Research Square

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Five-Year Outcomes of Laparoscopic Sleeve Gastrectomy and Roux-en-Y Gastric Bypass: A Comparative Study of Weight Loss and Nutritional Deficiencies

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Abstract

Introduction:

Sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) are the two most commonly performed metabolic and bariatric surgery (MBS) procedures worldwide, yet routine clinical practice long-term comparative data remain limited, particularly regarding gastroesophageal reflux disease (GERD), postoperative morbidity, and nutritional deficiencies.

Methods

We performed a retrospective observational cohort study including 860 consecutive adults undergoing primary laparoscopic SG (n = 502) or RYGB (n = 358) between 2014 and 2020 at a certified bariatric center. Outcomes were assessed at baseline and 3, 6, 12, 24, 36, 48, and 60 months. Longitudinal BMI, %EWL, and %TWL were analyzed using generalized linear mixed models; repeated binary outcomes were analyzed using generalized estimating equations.

Results

RYGB achieved greater long-term weight loss and lower BMI throughout follow-up (60 months: %EWL 84.0 ± 30.0 vs. 70.2 ± 26.9; %TWL 30.1 ± 10.3 vs. 26.8 ± 9.4). Clinical GERD was more prevalent after SG (60 months: 49.3% vs 29.9%); among individuals with baseline GERD, RYGB achieved higher GERD remission rates at 12 months (70.0% vs 21.9%). Major complications (Clavien–Dindo ≥ III) and readmissions were more frequent after RYGB (7.3% vs 1.8%; and 14.5% vs 6.7% within 12 months). SG was associated with higher rates of folate and vitamin D deficiency during the first two years.

Conclusion

At five years, RYGB provides superior weight-loss durability and more effective GERD control compared with SG, with an associated increase in major morbidity and readmission rates. SG remains an effective procedure but requires close long-term monitoring for reflux progression and specific micronutrient deficiencies.

Key Points

• RYGB achieved greater 5-year weight loss than SG.

• Clinical GERD was more prevalent after SG; remission favored RYGB.

• Major complications and readmissions were higher after RYGB.

• Nutritional deficiencies differed and improved with supplementation.

Introduction

Obesity is a chronic, relapsing disease associated with substantial cardiometabolic morbidity and premature mortality [1, 2]. Metabolic and bariatric surgery (MBS) remains the most effective long-term treatment for severe obesity, providing durable weight loss and improvement or remission of obesity-related comorbidities [3]. Sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) are the most frequently performed procedures worldwide [4]. Randomized trials and meta-analyses suggest a modest long-term advantage of RYGB for weight loss and control of gastroesophageal reflux disease (GERD), at the cost of higher procedure-related morbidity, but real-world long-term comparative data with systematic nutritional assessment remain limited [5, 6, 7].

We therefore assessed five-year outcomes after SG and RYGB in a large, real-world monocentric cohort. The primary objective was to compare longitudinal weight-loss trajectories up to 60 months (BMI, %EWL, and %TWL). Secondary objectives were to compare comorbidity remission, GERD prevalence and remission, major postoperative complications, readmissions, and nutritional deficiencies.

Materials and Methods

Study Design and Patients

This retrospective observational cohort study included all consecutive adults undergoing primary laparoscopic SG or RYGB between January 2014 and December 2020 in a certified bariatric center with a standardized multidisciplinary pathway. Eligibility followed national recommendations (BMI ≥ 40 kg/m², or BMI ≥ 35 kg/m² associated with at least one obesity-related comorbidity, including T2DM, hypertension requiring at least three antihypertensive agents, or OSAS. Exclusion criteria were age < 18 years, prior bariatric surgery, severe psychiatric contraindication, or missing baseline clinical data. All patients underwent standardized preoperative

evaluation including nutritional, psychological, anesthetic, and endoscopic assessments, with systematic screening and eradication of Helicobacter pylori when present.

Procedure allocation was determined through multidisciplinary decision-making reflecting routine clinical practice. In general, patients with higher metabolic burden (including T2DM, hypertension, dyslipidemia, Metabolic Dysfunction-Associated Steatotic Liver Disease (MASLD), or OSAS) and those with pre-existing GERD or endoscopic esophagitis were more often considered for RYGB.

Because allocation was not randomized, baseline differences between groups were expected and reflect usual care. Accordingly, all longitudinal analyses modeled the procedure-by-time interaction while accounting for within-patient correlation, to compare outcome trajectories over time using all available measurements.

Follow-up visits were scheduled at prespecified time points within a standardized pathway. Follow-up completeness decreased over time, particularly after SG. Mixed-effects and generalized estimating equation approaches permitted inclusion of patients with incomplete follow-up, mitigating the impact of unbalanced follow-up duration between procedures, while acknowledging potential attrition bias.

