was placed across the afferent limb of the small bowel and transected. An enterotomy was made in the afferent limb, and the 34-Fr blunt bougie was removed. The Roux limb was measured out 75 cm and a defect was made in the Roux limb at this point where it was secured to the biliopancreatic limb with an Endo-GIA 60 with a 2.5-mm load. The common enterotomy was approximated with a 2-0 Surgidac stitch and an Endo-GIA with a 2.5-mm load was placed across the common enterotomy and fired. A 2-0 Surgidac stitch was placed at the apex of the staple line and was used to close the mesenteric defect. Peterson's defect was examined and closed with a 2-0 Surgidac suture.

Laparoscopic sleeve technique

A mark was placed over the pylorus to identify the pylorus and 5 cm proximal to the pylorus a mark was placed as well to identify the mark of distal resection. Just distal to this 5-cm mark, a LigaSure device was used to mobilize the greater curve vessels starting from this area all the way up to the left crus of the diaphragm. We then took down all the posterior attachments from the stomach to the pancreas. A 34-Fr blunt bougie was placed down through the esophagus along the lesser curve and up toward the pylorus. Once the bougie was placed, an Endo-GIA 60 with a purple Tri-Staple load was placed along the antrum just distal to the 5-cm mark along the bougie taking care not to kink the angularis. A firing was then performed and taking care to come around the angularis, and Endo-GIA 60 with a purple tri-staple load was used to come around the angularis and sequentially complete the sleeve with several sequential loads up toward the left crus of the diaphragm. The angularis was tacked down to the retroperitoneum to prevent twisting of the staple line, and any other areas that were identified along the staple line were also oversewn with a 2-0 Surgidac stitch.

Results

Eight hundred seventy-eight patients were indented for analysis. Of 878 patients, 448, 270, and 160 underwent LSG, LRYGB, and LSADI-S, respectively. The mean age, preoperative weight, BMI, and sex can be seen in Table 1. Of 448 patients who underwent LSG, 448 patients and 315 patients were out by 12 and 24 months, respectively. Of the 270 patients who underwent LRYGB, 269 patients and 157 were out 12 and 24 months, respectively. Similarly, of the 160 patients who underwent LSADI-S, 160 patients and 123 patients were out 12 and 24 months, respectively. The follow-up rates at 12 and 24 months can be seen in Table 2.

Weight loss outcomes

The weight loss outcomes were studied in patients who underwent either LSG, LRYGB, or LSADI-S procedure (Table 2 and Fig. 1).

All patients

The patients who underwent LSADI-S lost 88.4% (excess weight loss) EWL at 24 months. The patients who underwent LRYGB and LSG lost 78.3% and 64.1% EWL at 24 months, respectively (Table 2). In addition, at 24 months, the patients lost 20.3, 16.7, and 11.6 BMI points after LSADI-S, LRYGB, and LSG, respectively.

Table1
Baseline characteristics of cohorts

Category	Variable	Procedure			*P* value
		LSG	LRYGB	LSADI-S	
All patients	n	448	270	160	
	Age, yr*	47 ± 10	49 ± 11	46 ± 10	*.015*
	M/F, %	16.2/83.7	21.8/78.1	21.8/78.1	.11
	Weight, kg*	120.9 ± 22	131.8 ± 26.7	138.1 ± 29.2	*<.001*
	BMI, kg/m^2*	43.7 ± 6.7	47 ± 7.5	48.2 ± 8.1	*<.001*
	IBW*	130 ± 18.7	131 ± 18	132.4 ± 19.3	.362
BMI <45	n	303	124	66	
	Age, yr*	48 ± 10	52 ± 11	45 ± 9	*<.001*
	M/F, %	15.1/84.8	20.1/87.9	19.6/80.3	.523
	Weight, kg*	111.5 ± 13.9	113.6 ± 16.3	115.5 ± 16.1	*.011*
	BMI (kg/m^2)*	40.3 ± 3	40.8 ± 2.9	40.7 ± 2.8	.062
	IBW*	130.5 ± 18.7	129.6 ± 18.2	130.9 ± 20.3	.747
BMI 45–55	n	119	113	65	
	Age, yr*	47 ± 9	47 ± 11	47 ± 9	.997
	M/F, %	15.1/84.8	18.5/81.4	23/76.9	.405
	Weight, kg*	133.7 ± 14.7	138.7 ± 18.5	143 ± 18.5	*<.001*
	BMI, kg/m^2*	48.6 ± 2.6	49.7 ± 2.9	49.5 ± 2.4	*<.001*
	IBW*	129.3 ± 17.9	132.3 ± 17.6	134 ± 18.4	*.007*
BMI >55	n	26	33	29	
	Age, yr*	47 ± 11	48 ± 10	47 ± 12	.887
	M/F, %	34.6/65.3	39.3/60.6	24.1/75.8	.433
	Weight, kg*	170.9 ± 29.4	175.4 ± 25.4	177.3 ± 25	*.014*
	BMI, kg/m^2*	62.5 ± 6.8	61.4 ±5.1	61.7 ± 4.5	*.043*
	IBW*	124.5 ± 19.2	134.4 ± 19.3	133.1 ± 19.3	*<.001*

