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Revisional Surgery for Malnutrition after SADI-S: Prevalence, Indications, Techniques and Outcomes. Single Center Experience

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Abstract: Single-Anastomosis Duodeno-Ileal bypass with Sleeve Gastrectomy (SADI-S) is a modification of the duodenal switch in which only one anastomosis is performed, with a longer common limb and an expected less malabsorptive effect. The present study analyzes presentation and treatment of malnutrition after SADI-S. 258 consecutive patients undergoing SADI-S between May 2007 and September 2017 were included. The common limb length was 200 cm in 50 cases, 250 cm in 156 and 300 in 52. 30 patients were admitted for severe hypoalbuminemia and 16 patients were submitted to revisional surgery and constitute the series of our study. Mean weight before reoperation was 57 kg and mean body mass index (BMI) was 21 kg/m2. Mean number of daily bowel movements was 5,6. Mean time to reoperation was 56 months. Revisional surgery consisted mainly in elongation of the common limb. Mean weight regain was 14 kg and mean final BMI was 26 kg/m2. Daily bowel movements were decreased to 1,3. Factors related to hypoalbuminemia were hypertension, poor controlled diabetes, age over 55 years and a shorter common limb. Although SADI-S is expected to be less malabsorptive than previous biliopancreatic diversions, caution has to be taken with selected patients to avoid postoperative malnutrition.

Keywords: SADI-S; malabsorption; revisional surgery

1. Introduction

Malnutrition is one of the most feared long-term complications of bariatric surgery. It has been historically related to malabsorptive operations, as jejunoileal bypass (JIB), biliopancreatic diversion (BPD) and duodenal switch (DS), although patients submitted to less aggressive techniques can also present some degrees of malnutrition. Single-Anastomosis Duodeno-Ileal bypass with Sleeve Gastrectomy (SADI-S) was introduced as a simpler alternative to the Duodenal Switch (DS) in which malabsorption was supposed to be milder because of the increase in the length of the common channel (1). However, a high rate of nutritional problems presented in the first series of patients in which the common limb measured 200 cm. This led us to elongate the absorptive channel (250 to 300 cm) to ameliorate the malabsorptive effect of the operation (2). The new longer common channel still showed good weight loss results in the long-term, whereas there was a reduction in the nutritional

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issues (3, 4). Despite this greater absorption, some patients still present with hypoalbuminemia and other deficiencies (5), perhaps secondarily to a wrong selection, errors in the limb measurement or poor adherence to diet and supplementation. The management of malnourished patients can be difficult, and many times involves the revision of the technique. This seems to be easier in a one-limb operation when compared to Roux en Y configuration, but still the handling of a duodeno-intestinal anastomosis can be a concern for many surgeons.

In the present study, we review our experience on malnutrition after SADI-S and analyze the possible causes for this malnutrition, the markers that permit an early detection of these patients to avoid dreadful consequences, the current surgical solutions to improve their nutritional status and the outcomes after revisional surgery.

2. Materials and Methods

From May 2007 to September 2017, 258 consecutive patients were submitted to SADI-S, either as a one step surgery (213 cases) or as a second surgery after a previous sleeve gastrectomy (45 patients). The study was limited to patients operated before 2018 to warrant at least a 5 year follow up. The common limb was 200 cm in 50 cases, 250 cm in 156 cases and 300 cm in 52. Indications for SADI-S, surgical technique, supplementation and follow up have been reported previously (5). Thirty patients (11,6%) were admitted for severe malnutrition. This was defined as low albumin levels plus edema, in the absence of an inflammation status, and not amenable for ambulatory management. Sixteen patients were submitted to revisional surgery (6,2%), and constitute the series of our study (Figure 1, Flow Chart).