Surgical Techniques

SG consisted of longitudinal gastrectomy over a 40-Fr bougie starting at 5 cm from the pylorus, with complete greater-curvature mobilization to the angle of His; staple-line reinforcement was at surgeon discretion. RYGB included a small gastric pouch, antecolic antegastric gastrojejunostomy, biliopancreatic limb 60 cm, alimentary limb 150 cm, side-to-side jejunojejunostomy, and closure of mesenteric defects according to institutional practice. Operative steps and limb lengths were standardized and performed by experienced bariatric surgeons.

Follow-Up, Outcomes, and Definitions

Patients were scheduled at 3, 6, 12, 24, 36, 48, and 60 months. Weight-loss outcomes were BMI, percent excess weight loss (%EWL), and percent total weight loss (%TWL). Clinical GERD was defined as reflux symptoms with regular proton pump inhibitor (PPI) use and/or documented reflux symptoms at visits; GERD remission was absence of symptoms without PPI therapy. Remission of T2DM followed the ADA consensus definition (HbA1c $< 6.5\%$ without antidiabetic medication) [8]. Hypertension remission was defined as discontinuation of all antihypertensive medications; OSAS remission as discontinuation of CPAP therapy.

Postoperative complications were graded using the Clavien–Dindo classification [9]; major complications were grade III or higher. Laboratory monitoring included ferritin, vitamin B12, folate (vitamin B9), vitamin D, calcium, phosphorus, albumin, and parathyroid hormone (PTH). Deficiencies were defined according to institutional laboratory thresholds. Patients were prescribed procedure-adapted multivitamin supplementation with additional nutrients guided by biochemical monitoring.

Statistical Analysis

Continuous variables are presented as mean ± SD and categorical variables as n (%). Longitudinal BMI, %EWL, and %TWL were analyzed using generalized linear mixed models including time, procedure type, and their interaction. Repeated binary outcomes (remission, GERD, readmissions, and deficiencies) were analyzed using generalized estimating equations with a logistic link function. Statistical significance was defined as two-sided $p < 0.05$. Reporting follows STROBE recommendation for observational studies. Models were specified with fixed effects for time, procedure, and their interaction, and random intercepts for participants as appropriate. For binary outcomes, GEE models used a logistic link with robust standard errors to account for repeated measures.

Results

Cohort and Baseline Characteristics

A total of 860 patients were included (SG, n = 502; RYGB, n = 358). Baseline characteristics differed between groups (Table 1). SG patients were younger (40.1 ± 13.1 vs 47.6 ± 11.4 years), more frequently male, and had slightly higher baseline BMI (41.2 ± 4.6 vs 40.2 ± 3.8 kg/m□). Baseline T2DM (31.7% vs 48.6%), hypertension (36.1% vs 51.4%), and clinical GERD (9.4% vs 35.5%) were more prevalent in the RYGB group. Follow-up to 60 months was reached more frequently after RYGB (47.2% vs 16.7%).

Table 1
Baseline characteristics

Variable	SG (n = 502)	RYGB (n = 358)	p-value
Sex, No (%)			< 0.0001
Women	304 (60.6%)	270 (75.4%)	
Men	198 (39.4%)	88 (24.6%)	
Age, mean (SD), y	40.1 (13.1)	47.6 (11.4)	< 0.0001
BMI, mean (SD)	41.2 (4.6)	40.2 (3.8)	0.0006
Type 2 diabetes, No. (%)	159 (31.7)	174 (48.6)	< 0.0001
Hypertension, No. (%)	181 (36.1)	184 (51.4)	< 0.0001
Baseline clinical GERD, No. (%)	47 (9.4)	127 (35.5)	< 0.0001

Weight Loss

Both procedures produced rapid early weight loss (Tables 2–4; Fig. 1–3). Across all time points, BMI was lower after RYGB than SG ($p < 0.05$). At 60 months, mean BMI was 27.6 ± 4.52 after RYGB vs 30.4 ± 4.91 after SG. At 60 months, RYGB achieved higher %EWL (84.0 ± 30.0 vs 70.2 ± 26.9) and higher %TWL (30.1 ± 10.3 vs 26.8 ± 9.35). Differences in %EWL were significant at all time points except at 6 months; differences in %TWL were significant from 12 months onward.

Figure 1 BMI from baseline to 60 months after SG and RYGB. Values are shown as means with 95% confidence intervals. BMI was significantly lower after RYGB compared with SG at all postoperative time points ($p < 0.05$).

Table 2
Evolution of BMI over 60 months after SG and RYGB. Values are expressed as mean ± standard deviation.