LSG = laparoscopic sleeve gastrectomy; LRYGB = laparoscopic Roux-en-Y gastric bypass; LSADI-S = laparoscopic single-anastomosis duodenal-ileal bypass with sleeve gastrectomy; BMI = body mass index; IBW = ideal weight.

Age: In all patients and <45 BMI categories, there was no statistically significant difference between LSG and LSADI-S patients.

Weight and BMI: LSADI-S group had the highest preoperative weight and BMI in all 4 categories.

Italicized values are statistically significant.

* Values are expressed as means ± SD; *P* value is for LSG versus LRYGB versus LSADI-S.

Table 2
Weight loss outcomes with LSG, LRYGB, and LSADI-S at 12 and 24 mo

Category	Variable	12 mo			24 mo		
		Procedure			Procedure		
		LSG	LRYGB	LSADI-S	LSG	LRYGB	LSADI-S
All patients	Available/ eligible patients, n	293/448	228/269	148/160	158/315	125/157	84/123
	Follow-up, %	65.4	84.7	92.5	50.1	79.6	68.2
	Preoperative BMI, kg/m²*	43.7 ± 6.7	47 ± 7.5	48.2 ± 8.1	43.7 ± 6.7	47 ± 7.5	48.2 ± 8.1
	BMI, kg/m²*	31.8 ± 6.2	31.2 ± 6	29.9 ± 6.1	32.1 ± 6	30.3 ± 6.2	27.9 ± 4.6
	Change in BMI, kg/m²*	12 ± 4.5	15.8 ± 5	18.6 ± 6	11.3 ± 5	16.1 ± 5.9	19.5 ± 6.5
	% EWL*	67.7 ± 24.5	75.6 ± 21.9	83.3 ± 20.4	64.1 ± 23.6	78.3 ± 22.6	88.6 ± 20
BMI <45	Available/ eligible patients, n	200/301	105/124	62/65	108/208	62/75	36/50
	Follow-up, %	66.4	84.6	95.3	51.9	82.6	72
	Preoperative BMI, kg/m²*	40.3 ± 3	40.8 ± 2.9	40.7 ± 2.8	40.3 ± 3	40.8 ± 2.9	40.7 ± 2.8
	BMI, kg/m²*	29.3 ± 3.9	27.4 ± 3.4	26 ± 6.2	29.8 ± 4.8	27.2 ± 3.7	25.8 ± 3.5
	Change in BMI, kg/m²	10.9 ± 3.7	13.3 ± 3.6	14.7 ± 3.7	10.2 ± 3.7	13.2 ± 4.1	15.3 ± 4.3
	% EWL*	73.3 ± 24.8	85.9 ± 21.5	94.3 ± 19.1	68.8 ± 23.3	86.2 ± 23.2	94.4 ± 21.8
BMI 45–55	Available/ eligible patients, n	73/118	94/111	57/65	40/84	50/62	37/48
	Follow-up, %	61.8	84.6	87.6	47.6	80.6	77
	Preoperative BMI, kg/m²*	48.6 ± 2.6	49.7 ± 2.9	49.5 ± 2.4	48.6 ± 2.6	49.7 ± 2.9	49.5 ± 2.4
	BMI, kg/m²*	35.4 ± 4.7	32.5 ± 4.6	29.7 ± 4.5	36.2± 5	32.3 ± 4.7	28.4 ± 4.3
	Change in BMI, kg/m²*	13.5 ± 4.3	17 ± 4.6	19.7 ± 4	12.5 ± 4.7	17.5 ± 4.9	20.8 ± 4.2
	% EWL*	56.8 ± 18.3	69.7 ± 18.5	81.2 ± 17.1	53.8 ± 19.6	71 ± 19	86.2 ± 17.4
BMI >55	Available/ eligible patients, n	18/26	28/33	28/29	8/22	12/19	11/24
	Follow-up, %	69.2	84.8	96.5	36.3	63.1	45.8
	Preoperative BMI, kg/m²*	62.5 ± 6.8	61.4 ± 5.1	61.7 ± 4.5	62.5 ± 6.8	61.4 ± 5.1	61.7 ± 4.5
	BMI, kg/m²*	43.8 ± 10.3	41 ± 4.8	38.4 ± 5.6	41.3 ± 12.8	37.7 ± 7.3	32.8 ± 5
	Change in BMI, kg/m²*	18.9 ± 6.2	20.9 ± 5.9	23.4 ± 4.8	21.7 ± 8.4	24.8 ± 7.3	28.9 ± 7.8
	% EWL*	52.3 ± 20.9	56.3 ± 12.9	64.4 ± 12.9	59.9 ± 25.7	66.4 ± 19.5	76.7 ± 15.4

