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ORIGINAL CONTRIBUTIONS

Outcome of Revisional Bariatric Surgery After Failed Sleeve Gastrectomy: a German Multicenter Study

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Abstract

Purpose Sleeve gastrectomy (SG) is a common bariatric procedure that has been shown to be effective in both the short and long term, but it is not without risks, some of which necessitate revision or redo surgery (RS).

Materials and Methods GBSR (German Bariatric Surgery Registry) data were evaluated in this multicenter analysis. Short-term results (1-year follow-up) of RS (Re-Sleeve gastrectomy, Roux-en-Y gastric bypass, RYGB, Omega-loop gastric bypass, OLGB, and duodenal switch, DS) following primary SG ($n = 27939$) were evaluated.

Results Of PSG patients, 7.9% (n=2195) needed revision surgery. Nine hundred ninety-four patients underwent the aforementioned four surgical procedures (95 with R-SG, 665 with RYGB, 141 with OLGB, and 93 DS). Loss of follow-up within 1 year 52.44%. The most common reasons for RS were weight regain and/or a worsening of preexisting comorbidities. Regarding the operating time, R-SG was the shortest of the four procedures, and DS was the longest. In general, there were no significant advantages of one procedure over another in terms of complication incidence in these categories. However, certain complications were seen more often after R-SG and DS than with other redo procedures. There were significant differences in BMI reduction 1 year after surgery (RYGB: 5.9; DS: 10.1; OLGB: 9.1; and R-SG: 9.1; p<0.001). GERD, hypertension, and sleep apnea demonstrated statistically significant comorbidity remission. Diabetes exhibited non-significant differences.

Conclusion According to the findings of our study, all revision surgeries effectively resolved comorbidities, promoted weight loss, and lowered BMI. Due to the disparate outcomes obtained by various methods, this study cannot recommend a particular redo method as the gold standard. Selecting a procedure should consider the redo surgery's aims, the rationale for the revision, the patient's current state, and their medical history.

Keywords Redo-sleeve gastrectomy · Revisional bariatric surgery · Weight gain · Perioperative outcome · Comorbidities

Key Points
1. Despite the advantages of sleeve gastrectomy (SG), insufficient weight loss, complications, or the persistence of comorbidities may necessitate revision surgery (7.9% documented in GBSR).
2. Depending on the revision procedure, revision surgery after a failed sleeve gastrectomy results in varying degrees of adequate weight loss and remission of comorbidities.
3. Although certain revision surgical procedures were linked with an increased complication rate, revision surgery appears to be a safe and effective therapeutic option following failed SG.
4. Patients deciding to undergo a bariatric revision surgery should be informed of the procedure's intermediate and long-term risks.

Introduction

The prevalence of obesity has recently been rising across all demographics globally despite advancements in medicine. This is also associated with an increase in the severity and prevalence of obesity-related diseases [1].

Consequently, several advancements in the non-surgical and surgical management of obesity have been documented in recent decades [2].

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Sleeve gastrectomy (SG) is one of the most commonly performed bariatric surgical procedures used to treat obesity. Besides the treatment's technical simplicity, the procedure's outstanding short- and long-term outcomes distinguish it from other bariatric and metabolic surgeries [3]. However, results are not uniform and unpredictable in which the effects are not as predicted, either in the short or long term. These conditions necessitate constant monitoring of the affected individuals and, in severe stages, may require a revision surgery (RS) strategy adjustment [4, 5].

In recent years, numerous concepts related to this topic have been researched and evaluated. Surgical intervention is often the first line of treatment, coupled with other non-invasive methods [6].

In addition to re-sleeve gastrectomy (R-SG), other bariatric surgical procedures may be considered for patients whose original sleeve gastrectomy was unsuccessful [7–9]. Although sufficient information is available on the benefits of various surgical procedures as revision procedure (RP) following failed primary SG, determining which surgical RP is most appropriate in this case remains contentious and requires additional scientific investigation.

This study addresses and investigates the short- and long-term outcomes of Re-SG, duodenal switch (DS), Roux-en-Y gastric bypass (RYGB), and Omega-loop gastric bypass (OLGB) as RP following unsuccessful sleeve gastrectomy.

Material and Methods

Aim of the Study

This study aims to compare different redo procedures after primary SG at 1-year follow-up, using both perioperative and 1-year follow-up data (182–547 days). Figure 1 summarizes the inclusion and exclusion criteria.

All patients with revision surgery (RS), DS, Re-SG, RYGB, and OLGB after failed SG between 2005 and 2021 were included in our analysis. Reasons for converting from SG to the above-mentioned bariatric procedures were weight regain, reflux disease, or persistence or worsening of comorbidities after primary SG.