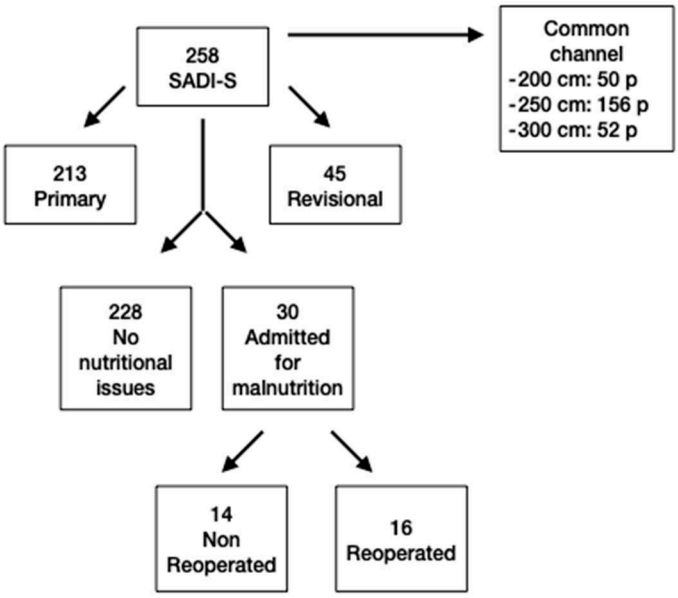

Figure 1. Flow chart.

Two surgeons (ASP and AJT) performed all the operations, both primary and revisional.Interventionary studies involving animals or humans, and other studies that require ethical approval, must list the authority that provided approval and the corresponding ethical approval code.

Statistics

Data are expressed by mean, range and standard error of the mean. Comparisons between the study series and the total SADI-S series are done with the t-test and chi-square test for numerical and categorical variables respectively.

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3. Results

Follow up for the whole series was 85% at 5 years. Sixteen patients (6,2%) were reoperated. The incidence density was 0,6 cases per 100 patients-year. They were 6 men and 10 women, with a mean age at the index operation of 51 years (35 to 68), a mean initial weight of 118 kg (87 to 180), and a mean initial body mass index (BMI) of 44 kg/m2 (38 - 54). Type 2 diabetes was present in 10 patients (62%), 3 were under oral therapy and 7 under insulin treatment; 14 patients had hypertension (87%), 11 had dyslipidemia (69%), and 9 had sleep apnea (56%). One patient had been submitted to a previous bariatric operation, a sleeve gastrectomy. SADI-S had been performed with a 2 meter common limb in 8 cases (8/50, 16% malnutrition rate for SADI-S 200), and with a 250 cm common limb in the other 8 patients (8/156, 5,1% malnutrition rate for SADI-S 250). No one had undergone SADI-S with a 3 meter common limb.

3.1. Presentation

The mean time to first admission was 37 months, 2 months being the earliest one and 180 months the latest one. The mean number of hospital admissions before revision was 2,6 (0 - 5). Seven patients (43%) had the first episode requiring hospital admission in the first postoperative year, while 4 of them (25%) presented with malnutrition more than 5 years from surgery.

The mean time to reoperation was 56 months, from 16 to 186 months; 50% of the patients were reoperated in the first 3 postoperative years, and 37% of them beyond the 5th postoperative year.

Indication for reopeation was individualized, and different parameters influenced this decision, as were age, severity of the episode, psychiatric evaluation, social status, number of episodes, coexisting diseases, etc. The main cause for reoperation was severe malnutrition in most cases (11 patients), but also intractable diarrhea was present in some patients (4 cases); there was one patient with severe hypocalcemia and 3 had developed liver failure, two secondary to alcohol consumption and one to viral hepatitis and cirrhosis (Table 1).

Table 1. Indications for surgery, findings, and surgical attitude.