LSG = laparoscopic sleeve gastrectomy; LRYGB = laparoscopic Roux-en-Y gastric bypass; LSADI-S = laparoscopic single anastomosis duodenal-ileal bypass with sleeve gastrectomy; BMI = body mass index; % EWL = percentage excess weight loss.

* Values are expressed as means ± standard deviation.

There was a statistically significant difference between all the weight loss parameters between all 3 procedures at 12 ($P < 0.001$) and 24 months ($P < 0.001$).

BMI <45

The patients who underwent LSADI-S lost 94.1% EWL at 24 months. The patients who underwent LRYGB and LSG lost 86.2% and 68.8% EWL at 24 months, respectively (Table 2). In addition, at 24 months, the patients lost 14.8, 13.5, and 10.4 BMI points after LSADI-S, LRYGB, and LSG, respectively.

In this group, there was a statistically significant ($P < .001$) difference between all the weight loss parameters between all 3 procedures except, % EWL with LRYGB versus LSADI-S at 12 and 24 months.

BMI 45–55

The patients who underwent LSADI-S lost 86.2% EWL at 24 months. The patients who underwent LRYGB and LSG lost 71% and 53.8% EWL at 24 months, respectively (Table 2). The patients who underwent LSADI-S, LRYGB, and LSG lost 21.1, 17.5, and 12.3 BMI points at 24 months, respectively.

In this group, there was a statistically significant difference between all the weight loss parameters between all 3 procedures ($P < .001$).

BMI >55

The patients who underwent LSADI-S lost 76.7% EWL at 24 months. The patients who underwent LRYGB and LSG lost 66.5% and 59.9% EWL at 24 months, respectively (Table 2). The patients who underwent LSADI-S, LRYGB, and LSG lost 28.9, 23.6, and 21.1 BMI points at 24 months, respectively.

In this group, there was a no statistically significant difference between all the weight loss parameters between all 3 procedures at 12 and 24 months.

Overall, at 12 and 24 months, the weight loss was highest with LSADI-S followed by LRYGB and LSG in all 4 categories. In addition, the weight loss was highest in patients with BMI <45 and lowest in patients with BMI >55 kg/m^2 at 12 and 24 months (Table 2).

Nutritional outcomes

The preoperative data for vitamins A, E, and K were unavailable for the LRYGB group.

