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Remission of comorbidities, weight loss, and adverse events after Sleeve Gastrectomy and Roux-en-Y gastric bypass in patients with obesity

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Abstract

Background: Despite the extensive literature on the outcome and impact of Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) on comorbidities and weight loss, clear evidence is still lacking. Our study aims to compare the short- and long-term efficacy and safety of the two procedures in patients with obesity.

Methods: The primary endpoint of this retrospective registry study is to examine the adverse events after surgery, weight loss, and remission rate of comorbidities 12 months after surgery. Any result with a p-value of 5% corresponds to a significant outcome.

Results: 27,882 patients had completed a one-year follow-up. 14,399 patients after SG and 13,483 after RYGB. The overall rate of intraoperative and postoperative complications was not significantly different between the two groups (overall p>5%). The %EWL was 62.4% in the SG group vs. 69.2% in the RYGB group; p<0.001. BMI reduction and mean weight loss were significantly different between the two groups in favor of SG.

The RYGB group achieved significantly better remission of diabetes mellitus (T2DM; p<0.001), hypertension (28.8% vs. 23.5%; p < 0.001) and reflux 22.3% vs. 7.8%; p<0.001). Sleep apnea remission was similar between the two groups (10.2%; p<0.001).

Conclusion: SG and RYGB are effective methods in the treatment of obesity. RYGB achieved better results in terms of remission of comorbidities and %EWL. However, further studies are needed to investigate the sustainability of weight loss and remission of comorbidities after both procedures.

Keywords: Sleeve gastrectomy; Gastric bypass; Morbidity and comorbidities; One-year follow-up.

1. Introduction

Despite the advanced health care and tremendous development in medicine, some diseases such as obesity and cardiopulmonary diseases still pose a medical challenge. This development leads to an additional burden on the health and economic system and the health damage and reduction in the quality of life of the affected patients [1; 2].

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Several studies have shown that bariatric surgery achieves more effective results in the remission of comorbidities than conservative therapy [3; 4]. However, diverse bariatric surgical methods differ significantly in the remission of comorbidities and perioperative outcomes [5; 6].

Our study aims to compare the effects of two well-known bariatric surgical procedures, namely sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB), on remission of comorbidities and perioperative outcomes.

Each of the two procedures has its advantages and disadvantages. Because of its technical simplicity and associated low complication rate, SG has quickly become one of the most popular bariatric surgical procedures in treating patients with obesity [7]. However, when bariatric surgical therapy aims to treat obesity-associated diseases, surgical methods such as RYGB showed better results than SG [8].

Despite the advantages of both surgical methods, to date, there is no direct recommendation in favor of either method regarding the development of comorbidities and long-term impact on weight loss. The indication remains controversial and needs further support from scientific studies and guidelines.

2. Material and methods

Our multicenter study included 54,984 patients with morbid obesity according to primary SG and RYGB. 27,882 patients had completed the one-year follow-up period with final data export in April 2021. The present study focused exclusively on perioperative outcomes and one-year follow-up results. The main inclusion criteria for the analysis population were:

- A minimum age of 18 years,
- a primary procedure using the RYGB or SG technique, and
- availability of data at the time of one-year follow-up.

All patients were examined and asked to consent to data entry into the GBSR preoperatively. Data collected included demographic data and preoperative and postoperative measurements. In addition, information on comorbidities was collected and documented preoperatively as well. We assumed that a patient suffered from diabetes mellitus (T2DM), hypertension, sleep apnea (SA), and reflux disease (GERD) if the patient had a documented preoperative diagnosis or was taking medications preoperatively for any of these conditions. After surgery, remission of T2DM was defined as normal or near-normal blood glucose levels and or discontinuation of hypoglycemic medications. Our analysis did not consider HbA1c level as a parameter for the remission of T2DM. Remission of hypertension was reported when patients had normal blood pressure after surgery or discontinuation of antihypertensive medication. This was also true for patients with reflux and sleep apnea. Intraoperative and postoperative complications were also recorded. During follow-up, patient data were calculated and documented in terms of percentage excess weight loss (%EWL), body mass index (BMI) reduction, and remission of comorbidities within the appropriate time.

With one exception, patients were selected for RYGB or SG treatment based on patient characteristics and weight center provider consensus. In addition, because this is a registry data collection, we cannot describe the surgical steps for RYGB and SG. It depends on the surgeon and their expertise as to which method to use during the procedure.