Data Selection

Prospective data were collected from multiple centers in Germany using the German Bariatric Surgery Registry (GBSR).

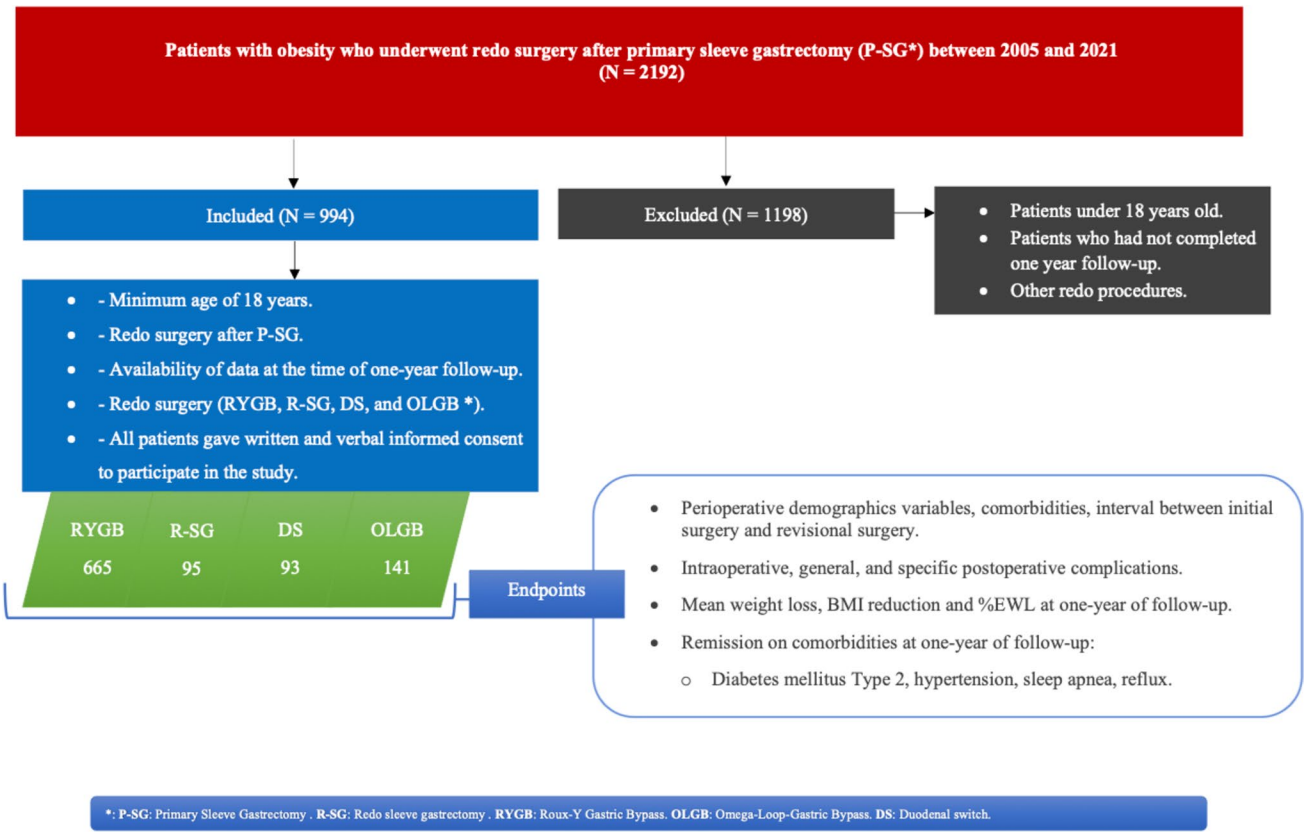

Fig. 1 Flow chart of the study and patient criteria

From the processed data, patients are selected for analysis according to the following inclusion criteria:

- All bariatric patients up to 04/08/2021 with the status "clean."
- Valid age of at least 18 years.
- Redo procedure after primary SG.
- Redo procedures: DS, RYGB, R-SG, or OLGB.
- Presence of a valid 1-year follow-up.

During the outpatient presentation, preoperative data were gathered. A standardized questionnaire was used to obtain demographic data and comorbidities. During follow-up, data were collected either by presenting patients in person or by sending patients a questionnaire.

All data were collected in accordance with the principles of biomedical research outlined in the Declaration of Helsinki. Prior to prospective data collection, both patients and hospitals consented to the analysis of anonymized data in scientific studies.

Data Preparation and Definition of Variables

Individual target variables are each recorded individually as well as aggregated into one variable, for example, intraoperative complications are given if at least one intraoperative complication was selected.