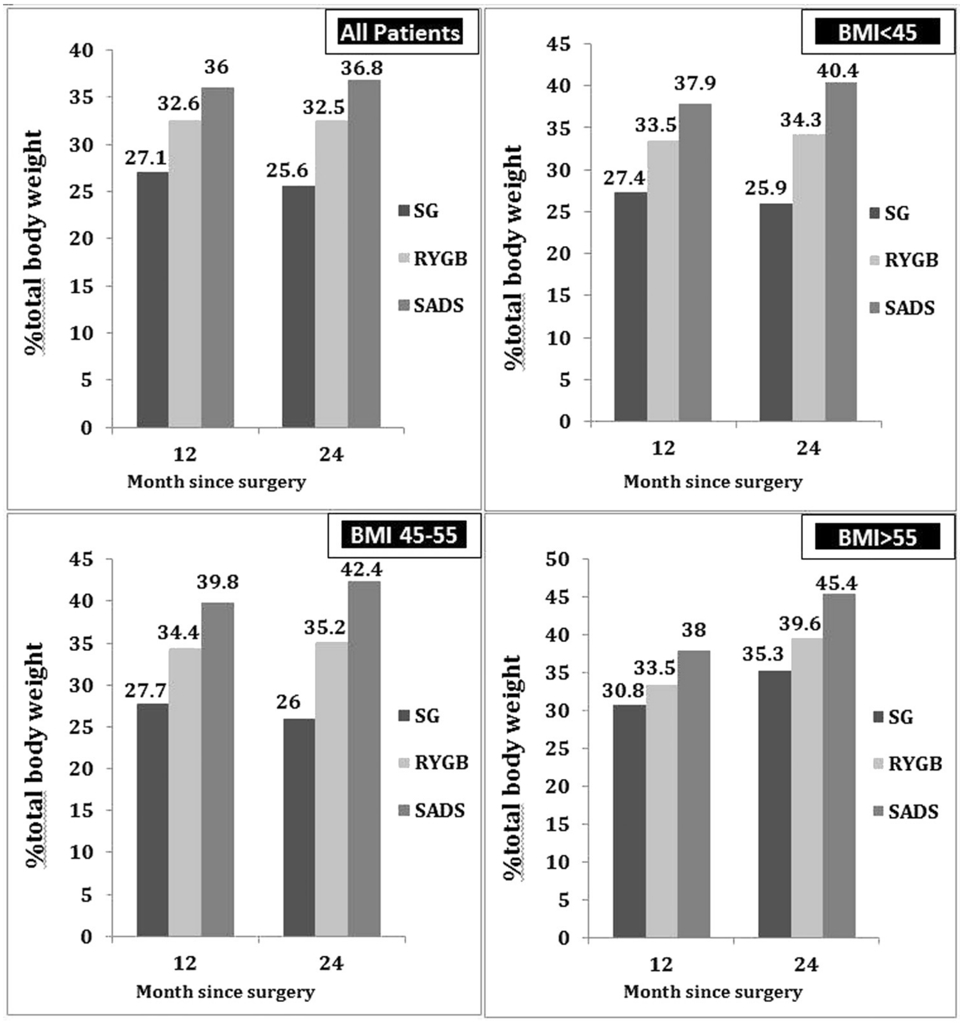

Fig. 1. Percent TBWL with SG, RYGB, and SADI-S at 12 and 24 months. TBWL = total weight; SG = sleeve gastrectomy; RYGB = Roux-en-Y gastric bypass; SADI-S = single-anastomosis duodenal-ileal bypass with SG.

LRYGB versus LSADI-S

There were no statistically significant differences between the nutritional outcomes (vitamins A, D, E, K, B12, ferritin, iron, and albumin) of the 2 procedures.

Pre- versus Postoperative

Postoperatively, in both groups, the percentage of patients with abnormal vitamin D decreased significantly. In contrast, the percentage of patients with abnormal vitamin B12 and ferritin levels increased.

In both groups, the percentage of patients with abnormal iron values were increased significantly at 6 months and decreased significantly at 12 and 24 months (Table 3).