All analyzes were performed using SAS 9.4 software (SAS Institute Inc., Cary, NC, USA). Because this was an exploratory analysis, tests were intentionally performed at the full 5% significance level, i.e., there is no correction for multiple testing, and any p-value of 5% corresponds to a significant result.

The study was conducted following the recommendations of the Declaration of Helsinki for biomedical research. Before entering the data into the registry, all participants signed the informed consent form and consent.

2.1. Data preparation

Individual variables are not explicitly listed but must be derived from the data. These relate to:

- Comorbidities, intraoperative, general, and specific postoperative complications are recorded individually and combined into one variable, e.g., intraoperative complications are reported if at least one intraoperative complication is selected.
- Follow-up period: one year - considering a visit window of 182 to 547 days after surgery.
- BMI reduction: the difference between BMI at baseline and BMI at follow-up.

- %EWL: ratio of weight loss to excess weight as a percentage, where excess weight is defined as the difference between weight and ideal weight (based on height and BMI = 25) at baseline.

2.2. Descriptive statistics, univariates / unadjusted analyses

For the distributions of (quasi-) continuous variables, the mean and standard deviation (STD) or the range of dispersion for log-transformed data are given. For categorical variables, absolute (N) and relative (%) frequencies are reported.

For unadjusted analyzes of surgical interventions, the chi-square test was used for categorical variables and the robust t-test (Satterthwaite) for continuous variables.

3. Results

We analyzed data from 27,882 patients from January 2005 to April 2021 who completed a one-year follow-up after primary SG or RYGB. Over 98% of RYGB and SG procedures were performed laparoscopically (Table 1; 2).

Table 1 Distribution of surgical method at the time of primary surgery and at one-year follow-up

Method	At time of surgery		One-year follow-up	
	N	%	N	%
SG	27854	50.7	14399	51.6
RYGB	27130	49.3	13483	48.4
Total	54984	100	27882	100

Table 2 Type of surgery and operating time for patients who had completed the one-year follow-up

	Method				
	SG		RYGB		
	N	%	N	%	p-value
Laparotomy	89	0.6	112	0.8	0.035
Laparoscopy	14231	99.1	13294	98.7	
Conversion	46	0.3	58	0.4	
Operating time [min]* (mean [range of dispersion])	14356 / 78.9 [74.7; 83.0]		13473 / 102.1 [97.0; 107.2]		<0.001

* Logarithmic transformation: Illustration of the back-transformed mean values and ranges

The distribution of age showed significant results between the two groups. Sleeve gastrectomy patients were 0.4 years older than RYGB patients (43.7 ± 11.4 vs. 43.3 ± 11.2; p<0.001). Regarding gender, the proportion of females was significantly greater than the proportion of males in both groups (67.1% female vs. 32.9% male in the SG and 78.8% female vs. 21.2 male in the RYGB; p<0.001) (Table 3).

Table 3 Distribution of demographic variables at the time of surgery and at one-year follow-up

		Method		p-value
		SG	RYGB	
Age (years) (At time of surgery)	N/mean value ± STD	14399 / 43.7 ± 11.4	13483 / 43.3 ± 11.2	<0.001
BMI Kg/m^2 (At time of surgery)	N/mean value ± STD	14389 / 51.3 ± 9.1	13471 / 47.8 ± 7.0	<0.001
Gender (m/f)	%	32.9/67.1	21.2/78.8	<0.001
	(N)	4732/9667	2860/10623	
Mean weight loss, BMI reduction and %EWL at one-year follow-up				
%EWL	N/mean value ± STD	14362 / 62.4 ± 22.6	13445 / 69.2 ± 21.5	<0.001
BMI reduction (Kg/m^2)	N/mean value ± STD	14291 / 15.5 ± 5.9	13348 / 15.2 ± 5.0	<0.001
Mean weight loss (kg)	N/mean value ± STD	14365 / 45.6 ± 18.0	13451 / 43.6 ± 14.9	<0.001

3.1. Comorbidities

While ASA II was documented more frequently in the RYGB group, ASA III was more common in the SG group (p<0.001). The percentage distribution of comorbidities was significantly higher in the SG group than in the RYGB group (92% in the SG group vs. 89.7% in the RYGB group; p<0.001). More patients in the RYGB group suffered from T2DM than patients in the SG group (36.8% vs. 33.3%; p<0.001). This was also true for reflux disease (24% vs. 11%; p<0.001). In contrast, more patients in the SG group suffered from hypertension (63.9% vs. 60.3%; p<0.001) and sleep apnea (28.3% vs. 21.8%; p<0.001). A detailed overview of comorbidities can be found in Table 4.