Patients were assumed to have hypertension, sleep apnea (SA), or reflux if they had a documented preoperative diagnosis or were medicated for one or more of these conditions.

During follow-up, a complete remission of hypertension was observed if the patient had normal blood pressure after surgery and had stopped taking antihypertensive medications. The same was true for patients with diabetes mellitus type II (T2D), reflux, and SA.

Statistical Analysis

All analyses were performed using SAS 9.4 software. As this is an exploratory analysis, testing was deliberately performed at the full 5% significance level and any p-value $\leq$ 0.05 corresponds to a significant result.

Since the data came from GBSR as a multicenter registry study, it must also be considered that the cleanliness of the data cannot be assumed. In addition, only available data were analyzed. Therefore, bias due to incorrect values cannot be excluded.

If the target variable is categorical, the chi-square test was performed. For continuous target variables, an ANOVA (analysis of variance) was used. In the case of strong deviations of the distribution from the normal distribution (surgery duration, hospital length of stay, and postoperative length of stay), a transformation based on the root function is applied for the execution of the test to approximate a normal distribution.

Results

The registry included 27,939 patients with primary SG, of whom 2195 required revision surgery (7.9%). As this research focuses on the four most frequent revision procedures, data from 994 patients who underwent revisional surgery were analyzed. Loss of follow-up within 1 year was 52.44%. The most common RP performed was RYGB with 665 patients, followed by OLGB with 141, then R-SG with 95, and finally DS with 93 patients. Laparoscopy was the main method of revision. Conversion from laparoscopy to laparotomy was most commonly documented in DS (2.2%), RYGB (1.8%), R-SG, and OLGB (0%); $p<0.001$. Table 1 shows the distribution of RP and the type of procedure by access type.

Table 1 Distribution of surgical method and type of access

Method of redo surgery									
	N				%				
R-SG	95				9.6				
RYGB	665				66.9				
DS	93				9.4				
OLGB	141				14.2				
Total	994				100				
Type of access									
	R-SG		RYGB		RYGB DS		OLGB		*p*-value
	N	%	*N*	%	*N*	%	*N*	%	
Laparotomy	2	4	20	3	8	8.6	1	0.7	<0.001
Laparoscopy	46	92	630	95.2	83	89.2	140	99.3	
Conversion	0	0	12	1.8	2	2.2	0	0	

Redo interventions were performed at various times after sleeve gastrectomy. The mean interval between PSG and redo procedures is displayed in Table 2.

Demographic and Preoperative Variables

All RPs showed substantial differences in demographic and preoperative variables. Females outnumbered males in all RPs. DS patients had the highest BMI and RYGB patients the lowest. OLGB patients were the oldest and R-SG patients the youngest. DS patients had the longest operating time and hospital stays. Table 3 presents a summary of the steady and preoperative parameters.

The distribution of comorbidities differed between the procedures and is demonstrated in Table 4.

Perioperative Adverse Events

Intraoperative complications showed no significant differences between the four RPs. However, a distinction existed between general and specific postoperative complications. Here, DS and R-SG had the greatest overall rate of complications. Regarding specific complications, the R-SG group had the greatest incidence of renal complications (2.1%; p=0.046). In contrast to RYGB and OLGB (4.3% and 4.2%, respectively; p=0.017), the prevalence of fever was highest in the group with DS and R-SG. The R-SG group had the highest documented rate (3.2%; p=0.004) of postoperative bleeding requiring transfusion. Moreover, anastomotic insufficiency and staple line leakage were most prevalent following DS and R-SG (6.5% and 6.3%, respectively; p=0.034). This also held true for sepsis, wound infections, and intraabdominal abscesses (p<0.001). In contrast, ileus occurred more frequently after DS than after RYGB (2.2% and 0.2%, respectively; p=0.008). Table 5 provides a summary of intra- and postoperative complications.

BMI and Weight Reduction

All groups experienced significant BMI and weight reductions 1 year after RS. Compared to the other groups, the DS group had the greatest average BMI reduction, followed by the R-SG group. Table 6 provides a comprehensive presentation of the evolution of weight, %EWL, and BMI.