HbA1C analysis

The LSADI-S had significantly better HbA1C rates compared with LRYGB at both 12 and 18 months (Table 4). The LSADI-S was found to have statistically better HbA1C rates compared with LSG at 12 but not 18 months. This is likely due to the sample size as patients with normal HbA1C rates were similar at both follow-up points, but only half of the number of patients came in at 18 compared with 12 months.

Discussion

The LSADI-S procedure has been reported to be safe in several studies [15–30]. This study examined the outcomes of LSADI-S procedure as well as compared the outcomes with LSG and LRYGB. Moreover, this is the first report in the literature to compare all 3 procedures together. While there was no statistically significant difference in nutritional outcomes between SADI-S and LRYGB, LSADI-S had a better weight loss and HbA1C values than LRYGB and LSG.

Up until 2012, RYGB was the most common procedure performed in the United States and worldwide [7]. High

Table 3
Nutritional outcomes with RYGB and SADI-S

Parameter	Normal range	Abnormally low, %							
		LRYGB				LSADI-S			
		Preoperative	6	12	24	Preoperative	6	12	24
Vitamin A	20–65 ug/dL	N/A	0 (20)*	0 (58)*	0 (40)*	0 (29)*	0.9 (110)*	1.8 (113)*	1.4 (69)*
Vitamin D	32–100 ng/mL	28.7 (223)*	4.9 (185)*	6.8 (162)*	4.8 (42)*	27.1 (144)*	10.5 (124)*	11.9 (109)*	16.9 (71)*
Vitamin E	5.5–18 mg/L	N/A	0 (20)*	0 (58)*	0 (37)*	0 (30)*	0.9 (106)*	0 (105)*	0 (69)*
Vitamin K	13–1.8 ng/mL	N/A	0 (20)*	1.8 (55)*	0 (37)*	13.3 (30)*	23.5 (98)*	7.4 (94)*	4.5 (67)*
Vitamin B12	211–911 pg/mL	8 (213)*	13 (184)*	19.3 (161)*	7.5 (40)*	4.3 (140)*	9.3 (118)*	15 (113)*	2.8 (72)*
Ferritin†	12–150/300 ng/mL	17.7 (209)*	28.7 (178)*	30.6 (154)*	25 (40)*	7.7 (142)*	20.9 (129)*	28.7 (115)*	33.8 (71)*
Iron	30–150 μg/dL	25 (212)*	39.6 (192)*	21.1 (161)*	7.3 (41)*	27.9 (136)*	48 (123)*	25.2 (119)*	22.9 (70)*
Albumin	3.2–4.8 g/dL	5 (240)*	3.1 (192)*	7.6 (166)*	0 (42)*	5.3 (151)*	2.5 (120)*	6.5 (108)*	2.8 (72)*

LRYGB = laparoscopic Roux-en-Y gastric bypass; LSADI-S = laparoscopic single-anastomosis duodenal-ileal bypass with sleeve gastrectomy; N/A = not available.

* Values are number of patients with labs at that time point.

† For males and females, we considered the serum ferritin value of 12–300 ng/mL and 12–150 ng/mL, respectively.

co-morbidity resolution, higher weight loss, and low-surgical morbidity were few reasons for its popularity. However, with the introduction of SG, most surgeons adopted SG over RYGB as it promised similar weight loss to RYGB but with fewer complications. Despite the promising outcomes, SG has poor results in patients with BMI >50 kg/m^2 and has a large standard deviation [31]. In some patients, SG does not work well for treating metabolic syndrome, like T2D [32]. To overcome inconsistent sleeve results and problems with the creation of Roux limb, Pernaute et al. [33] modified duodenal switch to SADI-S. Their early and midterm results have shown that SADI-S had weight loss comparable to RYGB if not better [34,35].