Case nº	Limb length	Indication	Other causes	Time to Surgery	Nº admissions	Real length	Technique	Stomach
1	200	Diarrhea	Hypocalcemia	65	5	200	SADI-S 350	Re-Sleeve
2	200	Malnutrition	Diarrhea	114	2	200	SADI-S 350	
3	200	Malnutrition		28	1	200	RnY DS	
4	200	Malnutrition	Diarrhea	120	1	200	SADI-S 300	
5	200	Malnutrition	Aged	28	2	200	RnY DS	
6	200	Liver Failure	Alcohol	133	1	200	SADI-S 300	Re-Sleeve
7	200	Diarrhea		37	1	250	SADI-S 350	
8	250	Malnutrition		156	1	170	SADI-S 300	
9	250	Malnutrition		17	2	250	RnY DS	
10	250	Malnutrition	Schizophrenia	16	1	250	Duodeno-duodenostomy	
11	250	Malnutrition		40	1	250	SADI-S 350	Re-Sleeve
12	250	Liver Failure	Viral Hepatitis	23	3	220	Duodeno-jejunostomy	
13	250	Malnutrition		19	3	150	SADI-S 350	
14	250	Malnutrition		76	1	190	SADI-S 350	
15	250	Liver Failutre	Alcohol	16	1	250	SADI-S 350	
16	250	Malnutrition		20	1	200	SADI-S 300	

Mean age at reoperation was 55 years (32 - 71), mean weight 57 kg (46 - 74), mean BMI 21 kg/m2 (18,6 - 27) and mean total weight loss (TWL) 50,2% (32,7 - 68). All patients were nutritionally

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optimized to achieve normal albumin and total protein levels, in 7 cases with the need of total parenteral nutrition. The mean number of daily bowel movements was 5,6 (2 - 10).

3.2. Surgical findings

The common limb was measured in all cases. In patients with an initial SADI-S 200, in 6 cases, the measured length was 2 meters; in 1 patient the limb was shorter, 170 cm, and in another one it was longer, 250 cm. In patients submitted to SADI-S 250, we found a correct common limb length in 4 cases, and a shorter one in the other 4 (220, 200, 190 and 150 cm) (Table 1).

3.3. Surgical technique

The first 3 patients had a conversion into a Roux en Y DS through a division of the efferent limb just beyond the anastomosis, and the creation of a new anastomosis between this and the afferent one one meter proximal to the duodeno-ileostomy (Figure 2). In this way the three patients had a DS with an antiperistaltic alimentary limb (1 meter) and a 2 meter common limb. Three patients were submitted to a "total" reversal (1 case, end to end duodeno-duodenostomy) or an "almost-total" reversal, a duodeno-jejunostomy in the first jejunal loop (2 cases). The other ten patients were submitted to an elongation of the common limb through the division of the previous anastomosis and the creation of a new one more proximally, leaving a final common channel of 270 in one case, 300 cm in 3 and 350 cm in 7 cases. A resizing of the sleeve gastrectomy over a 54 French bougie was performed along with the proximalization of the SADI-S in 3 cases; all three were suffering from severe diarrhea with no or mild hypoalbuminemia and had a very enlarged stomach (Table 1).

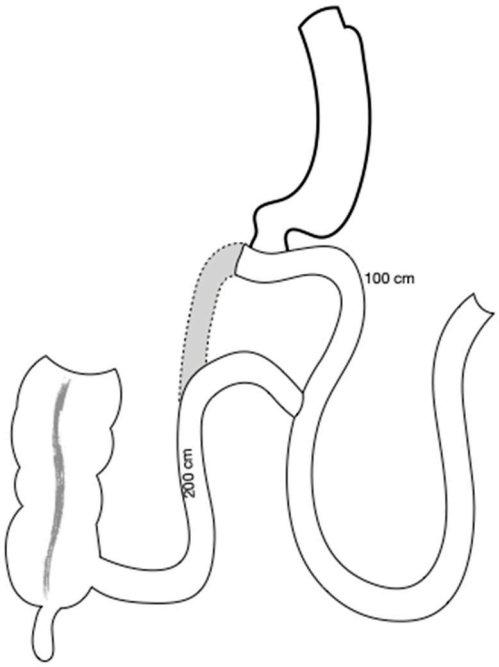

Figure 2. Scheme of the conversion of SADI-S to Roux en Y DS with an antiperistaltic alimentary limb. The efferent (common) limb has been divided close to the anastomosis and re-anastomosed to the afferent (biliopancreatic) limb one meter proximal to the previous duodenoileostomy. The final operation has a 100 cm antiperistaltic alimentary limb and a 200 cm common limb.