Development of Comorbidities at 1-Year Follow-Up

One year after RS, significant differences were found for hypertension, SA, and reflux disease. Table 7 presents the results of the evolution of comorbidities following RS. There

Table 2 Interval between primary sleeve gastrectomy and redo surgery in years

Redo procedure	*N*	*N* missing	Mean	STD	Min	Q1	Median	Q3	Max
RYGB	451	214	2.3	1.6	0.1	1.2	1.9	3.1	13.2
DS	78	15	1.8	1.1	0.5	1.0	1.6	2.2	6.0
OLGB	98	43	3.0	2.0	0.2	1.5	2.7	4.0	9.7
R-SG	38	57	2.4	2.2	0.0	0.6	1.7	3.5	7.3
Total	665	329	2.3	1.7	0.0	1.2	1.9	3.1	13.2

Table 3 Mean and standard deviation distribution of continuous parameters

Variables		Revision procedure				*p*-value
		RYGB	DS	OLGB	R-SG	
Age [year]	N/mean ± SD	665/46.5 ± 10.6	93/44.2 ± 9.8	141/47.6 ± 10.7	95/43.6 ± 11.7	0.007
Height [cm]	N/mean ± SD	663/169.8 ± 9.4	93/171.8 ± 9.7	141/172.3 ± 10.4	95/172.8 ± 10.8	0.002
Weight [kg]	N/mean ± SD	663/119.8 ± 30.6	93/139.8 ± 29.4	141/134.4 ± 27.8	95/135.7 ± 38.5	<0.001
Sex (%)	Male	24.4	40.9	33.3	38.9	<0.001
	Female	75.6	59.1	66.7	61.1	
BMI [kg/m^2]	N/mean ± SD	661/41.4 ± 9.3	93/47.2 ± 8.3	141/45.2 ± 8.1	95/45.2 ± 10.9	<0.001
Operating time [min]*	N/mean [range of dispersion]	664/121.7 [116.8; 126.6]	93/174.2 [170.6; 177.8]	141/92.3 [87.5; 97.0]	48/86.2 [80.5; 91.9]	<0.001
Postoperative length of stay [day]*	N/mean [range of dispersion]	665/5.9 [5.0; 6.8]	92/8.8 [5.8; 11.8]	141/5.1 [4.6; 5.5]	94/8.4 [4.3; 12.6]	<0.001
Hospital length of stay [day]*	N/mean [range of dispersion]	665/7.1 [6.0; 8.3]	92/10.3 [7.4; 13.2]	141/5.9 [5.4; 6.4]	95/10.0 [5.9; 14.0]	<0.001

*Root transformation; specification of back-transformed mean values and scatter ranges [mean-STD; mean+STD]

Table 4 Distribution of comorbidities

		Revision procedure								*p*-value
		RYGB		DS		OLGB		R-SG		
		n	%	*n*	%	*n*	%	*n*	%	
ASA	ASA I	13	2.0	1	1.1	2	1.4	7	7.4	0.053
	ASA II	373	56.3	45	48.4	74	52.5	47	49.5	
	ASA III	270	40.7	47	50.5	63	44.7	40	42.1	
	ASA IV	7	1.1	0	0	2	1.4	1	1.1	
Comorbidities (total)	Yes	588	88.4	83	89.2	124	87.9	76	80.0	0.126
	No	77	11.6	10	10.8	17	12.1	19	20.0	
T2D (total)	Yes	169	28.3	38	43.7	40	29.2	16	17.6	0.002
	No	428	71.7	49	56.3	97	70.8	75	82.4	
T2D (IDDM)	Yes	60	10.1	16	18.4	12	8.8	6	6.6	0.048
	No	537	89.9	71	81.6	125	91.2	85	93.4	
T2D (NIDDM)	Yes	78	13.1	20	23.0	19	13.9	6	6.6	0.014
	No	519	86.9	67	77.0	118	86.1	85	93.4	
T2D (dietary)	Yes	31	5.2	2	2.3	9	6.6	4	4.4	0.543
	No	566	94.8	85	97.7	128	93.4	87	95.6	
Arterial hypertension	Yes	330	49.6	66	71.0	89	63.1	50	52.6	<0.001
	No	335	50.4	27	29.0	52	36.9	45	47.4	
Other cardiac and vascular diseases (OCVD)	Yes	71	10.7	6	6.5	20	14.2	9	9.5	0.295
	No	594	89.3	87	93.5	121	85.8	86	90.5	
Pulmonary	Yes	96	14.4	19	20.4	17	12.1	10	10.5	0.208
	No	569	85.6	74	79.6	124	87.9	85	89.5	
Pulmonary embolism	Yes	8	1.2	1	1.1	2	1.4	2	2.1	0.902
	No	657	98.8	92	98.9	139	98.6	93	97.9	
Sleep apnea	Yes	111	16.7	26	28.0	33	23.4	9	9.5	0.002
	No	554	83.3	67	72.0	108	76.6	86	90.5	
Cholecystolithiasis	Yes	23	3.5	5	5.4	8	5.7	3	3.2	0.533
	No	642	96.5	88	94.6	133	94.3	92	96.8	
Reflux	Yes	293	44.1	5	5.4	27	19.1	13	13.7	<0.001
	No	372	55.9	88	94.6	114	80.9	82	86.3	
Varicosis	Yes	37	5.6	5	5.4	4	2.8	1	1.1	0.166
	No	628	94.4	88	94.6	137	97.2	94	98.9	
Lymphedema	Yes	32	4.8	4	4.3	3	2.1	3	3.2	0.500
	No	633	95.2	89	95.7	138	97.9	92	96.8	
Degenerative diseases of the skeletal system (DSD)	Yes	180	27.1	22	23.7	33	23.4	32	33.7	0.307
	No	485	72.9	71	76.3	108	76.6	63	66.3	
Orthopedic therapy	Yes	94	14.1	10	10.8	27	19.1	19	20.0	0.142
	No	571	85.9	83	89.2	114	80.9	76	80.0	
Degenerative spine diseases	Yes	141	21.2	12	12.9	39	27.7	24	25.3	0.046
	No	524	78.8	81	87.1	102	72.3	71	74.7	
Gonarthrosis	Yes	78	11.7	8	8.6	21	14.9	11	11.6	0.532
	No	587	88.3	85	91.4	120	85.1	84	88.4	
Coxarthrosis	Yes	21	3.2	2	2.2	3	2.1	3	3.2	0.883
	No	644	96.8	91	97.8	138	97.9	92	96.8	
Smoking	Yes	35	5.3	5	5.4	6	4.3	10	10.5	0.174
	No	630	94.7	88	94.6	135	95.7	85	89.5	
Alcohol	Yes	1	0.2	1	1.1	0	0	0	0	0.251
	No	664	99.8	92	98.9	141	100	95	100	