Recently, there have been several reports on the outcomes of SADI-S procedure [15–30]. One of the articles published by Neichoy et al. [16] on the midterm outcomes of SADI-S reported EWL of 88% at 24 months. This was very similar to the weight loss reported in our study. Pernaute et al. [34] reported % EWL of 94.7% at 1 year after SADI-S and then the weight was maintained over 24 months. The mean preoperative BMI in their study was <45 kg/m^2. In our study, especially in the patients with preoperative BMI <45 kg/m^2, the EWL at 12 and 24 months were higher than the ones reported by Pernaute et al. [34]. Recently, a midterm outcome study on SADI-S by Zaveri et al. [36] reported 77.6% and 85.9% EWL at 12 and 24 months, respectively, with the preoperative BMI of 49.8 kg/m^2. These results continue in other studies without significant weight regain out to 4 years. In our study, especially in the patients with preoperative BMI of 45 to 55 kg/m^2, the EWL at 12 and 24 months were 81.2% and 86.2%, respectively, and were similar to the study by Zaveri et al. [36].

Although several articles have proven the superiority of duodenal switch to RYGB, only a few surgeons perform this surgery due to its technical difficulty and possible malabsorption [37–40]. The SADI-S procedure is the modification of duodenal switch and retains the majority of efficacy while reducing the malnutrition problems [18]. More importantly, it decreases the technical complexity associated with duodenal switch without compromising outcomes. Cottam et al. [30] published a matched cohort between SADI-S and RYGB with 18-month follow-up and found the weight loss profile to be similar between the 2 procedures. While the complication rates were lower with SADI-S [30]. Similarly, Lee et al. compared RYGB with laparoscopic single-anastomosis duodenal-jejunal bypass with SG and found the weight loss to be superior to RYGB with no significant difference in perioperative parameters [37]. The laparoscopic single-anastomosis duodenal-jejunal bypass with SG is based on the principle of duodenal switch and similar to SADI-S. One of the major differences between SADI-S and RYGB is the presence of distal anastomosis that can be the cause of postoperative complication like small bowel obstruction secondary to internal hernias and adhesions. There have been no reports of internal hernias or small bowel obstruction after primary SADI-S in the literature, an advantage that can be attributed to the avoidance of distal anastomosis [15].

Similarly, we believe that 2 anastomoses instead of 1 as seen with RYGB will have a higher risk of leaks compared with SADI-S. Classically, traditional duodenal switch has had a higher rate of leaks than RYGB [40–42].

The SG is the most commonly performed procedure in the world today; however, weight recidivism and weight loss failure have been consistently reported at long-term follow-up. D'hondt et al. [43] observed decreasing % EWL at annual intervals; 81.5% EWL at 1 year was dropped to 55.9% EWL at 6 years. Similarly, the results with SG are poorer with higher BMI [44]. Cottam et al. [21] matched SG patients with SADI-S patients and found that early weight loss was similar between 2 procedures, while intestinal component became more important with weight loss differentials increasing as time since surgery lengthens. Similar results were shown by Marceau et al. [45]. In their study, the early weight loss was better with SG while 5-year weight loss and metabolic outcomes were better with duodenal switch. In our study, LSG patients lost the least amount of weight, although they were least heavy of all patients. While for patients with BMI >5 kg/m^2, EWL at 12 and 24 months was only 52.3% and 59.9%, respectively.

Weight loss plays a vital role in the treatment of co-existing conditions. In our study, the weight loss was highest with LSADI-S followed by LRYGB and LSG. Moreover, the HbA1C was better with LSADI-S. The difference in weight loss with these procedures could have been a contributing factor to the difference in T2D remission rates. In a recent study by Pucci et al. [46] comparing RYGB and SG, the authors concluded that the percentage weight loss rather than procedure type determines T2D remission 2 years postoperatively. We believe this could be a reason why our patients who underwent LSADI-S achieved the greatest weight loss and had better HbA1C values. Apart from weight loss, the gastric restriction, a bypass of duodeno-pancreas, selective fat malabsorption, and a rapid entrance of undigested chyme into the distal intestine explain the mechanism of higher T2D remission rate after SADI-S surgery [36]. The RYGB has been shown to be effective for those with T2D. Schauer et al. [47] reported that 83% of participants with T2D succeeded in obtaining HbA1C levels that were <6.0% when evaluated >12 months after surgery [47]. However, in the long term, this resolution rate dropped to 29% [32]. Low T2D remission rate and high-recurrence rate at long-term follow-up are commonly seen after RYGB [2]. Cottam et al. [48] compared RYGB with SADI-S in terms of T2D resolution rate and found 90% resolution rate (HbA1C <6%) with SADI-S versus 69% with RYGB (P = .008). Mingrone et al. [49] showed that the more the small intestine is bypassed, the higher the T2D resolution rates. Roslin et al. [50] have shown greater glycemic control with duodenal switch than RYGB. Our study also showed higher T2D resolution rates compared with LRYGB with a statistically significant difference. Thus, we can postulate that at any level of measurement for T2D resolution, LSADI-S is significantly better than LRYGB.