3.4. Outcome

After surgery, one patient with an advanced respiratory disease rejected ventilatory support and died. One patient with a Roux-en-Y DS was readmitted with an intestinal obstruction for an internal hernia, and was reoperated; intestinal resection was necessary, and she finally was converted into a Roux-en-Y Gastric Bypass. One patient with a Roux-en-Y DS with an antipersitaltic alimentary limb

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was reoperated 10 years later for gastro-ileal stasis with postprandial fullness and frequent regurgitation and vomiting. She was converted into a SADI-S with a 300 cm common limb.

3.5. Long term results

In the long term the mean weight was 71 kg (44 - 89) with a mean weight regain of 14 kg from revisional surgery; the mean BMI was 26 kg/m2 (17 - 37), and the stool frequency was normalized, with mean number of bowel movements of 1,3 (0,5 - 4).

3.6. Factors related to malnutrition

Clinical and laboratory data of patients needing surgery for malnutrition were crossed with data from the complete series of patients submitted to SADI-S to find out which parameters could be related to the development of malnutrition. Patients in which the common limb was found to be too short at reoperation (shorter than 15% than expected) were excluded, as we considered that the main reason for malnutrition in this subset was the technical error. Results are presented in Table 2. Older age, lower BMI, higher glycemia, higher glycated hemoglobin (HbA1c), lower alkaline phosphatase, hypertension and a shorter common limb in the initial SADI-S (2 meter) were all significantly related to the possibility of reoperation for malnutrition.

Table 2. Preoperative clinical and analytical data and relation to reoperation. No differences are found between non-malnourished patients (whole series) and patients admitted for malnutrition but not needing reoperation. Comparisons are made between reoperated patients and the whole series. The cut off is the value from which the possibility of a revisional operation was found to be signficantly greater.

	No Malnutrition	Admission - No Reoperation	Reoperation	Non reop. vs Reop. Significance (p)	Cut off
Male %	36,5 %	21,4 %	37,5 %	0,9	
Age (years)	46,8 (0,69)	49,5 (3,09)	53,5 (2,4)	**0,03**	**≥ 55**
BMI (kg/m²)	46,7 (0,45)	50,7 (2,97)	41,5 (1,15)	**0,01**	**≤ 44**
Hemoglobin (g/dL)	14,08 (0,09)	13,1 (0,42)	13,8 (0,42)	0,6	
Hematocrit (%)	42,5 (0,37)	40,7 (1,0)	41 (1,15)	0,36	
Iron (µg/dL)	76,1 (3,17)	67,8 (11,3)	79,2 (17)	0,81	
Albumin (g/dL)	4,19 (0,01)	3,99 (0,08)	4,2 (0,08)	0,3	
Total Proteins (g/dL)	7,13 (0,03)	6,7 (0,17)	7,2 (0,13)	0,36	
Calcium (mg/dL)	9,48 (0,04)	9,3 (0,13)	9,7 (0,09)	0,14	
Glucose (mg/dL)	131 (3,69)	129 (13,5)	174 (20,22)	**0,01**	**≥ 170**
HbA1c (%)	6,9 (0,12)	6,9 (0,41)	8,81 (0,79)	**0,048**	**≥ 7,5**
Triglycerides (mg/dL)	164 (6,9)	146 (20,7)	176 (44,1)	0,7	
HDL-Cholesterol (mg/dL)	49,2 (1,02)	56,3 (4,49)	47 (2,37)	0,4	
LDL-Cholesterol (mg/dL)	109,6 (2,73)	106,9 (9,88)	86,8 (11,3)	0,08	
Total Cholesterol (mg/dL)	190 (2,7)	194 (11,5)	180 (12,4)	0,4	
AST (U/L)	24 (0,9)	17,1 (2,57)	30,8 (5,2)	0,11	
ALT (U/L)	28,2 (1,28)	23,8 (5,3)	36,9 (5,09)	0,12	
GGT (U/L)	44 (4,02)	54,3 (25,3)	74,5 (36,08)	0,11	
Alkaline Phosphatase (U/L)	83,8 (2,47)	82,8 (8,14)	60,4 (6,02)	**0,029**	**≤ 70**
T2DM	54 %	50 %	75 %	0,36	
Hypertension	50 %	57 %	100 %	**<0,001**	
Obstructive Apnea	47 %	50 %	50 %	0,35	