Table 4 Distribution of comorbidities

		Method				p-value
		SG		RYGB		
		N	%	N	%	
ASA	ASA I	585	4.1	267	2.0	<0.001
	ASA II	5952	41.4	7235	53.8	
	ASA III	7525	52.3	5814	43.2	
	ASA IV	314	2.2	140	1.0	
Comorbidities (total)	Yes	13244	92.0	12089	89.7	<0.001
	No	1155	8.0	1394	10.3	
T2DM (total)	Yes	4427	33.3	4635	36.8	<0.001
	No	8864	66.7	7966	63.2	
T2DM (IDDM)	Yes	1410	10.6	1465	11.6	0.009
	No	11881	89.4	11136	88.4	
T2DM (NIDDM)	Yes	2406	18.1	2575	20.4	<0.001
	No	10885	81.9	10026	79.6	
T2DM (dietary)	Yes	611	4.6	595	4.7	0.634

	No	12680	95.4	12006	95.3	
Arterial hypertension	Yes	9206	63.9	8127	60.3	<0.001
	No	5193	36.1	5356	39.7	
Pulmonary	Yes	2975	20.7	2481	18.4	<0.001
	No	11424	79.3	11002	81.6	
Pulmonary embolism	Yes	166	1.2	88	0.7	<0.001
	No	14233	98.8	13395	99.3	
Other cardiac and vascular diseases (OCVD)	Yes	1562	10.8	1064	7.9	<0.001
	No	12837	89.2	12419	92.1	
Cholecystolithiasis	Yes	530	3.7	561	4.2	0.039
	No	13869	96.3	12922	95.8	
Reflux	Yes	1590	11.0	3233	24.0	<0.001
	No	12809	89.0	10250	76.0	
Lymphedema	Yes	891	6.2	961	7.1	0.002
	No	13508	93.8	12522	92.9	
Degenerative diseases of the skeletal system (DSD)	Yes	6894	47.9	5269	39.1	<0.001
	No	7505	52.1	8214	60.9	
Orthopedic therapy	Yes	3978	27.6	2946	21.8	<0.001
	No	10421	72.4	10537	78.2	
Degenerative spine diseases	Yes	5163	35.9	4765	35.3	0.369
	No	9236	64.1	8718	64.7	
Gonarthrose	Yes	3500	24.3	3103	23.0	0.011
	No	10899	75.7	10380	77.0	
Coxarthrose	Yes	902	6.3	849	6.3	0.911
	No	13497	93.7	12634	93.7	
Smoking	Yes	1380	9.6	1548	11.5	<0.001
	No	13019	90.4	11935	88.5	
Varicoses	Yes	775	5.4	1025	7.6	<0.001
	No	13624	94.6	12458	92.4	
Non-Alcoholic Steatohepatitis (NASH)	Yes	599	5.4	780	8.2	<0.001
	No	10594	94.6	8757	91.8	
Alcohol	Yes	193	1.3	136	1.0	0.010
	No	14206	98.7	13347	99.0	
Pseudotumor Cerebri	Yes	33	0.3	23	0.2	0.458
	No	11160	99.7	9514	99.8	
Rheumatoid inflammatory diseases (RID)	Yes	153	1.4	97	1.0	0.021
	No	11039	98.6	9440	99.0	
Polycystic ovary syndrome (PCOS)	Yes	174	2.3	175	2.3	0.919

	No	7391	97.7	7352	97.7	
Chronic inflammatory gastrointestinal diseases (CIGD)	Yes	49	0.4	8	<0.1	<0.001
	No	11143	99.6	9530	>99.9	
Hypogonadism	Yes	25	0.7	17	0.8	0.513
	No	3602	99.3	1993	99.2	
Transplantation	Yes	16	0.1	5	<0.1	0.041
	No	11176	99.9	9532	>99.9	
Sleep apnea	Yes	4070	28.3	2939	21.8	<0.001
	No	10329	71.7	10544	78.2	

3.2. Adverse Events

Evaluation of the overall intraoperative complication rate showed no significant difference between SG and RYGB (p=0.686). At least one intraoperative complication occurred in 200 patients after SG and 195 after RYGB. Analysis of individual complications showed significant results regarding splenic injury with a higher incidence in the SG group (0.3% in the SG group vs. 0.1% in the RYGB group; p=0.002). Other individual complications analyzed were not significantly different between the two groups (overall p>5%).