Some surgeons prefer RYGB over SADI-S because of nutritional deficiencies. In our study, the nutritional outcomes were similar between both groups. Cottam et al. [30] also found comparable nutritional outcomes between 2 surgeries at 3 years. Sometimes malnutrition can be due to patients' noncompliance toward diet regimen. Thus, most of the malnutrition that may arise can be corrected with diet and vitamin supplements.

Some of the limitations are noteworthy. The first is the fact that it is retrospective rather than prospective. At 2 years, we had a follow-up of 50% for the LSG group. The study did not include complication data and analysis of other obesity-related co-existing condition data in any of the groups. Moreover, we were unable to make a definite

Table 4
HbA1C rates and their comparison after LRYGB, LSADI-S, and LSG at 12 and 18 months in diabetic patients

Time point	LRYGB				LSADI-S				LSG				P value
	Eligible patient (n)/data available	Average HbA1C % ± SD	Abn. (n)	Nl, n (%)	Eligible patient (n)/data available	Average HbA1C % ± SD	Abn. (n)	Nl n (%)	Eligible patient (n)/data available	Average HbA1 C% ± SD	Abn. (n)	Nl n (%)	
Preoperative	149/149	6.8 ± 1.4	149	0	102/102	7.2 ± 1.7	102	0	179/179	6.5 ± 1.3	179	0	1
12 mo	149/32	5.4 ± .6	11	21 (65.6)	102/77	5.1 ± .8	6	71 (92.2)	179/50	5.4 ± .7	13	37 (74)	.001*
18 mo	149/36	5.4 ± .5	13	23 (63.8)	102/41	4.9 ± .7	3	39 (95.1)	179/20	5.7 ± 1.8	5	15 (75)	.005†

HbA1C = glycosylated hemoglobin; LRYGB = laparoscopic Roux-en-Y gastric bypass; LSADI-S = laparoscopic single-anastomosis duodenal-ileal bypass with sleeve gastrectomy; LSG = laparoscopic sleeve gastrectomy; Nl = normal.

* In post hoc comparisons using the Holm-Bonferroni correction LSADI-S was significantly different from LSG and LRYGB. No difference between LRYGB and LSG was present.

† In post hoc comparisons using the Holm-Bonferroni correction SADI-S was significantly different from RYGB. No difference between SADI-S and SG or RYGB and SG was found.

conclusion for patients with BMI >55 kg/m^2, as the group had a small number of patients. Another limitation was the lack of similarity between the 3 groups. In all 4 BMI categories, the patients that underwent LSADI-S had highest preoperative weight and BMI. Despite these differences, LSADI-S had better weight loss than LSG and LRYGB. Moreover, the T2D resolution rate was highest with LSADI-S. Also, the study did not include some of the nutritional data points like prealbumin, parathyroid hormone, and vitamins B1 and B9.

Conclusions

The patients with obesity have a better weight reduction and HbA1C rates with LSADI-S than LRYGB and LSG. The nutritional outcomes between LRYGB and LSADI-S were similar.

Disclosures

P.E. reports personal fees and other from Medtronic, outside the submitted work. D.C. reports personal fees and other from Medtronic and GI Windows, outside the submitted work. J.B. reports personal fees and other from J&J and Endo 360.

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

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