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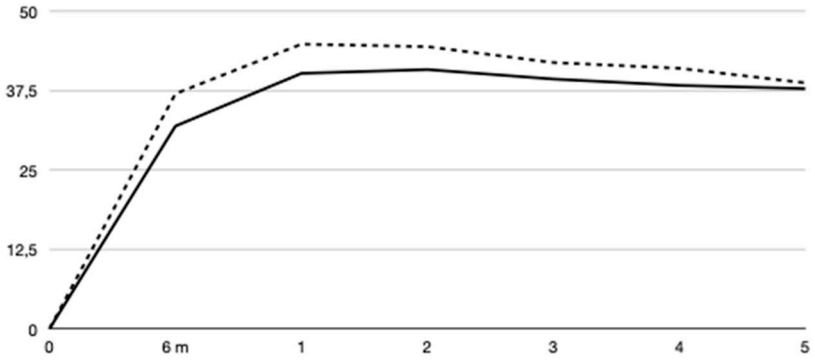
Patients submitted to reoperation had, after the index surgery, a greater weight loss (Figure 3), a higher number of daily bowel movements as well as many laboratory test alterations as shown in Table 3.



Time (months)	Reoperated	Non reoperated	P
0	0	0	-
6	37	31,9	0,021
12	44,8	40,2	0,048
24	44,4	40,8	0,22
36	41,9	39,3	0,2
48	41	38,3	0,19
60	38,7	37,8	0,18

Figure 3. Weight loss after initial SADI-S in patients with malnutrition (dotted line) and in those without (solid line). Numbers are given as total weight loss % (TWL). Differences are significant at 6 and 12 months.

Table 3. Postoperative laboratory tests and bowel movements of patients suffering from malnutrition vs non-reoperated patients.

	Reoperated	Non Reoperated	p
Hemoglobin (g/dL)	12,3	13,4	0,005
Hematocrit (%)	37,4	40,4	0,004
Albumin (g/dL)	3,4	3,9	0,01
Glucose (mg/dL)	81,8	90	0,002
HbA1c (%)	4,8	5,2	0,03
LDL-Cholesterol (mg/dL)	60	78	0,01
Total Cholesterol (mg/dL)	124	143	0,02
Transferrin (mg/dL)	153	223	0,006
Ferritin (ng/mL)	305	120	0,001
Gammaglutamyl transferase (U/L)	71	30	0,001
Cupper (µg/dL)	69	101	0,007
Bowel movements	3,3	2,2	0,03

4. Discussion

SADI-S is a safe operation for selected patients with adequate follow up and life-long supplementation (4). However, despite being apparently safer than prior malabsorptive operations as BPD and DS, some patients can experience malnutrition, a life-threatening condition that must be avoided or early detected and treated (5).

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The main findings of this review of our experience are that a short common channel (200 cm) is followed by a high rate of severe malnutrition; that errors in the measurement of the small bowel may also lead to malnutrition; and that there are some patients who can be especially vulnerable, as those older than 55 years, those with hypertension and poor controlled type-2 diabetes and patients with low liver reserve due to preexisting liver disease. Clinicians have to be aware when patients lose weight too rapidly, have more severe diarrhea, or their laboratory tests are significantly altered in the first postoperative year, as they are all markers of malnutrition.

The initial operation with a common channel of 2 meters was abandoned in 2009 because of the high incidence of malnutrition (2). The simple increase in 50 cm did not affect the good results on weight loss, and, on the other hand, increased the safety of the operation (5). To achieve a secure technique, the measurement of the ileum has to be accurate enough, either if it is done with marked graspers or if it is performed with a tape of known length (6, 7). We recommend measuring the bowel after relaxing the smooth muscle with intravenous Buscopan®, as the stretching of the small bowel has demonstrate to obtain more accurate measurements (8).