Comparison of the total postoperative general and specific complication rates also showed no significant difference between the two groups (p=0.139 and 0.169, respectively). However, analysis of individual postoperative complications showed different results between the two groups. While bleeding requiring surgical intervention, abscess formation, and sepsis were more common after SG, bleeding requiring endoscopic intervention, anastomotic stenosis, and the occurrence of ileus were reported more frequently after RYGB (p<0.001). A summary of intraoperative, general, and specific postoperative complications can be found in Tables 5 and 6.

Table 5 Intraoperative complications reported for Sleeve Gastrectomy and Roux-en-Y Gastric Bypass

		Method				**p-value**
		SG		**RYGB**		
		N	**%**	**N**	**%**	
Intraoperative complication (total)	Yes	200	1.4	195	1.4	0.686
	No	14199	98.6	13288	98.6	
Injury of splenic	Yes	43	0.3	17	0.1	0.002
	No	14356	99.7	13466	99.9	
Injury of liver	Yes	14	<0.1	4	<0.1	0.026
	No	14385	>99.9	13479	>99.9	
Pneumothorax	Yes	4	<0.1	0	0	0.053
	No	14395	>99.9	13483	100	
Perforation of the stomach	Yes	10	<0.1	5	<0.1	0.244
	No	14389	>99.9	13478	>99.9	
Bile duct injury	Yes	1	<0.1	1	<0.1	0.963
	No	14398	>99.9	13482	>99.9	
Vascular injury	Yes	7	<0.1	5	<0.1	0.643
	No	14392	>99.9	13478	>99.9	

Bleeding	Yes	5	<0.1	2	<0.1	0.295
	No	14394	>99.9	13481	>99.9	
Other	Yes	137	1.0	168	1.2	0.018
	No	14262	99.0	13315	98.8	

Table 6 General and special postoperative complications reported for Sleeve Gastrectomy and Roux-en-Y Gastric Bypass

		Method				**p-value**
		SG		**RYGB**		
		N	**%**	**N**	**%**	
General postoperative complication						
Total	Yes	580	4.0	497	3.7	0.139
	No	13819	96.0	12986	96.3	
Urinary tract infection	Yes	101	0.7	60	0.4	0.005
	No	14298	99.3	13423	99.6	
Cardiac complication	Yes	50	0.3	43	0.3	0.682
	No	14349	99.7	13440	99.7	
Renal complication	Yes	30	0.2	20	0.1	0.237
	No	14369	99.8	13463	99.9	
Pulmonary complication	Yes	97	0.7	67	0.5	0.054
	No	14302	99.3	13416	99.5	
Fever	Yes	104	0.7	99	0.7	0.906
	No	14295	99.3	13384	99.3	
Thrombosis	Yes	14	<0.1	2	<0.1	0.004
	No	14385	>99.9	13481	>99.9	
Other	Yes	314	2.2	282	2.1	0.607
	No	14085	97.8	13201	97.9	
Special postoperative complication						
Total	Yes	490	3.4	500	3.7	0.169
	No	13909	96.6	12983	96.3	
Bleeding requiring transfusion	Yes	100	0.7	88	0.7	0.670
	No	14299	99.3	13395	99.3	
Bleeding requiring surgery	Yes	175	1.2	92	0.7	<0.001
	No	14224	98.8	13391	99.3	
Bleeding requiring endoscopy	Yes	50	0.3	85	0.6	<0.001
	No	14349	99.7	13398	99.4	
Staple line and anastomosis leak	Yes	125	0.9	142	1.1	0.113

	No	14274	99.1	13341	98.9	
Stenosis	Yes	7	<0.1	53	0.4	<0.001
	No	14392	>99.9	13430	99.6	
Ileus	Yes	4	<0.1	38	0.3	<0.001
	No	14395	>99.9	13445	99.7	
Abscess formation	Yes	69	0.5	40	0.3	0.015
	No	14330	99.5	13443	99.7	
Sepsis	Yes	35	0.2	16	0.1	0.015
	No	14364	99.8	13467	99.9	
Peritonitis	Yes	51	0.4	53	0.4	0.594
	No	14348	99.6	13430	99.6	
Wound infection	Yes	80	0.6	76	0.6	0.928
	No	14319	99.4	13407	99.4	