Table 4 (continued)

		Revision procedure								*p*-value
		RYGB		DS		OLGB		R-SG		
		n	%	*n*	%	*n*	%	*n*	%	
Transplantation	Yes	2	0.3	0	0	0	0	0	0	0.811
	No	572	99.7	51	100	140	100	84	100	
Chronic inflammatory gastrointestinal diseases (CID)	Yes	2	0.3	0	0	0	0	1	1.2	0.503
	No	572	99.7	51	100	140	100	83	98.8	
Rheumatoid inflammatory diseases (RID)	Yes	9	1.6	0	0	0	0	1	1.2	0.387
	No	565	98.4	51	100	140	100	83	98.8	
Non-alcoholic steatohepatitis (NASH)	Yes	24	4.2	2	3.9	4	2.9	3	3.6	0.907
	No	550	95.8	49	96.1	136	97.1	81	96.4	
Pseudotumor cerebri	Yes	1	0.2	1	2.0	1	0.7	1	1.2	0.204
	No	573	99.8	50	98.0	139	99.3	83	98.8	
Polycystic ovary syndrome (PCOS)	Yes	0	0	3	9.7	0	0	1	1.9	<0.001
	No	448	100	28	90.3	93	100	51	98.1	
Hypogonadism	Yes	0	0	0	0	0	0	0	0	1.000
	No	126	100	20	100	47	100	32	100	

were no significant advantages in the development of T2DM between the four approaches used. However, it should be noted that more than 50% of NIDDM patients and more than 40% of IDDM patients experienced complete remission after undergoing any of the four procedures studied.

Discussion

Bariatric surgery is considered effective in achieving adequate weight loss and improvement of obesity-related comorbidities. Over the years, numerous bariatric and metabolic surgical procedures have been developed and modified. Nevertheless, certain surgical procedures are preferred due to their ability to achieve both better weight loss and adequate improvement of comorbidities.

Long-term weight loss and comorbidity improvement make sleeve gastrectomy (SG) a popular bariatric treatment. However, unfavorable outcomes may require revision or conversion surgery [10–12].

The most common reason for revision after SG was persistent obesity, gastroesophageal reflux disease, insufficient weight loss, and the persistence of comorbidities [4, 5, 13]. Several scientific papers have described a percentage of approximately 28% of patients with inadequate weight loss after primary SG and the need for RS or a redo operation [14, 15]. Additionally, other factors, such as strictures in the sleeve stomach or dilatation of the gastric sleeve, may contribute to the need for RS [16, 17]. In our analysis, the most common causes of RS were weight regain, the de novo or worsening of reflux disease, and the persistence or worsening of obesity-associated diseases. The percentages in this regard have not been studied in detail; rather, the work focuses on the outcome of revision procedures and the impact on the affected patient.