We found an association between older age and malnutrition. Cossu et al (9) reviewed the importance of age on malnutrition in patients submitted to BPD, finding that the group of patients older than 55 years had a 16% rate of malnutrition and an 8% rate of revisional surgery. The authors outlined the difficulty of aged patients in changing alimentary habits after surgery and the clinical importance of some disorders related to aging, as it is loss of appetite, the impaired sense of taste, the lack of teeth and therefore good mastication and sometimes even depression.

We also found that hypertension was more prevalent between reoperated patients, as well as higher preoperative values of glycemia and HbA1c. Hypertension and poor control of diabetes, defined by HbA1c above 7% or high glycemia are both related to atherosclerosis, which along with age could be the cause of an impaired intestinal absorption and a decreased adaption capacity of the small bowel. Although there are no studies on microvascularization of the small bowel and nutrition, atherosclerosis has been previously related to malnutrition in patients with peripheral arterial disease (10).

Aged patients and patients with glycemic alteration would preferable undergo a SADI-S with a longer common limb or perhaps another safer operation, as proximal Roux en Y gastric bypass or sleeve gastrectomy.

We find no explanation to the relationship between a low preoperative alkaline phosphatase (AP) and malnutrition; low AP levels are related to low zinc and magnesium levels, what is seen in malnutrition. Unfortunately, we do not routinely analyze them preoperatively, so we cannot establish a connection between them.

Liver disease, obesity, weight loss and malnutrition are intimately related. Non-alcoholic fatty liver disease (NAFL) improves after a successful weight loss operation. However, when weight loss happens too fast, the loss of adipose tissue leads to a massive mobilization of free fatty acids that reach the liver and provoke hepatotoxicity. This is compensated by the reduction of liver fat caused by the weight loss (11). But when other mechanisms are present, as protein malnutrition or deficiency of specific amino acids, or bacterial overgrowth, this toxicity can lead to a liver failure. Bacterial overgrowth is not supposed to happen after SADI-S, because there is not a real blind loop, as it was in old malabsorptive operations. Nevertheless, the mere absence of nutrients in an intestinal loop is enough to induce a substantial change in the jejunal microbiota (12), and this can have dramatic consequences in patients with liver disease. Patients with an underlying liver disease should never be offered this type of surgery because of the risk of hepatic insufficiency (13) that on some occasion has led to the need of liver transplantation (14).

Surgeons and endocrinologists should be specially alerted when weight loss is too fast in the first postoperative year, or when there is a high number of bowel movements. These patients have to be tested for micronutrient or protein insufficiency before clinical manifestations and treated with supplementation of protein and vitamins.

Regarding the revisional technique, we initially introduced the Roux-en-Y configuration with the antiperistaltic alimentary limb to avoid touching the previous duodeno-ileostomy. When we

demonstrated the feasibility of dividing the anastomosis and performing a new duodeno-enterostomy without affecting the pylorus function, the initial technique was abandoned. As a rule we first measure the biliary and the common limb, to know if the cause of malnutrition was an error of the first operation, and to assess how long can the proximalization be done. Then, 100 to 150 cm are usually added to the common limb, placing the new anastomosis at 300 to 350 cm from the ileo-cecal junction. When there is a severe underlying disease, as happened with the psychiatric patient and with those suffering from liver failure, the new anastomosis is placed in the first jejunal loop or even in the duodenum, restoring an almost normal anatomy.

In summary, SADI-S is an effective and safe operation when the selection of patients, the performance of the operation and the supplementation and follow up are correct. Older patients, patients with hypertension, lower BMI or bad controlled diabetes, as well as those with severe accompanying conditions or those with problems of adherence to supplementation and follow up should not undergo SADI-S 250. Limitations of this study are the single institution experience, the retrospective nature of the study, the short number of patients and the heterogeneity of the series.

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Institutional Review Board Statement: For this type of study formal consent is not required.

Conflicts of Interest: The authors declare that they have no conflicts of interest regarding this manuscript**.**

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