3.3. BMI, weight loss, and %EWL

There was a significant difference in mean BMI at baseline between the two groups. Thus, SG patients had a significantly higher BMI (51.3 ± 9.1 kg/m2 vs. 47.8 ± 7.0 in the RYGB group; p<0.001). At a one-year follow-up, the mean BMI reduction was 15.5 ± 5.9 kg/m2 in the SG group and 15.2 ± 5.0 kg/m2 in the RYGB group (p<0.001). This was also true for mean weight loss with a significantly higher reduction in favor of the SG group (45.6 kg vs. 43.6 kg; p<0.001). However, %EWL was significantly higher in the RYGB group than in the SG group (69.2% vs. 62.4%; p<0.001). Table 3 summarizes the distribution of demographic variables and the change in BMI, mean weight loss, and %EWL at one-year follow-up.

3.4. Remission on comorbidities

3.4.1. Diabetes mellitus type II (T2DM)

At baseline, 4,427 (33.3%) patients in the SG group and 4,635 (36.8%) patients in the RYGB group suffered from T2DM. After one year of follow-up, 7.1% in the RYGB group and 5.9% in the SG group showed complete remission of insulin-dependent diabetes mellitus (IDDM; p<0.001). No change in symptoms and medication adherence was seen in 4.6% in the RYGB group and 4.8% in the SG group. De novo of IDDM symptoms was more frequent in the RYGB group than in the SG group (0.8% vs. 0.6%).

As for non-insulin-dependent diabetes mellitus (NIDDM), there was also a significant difference between the two groups with a higher rate of complete remission after RYGB compared to SG (16.1% vs. 12.8%; p<0.001). No change in NIDDM was found more frequently in the SG group than in the RYGB group (5.3% vs. 4.3%). In the present study, changes in blood glucose levels and required medication (insulin) during the one-year follow-up period were considered changes in T2DM. Table 7 presents the remission and change of IDDM and NIDDM according to SG and RYGB after one year.

3.4.2. Hypertension

9,206 patients (63.9%) in the SG group and 8,127 (60.3%) in the RYGB group were taking antihypertensive medication at baseline. With a p-value of <0.001, a significant change in the rate of hypertension was observed after one year. 23.5% of patients in the SG group and 28.8% in the RYGB group had complete remission of hypertension at one year (p<0.001). No change (40.4% vs. 31.5%) and new development of comorbidities (1%% vs. 0.8%) were noted more frequently after SG than after RYGB (Table 7).

3.4.3. Sleep apnea (SA)

Sleep apnea was more frequent in the SG group than in the RYGB group at the time of surgery. After one-year, complete remission of sleep apnea was the same in both groups (10.2%; p<0.001). However, no change in symptoms was noted

more frequently after SG than after RYGB (18.1% after SG vs. 11.6% after RYGB). This was also true for the recurrence of comorbidities (0.8% after SG vs. 0.6% after RYGB). The detailed results of sleep apnea remission are summarized in Table 7.

3.4.4. Gastroesophageal reflux (GERD)

At the time of surgery, more patients (24%) in the RYGB group had gastroesophageal reflux disease (GERD) than in the SG one (11%). This distribution also held for the complete remission of symptoms one year after surgery (22.3% in the RYGB group versus 7.8% in the SG group; p<0.001). In addition, more patients reported de novo symptoms after SG compared with RYGB (15.6% vs. 3%), and no change in GERD symptoms was noted in 3.2% of patients after SG compared with 1.7% after RYGB (Table 7).