This analysis examined in depth a total of four revision procedures. RYGB was the most frequently performed procedure, followed by OLGB, R-SG, and DS. Although it was a revision treatment, laparoscopic surgeries were much more common than open procedures. Notably, the conversion rate from laparoscopy to laparotomy was highest after DS, followed by RYGB. Patient demographics, perioperative variables, and technical and anatomical complexity may affect these results. Depending on the revision approach, the average interval between RS and primary SG ranged from 18 to 36 months.

Our analysis and the existing literature are incapable of establishing a standard indication for the respective revision processes. Consequently, some studies characterize the possibility of using R-SG as an adequate RP if the weight loss is due to dilatation of the sleeve stomach [18]. In contrast, the literature suggests avoiding R-SG in the presence of reflux disease and opting instead for RYGB, OLGB, or DS [19–22]. This principle also pertains to the management of comorbidities, although the long-term efficacy of bariatric procedures is debatable and cannot be used to select a procedure.

Operating time can be influenced by several variables, such as patient demographics and the type of procedure. According to our analysis, patients with DS had the longest surgery time among the 4 procedures. This may be due to both the higher BMI and the technical aspects of the

Table 5 Intra- and postoperative complications

		Redo procedure								
		RYGB		DS		OLGB		R-SG		
		n	%	*n*	%	*n*	%	*n*	%	*p*
Intraoperative complication										
Total	Yes	11	1.7	2	2.2	1	0.7	3	3.2	0.543
	No	654	98.3	91	97.8	140	99.3	92	96.8	
• Injury of splenic	Yes	1	0.2	0	0	0	0	0	0	0.920
	No	664	99.8	93	100	141	100	95	100	
• Injury of liver	Yes	0	0	0	0	0	0	0	0	1.000
	No	665	100	93	100	141	100	95	100	
• Pneumothorax	Yes	0	0	0	0	0	0	0	0	1.000
	No	665	100	93	100	141	100	95	100	
• Perforation of the stomach	Yes	1	0.2	0	0	0	0	0	0	0.920
	No	664	99.8	93	100	141	100	95	100	
• Bile duct injury	Yes	0	0	0	0	0	0	0	0	1.000
	No	665	100	93	100	141	100	95	100	
• Vascular injury	Yes	2	0.3	1	1.1	0	0	0	0	0.464
	No	663	99.7	92	98.9	141	100	95	100	
• Bleeding	Yes	0	0	0	0	0	0	0	0	1.000
	No	665	100	93	100	141	100	95	100	
• Other	Yes	8	1.2	2	2.2	1	0.7	3	3.2	0.367
	No	657	98.8	91	97.8	140	99.3	92	96.8	
General postoperative complication										
Total	Yes	42	6.3	8	8.6	4	2.8	16	16.8	<0.001
	No	623	93.7	85	91.4	137	97.2	79	83.2	
• Urinary tract infection	Yes	5	0.8	1	1.1	0	0	1	1.1	0.713
	No	660	99.2	92	98.9	141	100	94	98.9	
• Cardiac complication	Yes	1	0.2	1	1.1	0	0	1	1.1	0.207
	No	664	99.8	92	98.9	141	100	94	98.9	
• Renal complication	Yes	2	0.3	0	0	0	0	2	2.1	0.046
	No	663	99.7	93	100	141	100	93	97.9	
• Pulmonary complication	Yes	11	1.7	1	1.1	1	0.7	3	3.2	0.506
	No	654	98.3	92	98.9	140	99.3	92	96.8	
• Fever	Yes	9	1.4	4	4.3	0	0	4	4.2	0.017
	No	656	98.6	89	95.7	141	100	91	95.8	
• Thrombosis	Yes	2	0.3	0	0	0	0	1	1.1	0.477
	No	663	99.7	93	100	141	100	94	98.9	
• Other	Yes	22	3.3	2	2.2	3	2.1	11	11.6	<0.001
	No	643	96.7	91	97.8	138	97.9	84	88.4	
Special postoperative complication										
Total	Yes	46	6.9	13	14.0	3	2.1	15	15.8	<0.001
	No	619	93.1	80	86.0	138	97.9	80	84.2	
• Bleeding requiring transfusion	Yes	2	0.3	2	2.2	0	0	3	3.2	0.004
	No	663	99.7	91	97.8	141	100	92	96.8	
• Bleeding requiring endoscopy	Yes	7	1.1	0	0	0	0	3	3.2	0.078
	No	658	98.9	93	100	141	100	92	96.8	
• Bleeding requiring surgery	Yes	12	1.8	2	2.2	0	0	2	2.1	0.426
	No	653	98.2	91	97.8	141	100	93	97.9	
• Anastomotic leakage	Yes	17	2.6	6	6.5	2	1.4	6	6.3	0.034
	No	648	97.4	87	93.5	139	98.6	89	93.7	