Table 7 Change in comorbidities at one-year follow-up

Remission on obesity-associated diseases		**Method**				**p-value**
		SG		**RYGB**		
		N	%	N	%	
IDDM	Complete remission	778	5.9	890	7.1	<0.001
	De novo development of comorbidity	81	0.6	95	0.8	
	No change	632	4.8	575	4.6	
	No comorbidities before and after surgery	11791	88.8	11031	87.6	
NIDDM	Complete remission	1696	12.8	2026	16.1	<0.001
	De novo development of comorbidity	39	0.3	43	0.3	
	No change	709	5.3	546	4.3	
	No comorbidities before and after surgery	10838	81.6	9976	79.2	
Hypertension	Complete remission	3383	23.5	3874	28.8	<0.001
	De novo development of comorbidity	140	1.0	108	0.8	
	No change	5815	40.4	4247	31.5	
	No comorbidities before and after surgery	5052	35.1	5244	38.9	
Sleep apnea	Complete remission	1469	10.2	1378	10.2	<0.001
	De novo development of comorbidity	120	0.8	85	0.6	
	No change	2601	18.1	1558	11.6	
	No comorbidities before and after surgery	10200	70.9	10452	77.6	
Reflux	Complete remission	1119	7.8	3005	22.3	<0.001
	De novo development of comorbidity	2243	15.6	409	3.0	
	No change	467	3.2	226	1.7	
	No comorbidities before and after surgery	10561	73.4	9833	73.0	

4. Discussion

Obesity is a global problem with adverse effects on health and the economic system [9]. In affected patients, obesity leads to exacerbation of certain diseases such as diabetes mellitus (T2DM), hypertension, reflux, sleep apnea, and deterioration of patients' quality of life [10]. Moreover, the prevalence of the disease has increased tremendously in recent years, especially in young people and children [11]. According to statistical analyses, the number of people with

obesity is expected to increase in the coming years [12]. This increase is due to our modern lifestyle, poor eating habits and lack of exercise.

In addition to the well-known conservative therapeutic measures, which should be exhausted as the first therapeutic option, several surgical methods offer suitable treatment for obesity. However, these vary widely in terms of difficulty and postoperative outcome, and the impact of obesity-related diseases. While many procedures, such as SG, have a simple technical complexity, other surgical methods, such as RYGB, involve a high technical complexity. Nevertheless, the technical complexity of a procedure is not considered the only determining factor in the indication. Instead, long-term therapeutic goals are critical in determining how a patient should be operated on.

Different distributions of demographic variants were found between the two groups, but their impact on the study results was not considered in the analysis. Primarily, the study aims to compare the outcomes of two surgical procedures, namely SG and RYGB, in patients with obesity and to highlight the differences in perioperative outcomes and remission of comorbidities.

The overall distribution of comorbidities was significantly higher in patients in the SG group than in the RYGB group, although the distribution of individual comorbidities, such as T2DM, hypertension, sleep apnea, and reflux differed in the two groups. The distribution of individual intraoperative and postoperative complications showed different distribution patterns between the two groups, although the overall complication rate was not significantly different for both intraoperative and postoperative complications. Our results are comparable with those of other international studies. In the study by Montgomery et al. [13], the same results were shown regarding the overall rate of intraoperative and postoperative complications. This is also true for the study by Topart et al. [14] and the randomized trial by Helmiö et al. [15]. However, other studies have shown fewer complications after SG than after RYGB [16; 17]. The difference between studies in this regard may be the demographic quality of the patients and the technical complexity of RYGB compared with SG. It should be noted that the differences between the two groups are not that far apart, making the occurrence of complications not a determining factor for the indication. The goal of the procedure, and in particular the long-term goal, is more important than consideration of short-term outcomes when determining indications.

The outcome in terms of BMI reduction and %EWL was significantly different between the two groups. In general, based on our study and other studies, a consistent conclusion could be drawn regarding better %EWL after RYGB than after SG. In the study by Zilberstein et al. [18], the %EWL 5 years after surgery was significantly different at 71.04% after RYGB and 52.7% after SG. One year after surgery, Lee et al. [19] showed a significant difference in %EWL in favor of RYGB (41.4±11.6% after RYGB vs. 26.7±27.6% after SG). BMI reduction was significantly higher one year after surgery after SG than after RYGB. In our study, %EWL after RYGB was significantly higher one year after surgery than after SG. BMI reduction and mean weight loss were significantly different between the two groups in favor of SG. However, the difference between the two groups was not extremely high, so these results should not be strongly perceived as a recommendation in favor of SG.