Table 5 (continued)

		Redo procedure								
		RYGB		DS		OLGB		R-SG		
		n	%	*n*	%	*n*	%	*n*	%	*p*
• Anastomotic stenosis	Yes	1	0.2	0	0	0	0	0	0	0.920
	No	664	99.8	93	100	141	100	95	100	
• Ileus	Yes	1	0.2	2	2.2	0	0	0	0	0.008
	No	664	99.8	91	97.8	141	100	95	100	
• Intraabdominal abscess formation	Yes	4	0.6	1	1.1	0	0	5	5.3	<0.001
	No	661	99.4	92	98.9	141	100	90	94.7	
• Sepsis	Yes	1	0.2	2	2.2	0	0	3	3.2	<0.001
	No	664	99.8	91	97.8	141	100	92	96.8	
• Peritonitis	Yes	9	1.4	1	1.1	2	1.4	4	4.2	0.209
	No	656	98.6	92	98.9	139	98.6	91	95.8	
• Wound infection	Yes	4	0.6	1	1.1	0	0	3	3.2	0.043
	No	661	99.4	92	98.9	141	100	92	96.8	

Table 6 Development of BMI and weight at 1-year follow-up

		Redo procedure				*p*-value
		RYGB	DS	OLGB	R-SG	
Mean weight loss (kg)	Mean value ± STD	661/17.2 ± 16.3	93/30.0 ± 17.4	141/27.0 ± 15.8	95/27.4 ± 23.1	<0.001
BMI reduction (kg/m^2)	Mean value ± STD	654/5.9 ± 5.4	93/10.1 ± 5.9	141/9.1 ± 5.2	94/9.2 ± 7.5	<0.001
%EWL	Mean value ± STD	640/41.2 ± 67.7	93/47.9 ± 28.5	140/55.0 ± 100.4	95/46.0 ± 36.8	0.170

procedure. The available literature also supports this theory. This observation was particularly evident in patients with super obesity (BMI > 60 kg/m^2) [23].

Literature indicates that an extended operating time can negatively affect perioperative outcomes [24]. DS had the longest operation duration among the four procedures analyzed. In addition to the technical complexity of the procedure and the health status of the patients, this may also explain the approximately negative intraoperative and postoperative outcomes of the procedure as well as the longer hospital stay than with other procedures. Considering this context, this factor should be considered when deciding whether or not to intervene. Nevertheless, it should not be decisive.

Our analysis revealed that DS achieved the highest BMI reduction and the highest rate of complete remission of SA among the procedures examined. However, the procedure's complications and conversion rate were more severe, and hospital stays were the longest compared with other bariatric revision procedures. This, together with the technical complexity of the intervention, is in our opinion the reason why the intervention is much less common as a RP compared to OLGB, Re-SG, and RYGB.

According to the frequency of its use, RYGB is regarded as an attractive, sufficient, and effective RP following SG in both our analysis and other works of literature [4, 25]. In addition, the procedure resulted in fewer perioperative adverse events and sufficient comorbidity remission compared to DS. Interestingly, RYGB had the lowest reduction in BMI 1 year after surgery. Nonetheless, this outcome should not be the sole deciding factor, particularly since our analysis does not include long-term outcomes.

Re-SG ranks third among the four procedures in terms of application frequency. The analysis is unable to ascertain the low rate of secondary SG utilization. Nonetheless, we hypothesize that reflux disease was the primary reason why the operation was not employed as a revision method. However, 1 year after the procedure, Re-SG attained a significant BMI reduction and complete remission of SA in approximately 30% of patients and arterial hypertension in 22% of patients. According to the literature, R-SG is recommended for patients with dilatation of the sleeve stomach or weight loss failure [26, 27]. In the presence of reflux disease, other procedures such as RYGB should be used [28]. A study contrasted the outcomes of RYGB