Several studies compare RYGB and SG in terms of remission of T2DM. In our study, RYGB showed superiority over SG in T2DM remission, which may have been influenced by better %EWL. However, the results are contradictory, as some studies show similar results or no significant difference between the two procedures in this regard [20]. The randomized trial by Salminen et al. [21] tended to show better remission of T2DM after RYGB (45%) than after SG (37%), but without significant effect. The same results were shown in a meta-analysis of 21 studies with no statistically significant difference between the two groups regarding remission of diabetes mellitus 0.5 to 1.5 years after intervention [22]. In our study, remission of both IDDM and NIDDM was more frequent after RYGB than after SG. In addition, more patients in SG showed no change in disease compared with patients in the RYGB group. The different results of existing studies regarding the postoperative evolution of T2DM depend on several factors, such as disease severity, weight loss after bariatric surgery, and the quality of patients enrolled in the study.

Some systematic review studies and studies with longer follow-up comparing SG with RYGB have shown significant remission of hypertension after RYGB and SG during the first 12 months [23]. However, when comparing the two methods, a more significant remission of hypertension was demonstrated after RYGB than after SG [24]. This is also true for the results of our study. Patients in both groups also experienced remission of hypertension, especially those in the RYGB group. Various scientific studies have shown that remission of hypertension depends not only on the surgical method but also on other factors such as postoperative weight loss, the level of preoperative antihypertensive medication, and the severity of the disease [25; 26].

In several studies, remission and improvement of sleep apnea were more pronounced after bariatric surgery than with conservative therapeutic measures [27; 28]. However, the results of all studies of reduction and elimination of sleep

apnea after bariatric surgery vary because of the characteristics of symptoms, duration of follow-up, and diagnostic procedures [29]. Zilberstein et al. [18] showed improvement in sleep apnea after various bariatric surgery methods. However, RYGB was more effective in improving SA than restrictive procedures, such as SG and gastric banding. These results are also consistent with the results of the study by Sakhosh et al. [30].

In contrast to the previous study results, our study showed similar remission rates of sleep apnea after the two procedures. However, we believe our results are due to the short duration of follow-up. Studies with more extended follow-up periods should be performed to detect a significant difference between the two groups.

According to clinical studies, a higher incidence of GERD was observed in patients with obesity than in normal-weight patients [31]. Therefore, several surgical procedures have been developed and changed to prevent the development or exacerbation of reflux disease in the long term. RYGB has been reported in the literature to relieve GERD symptoms, and some bariatric procedures were eventually converted to RYGB for refractory reflux symptoms [32]. In addition, some studies report a higher risk of GERD after this surgical intervention compared with RYGB [33]. A randomized trial by Peterli et al. showed a significant worsening of reflux disease after SG than after RYGB (31.8% vs. 6.3%) [34]. Another study by Barr et al. [35] showed that more acid-reducing medications had to be taken 12 months after SG than after RYGB. The results of our study are consistent with the results of the previously mentioned studies. At 12 months after surgery, recurrence of reflux disease was observed in 15.6% of patients after SG and in 3% after RYGB. Remission of the disease was observed more frequently after RYGB than after SG. Based on our analysis and the literature results, if reflux disease is present and bariatric surgery is needed, the decision should be made in favor of RYGB surgery over SG.

5. Conclusion

The efficacy of bariatric surgery in comorbidities and weight in patients with obesity compared with conservative treatment options has been demonstrated and well documented in several clinical trials. When differentiating the efficacy of each surgical procedure, RYGB consistently has a better outcome in terms of %EWL, remission rates of diabetes mellitus, hypertension, and reflux.

However, despite the existing studies, there are heterogeneous opinions worldwide about the outcome after the two surgical procedures, as also mentioned in our study. In addition, there is still no clear evidence on which of the two methods is suitable for which patient group. The decision still depends on the quality of the patient, the intended goal of the surgery, and the surgeons' skills.

In conclusion, our study shows that both methods are effective in improving comorbidities and reducing BMI, especially compared with conventional medical treatment. However, RYGB has an advantage over SG, especially when considering the long-term outcomes of the two procedures. Our results may perhaps help establish indications. However, it should be noted that further studies with more extended follow-up periods are under consideration and that the decision on how to proceed should be individualized and depends on the patient's medical history. In addition, interdisciplinary decision-making, patient care, and careful education about the advantages and disadvantages of the two surgical procedures are essential for better outcomes and higher patient satisfaction.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

Martin Hukauf was employed by the company StatConsult GmbH, Magdeburg. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Statement of ethical 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.

Statement of informed consent

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

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