Table 7 Remission of comorbidities at 1-year follow-up

		Redo procedure								*p*-value
		RYGB		DS		OLGB		R-SG		
		n	%	*n*	%	*n*	%	*n*	%	
IDDM	Reduction	18	27.7	7	38.9	1	9.1	1	16.7	0.745
	Worsening	1	1.5	0	0	0	0	0	0	
	No change	15	23.1	0	0	3	27.3	2	33.3	
	Complete remission	27	41.5	10	55.6	7	63.6	3	50.0	
	NIDDM → IDDM	2	3.1	0	0	0	0	0	0	
	De novo	2	3.1	1	5.6	0	0	0	0	
NIDDM	Reduction	12	16.0	1	6.3	4	25.0	2	33.3	0.418
	Worsening	0	0	0	0	1	6.3	0	0	
	No change	15	20.0	3	18.8	3	18.8	0	0	
	Complete remission	45	60.0	12	75.0	8	50.0	4	66.7	
	IDDM → NIDDM	0	0	0	0	0	0	0	0	
	De novo	3	4.0	0	0	0	0	0	0	
Art. hypertension	Reduction	82	23.8	21	30.9	20	21.7	19	38.8	0.044
	Worsening	5	1.4	0	0	2	2.2	0	0	
	No change	139	40.3	25	36.8	53	57.6	18	36.7	
	Complete remission	113	32.8	20	29.4	15	16.3	11	22.4	
	De novo	6	1.7	2	2.9	2	2.2	1	2.0	
Sleep apnea	Reduction	41	33.6	9	31.0	9	25.0	4	40.0	<0.001
	Worsening	40	32.8	8	27.6	22	61.1	2	20.0	
	No change	0	0	0	0	0	0	0	0	
	Complete remission	41	33.6	12	41.4	5	13.9	3	30.0	
	De novo	0	0	0	0	0	0	1	10.0	
Reflux	Reduction	10	4.3	2	14.3	11	28.9	2	8.7	<0.001
	Worsening	31	13.4	2	14.3	3	7.9	6	26.1	
	No change	0	0	0	0	0	0	0	0	
	Complete remission	165	71.1	4	28.6	18	47.4	4	17.4	
	De novo	26	11.2	6	42.9	6	15.8	11	47.8	

and DS following SG. Two years after revision surgery, the results of the two procedures were nearly identical in terms of BMI reduction and both procedures resulted in adequate remission of comorbidities [29].

In comparison to Re-SG and DS, OLGB is the preferable revision technique following SG. One year after surgery, OLGB obtained better BMI reduction than RYGB and practically similar results to DS and SG and it demonstrated better remission of reflux disease than Re-SG and DS. In one study, the outcome of RYGB was compared with OLGB as a revision procedure after SG. In terms of reflux disease, RYGB had better results than OLGB. Regarding remission of comorbidities and weight loss, the two procedures had the same results about 5 years after surgery [28]. The same results were obtained in another study that compared the two procedures (RYGB and OLGB) 2 years after surgery [21]. Given these findings, the strategy appears promising as a method for SG revision. Since the method is relatively new and long-term data are inadequately available in comparison to RYGB and SG, we infer that it has not yet been widely adopted and firmly established. The findings of future studies in this area should be anticipated, as it is currently impossible to forecast their direction.

Limitation of our study: as the data come from a registered study, we cannot presume its accuracy. The available data were the only ones analyzed. In addition, the analysis results should not be used to decide for or against intervention because they only provide short-term results. Consequently, the long-term data may differ from the medium-term outcomes, which may lead to radically different conclusions regarding specific interventions.

Conclusion

Based on our analysis, all four RP achieve sufficient results in various categories and contribute to addressing the root cause of revision following a primary SG. RYGB is one of

the most prevalent revision methods, following SG. Due to the novel nature of OLGB, its use is not yet prevalent, even though the procedure provides adequate results in many categories following SG. Considering this, we anticipate the procedure to become more common over the next few years and it will be one of the most common bariatric procedures compared to RYGB and R-SG, including revision procedures. Re-SG, like the other procedures, reduces weight and comorbidities but is rarely performed after SG due to reflux disease, especially since the literature does not recommend it in the presence of these diseases. Compared to the other methods, DS had a greater effect on weight and specific comorbidities, but due to its technical complexity, it should only be performed by experienced surgeons in specialized centers, just like revision surgery in general.

Due to the short-term observation of affected individuals, it should be noted that the results of this analysis may differ from those reported in the available literature with long-term follow-up, particularly concerning the development of comorbidities. In case of ambiguity, the results from the existing literature should be considered alongside the results of our analysis to provide appropriate treatment to affected patients.

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Author Contribution Omar Thaher and Juan Fernando Mesa Daza: study concept, literature review, manuscript writing. Christine Stroh and Roland Croner: study concept, preparation of data for statistical analysis, revision of manuscript, final approval of the manuscript. All authors contributed to the article and approved the submitted version.

Declarations

Ethics Approval For this type of retrospective study, no formal consent was required. All data were gathered and analyzed in accordance with the privacy and ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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

Conflict of Interest The authors declare no competing interests.

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