Time (months)	SG – N	SG – BMI (kg/m²)	RYGB – N	RYGB – BMI (kg/m²)
0	502	41.2 ± 4.62	358	40.2 ± 3.80
3	444	33.3 ± 4.31	322	32.2 ± 3.58
6	281	29.7 ± 3.98	290	29.0 ± 3.61
12	358	27.5 ± 3.81	302	26.3 ± 3.75
24	252	27.9 ± 4.17	243	25.7 ± 3.57
36	160	28.7 ± 4.25	196	26.3 ± 4.02
48	103	29.6 ± 4.73	177	26.9 ± 4.37
60	72	30.4 ± 4.91	149	27.6 ± 4.52

Table 3
Evolution of %EWL over 60 months after SG and RYGB. Values are expressed as mean ± standard deviation.

Time (months)	SG – N	SG – %EWL	RYGB – N	RYGB – %EWL
3	444	50.9 ± 15.6	322	54.0 ± 15.6
6	281	73.1 ± 18.7	290	76.1 ± 20.0
12	358	86.9 ± 21.4	302	94.0 ± 24.3
24	252	85.0 ± 23.9	243	97.1 ± 23.4
36	160	79.2 ± 25.0	196	93.6 ± 25.5
48	103	74.7 ± 27.5	177	89.0 ± 29.4
60	72	70.2 ± 26.9	149	84.0 ± 30.0

Table 4
Evolution of %TWL over 60 months after SG and RYGB. Values are expressed as mean ± standard deviation.

Time (months)	SG – N	SG – %TWL	RYGB – N	RYGB – %TWL
3	444	19.2 ± 5.11	322	19.7 ± 4.87
6	281	27.4 ± 5.74	290	27.6 ± 5.86
12	358	33.0 ± 7.16	302	34.2 ± 7.62
24	252	32.6 ± 8.47	243	35.6 ± 8.22
36	160	30.0 ± 9.14	196	33.9 ± 8.85
48	103	28.5 ± 9.35	177	31.8 ± 9.89
60	72	26.8 ± 9.35	149	30.1 ± 10.3

Comorbidity Outcomes

T2DM remission increased during follow-up in both groups. At 12 months, remission was higher after SG than RYGB (71.2% vs 45.0%; $p = 0.0005$), but differences attenuated with longer follow-up and were not statistically significant beyond 12 months (Table 5). Hypertension remission did not differ significantly between procedures, and OSAS analyses were limited by smaller numbers with available longitudinal data.

Table 5
Remission of T2DM from 3 to 60 months after SG and RYGB. Data are presented as number (percentage) with 95% confidence intervals.

Time (months)	SG – N	SG – T2DM remission, n (%)	95% CI	RYGB – N	RYGB – T2DM remission, n (%)	95% CI
3	101	30 (29.7)	21.0–39.6	126	27 (21.4)	14.6–29.6
6	57	30 (52.6)	39.0–66.0	110	36 (32.7)	24.1–42.3
12	73	52 (71.2)	59.4–81.2	111	50 (45.0)	35.6–54.8
24	44	32 (72.7)	57.2–85.0	87	49 (56.3)	45.3–66.9
36	41	33 (80.5)	65.1–91.2	73	34 (46.6)	34.8–58.6
48	28	19 (67.9)	47.6–84.1	76	38 (50.0)	38.3–61.7
60	27	18 (66.7)	46.0–83.5	57	24 (42.1)	29.1–55.9

GERD

Despite higher baseline GERD prevalence in the RYGB group, postoperative clinical GERD was consistently more prevalent after SG (Table 6). At 12 months, GERD prevalence was 32.9% after SG vs 18.6% after RYGB ($p < 0.0001$) and increased over time after SG, reaching 49.3% at 60 months. In contrast, GERD prevalence remained comparatively stable after RYGB (29.9% at 60 months). Among patients with baseline GERD, remission at 12 months favored RYGB (70.0% vs 21.9%; $p < 0.0001$).

Table 6
Prevalence of clinical GERD from baseline to 60 months after SG and RYGB. Data are presented as number (percentage) with 95% confidence intervals. GERD prevalence was consistently higher after SG than after RYGB during postoperative follow-up.

Time (months)	SG – N	SG – GERD, n (%)	95% CI	RYGB – N	RYGB – GERD, n (%)	95% CI
0	502	47 (9.4)	7.0–12.3	358	127 (35.5)	30.5–40.7
3	440	178 (40.5)	35.8–45.2	301	100 (33.2)	27.9–38.9
6	277	96 (34.7)	29.1–40.6	255	59 (23.1)	18.1–28.8
12	346	114 (32.9)	28.0–38.2	295	55 (18.6)	14.4–23.6
24	240	91 (37.9)	31.8–44.4	235	57 (24.3)	18.9–30.3
36	155	61 (39.4)	31.6–47.5	192	45 (23.4)	17.6–30.1
48	100	46 (46.0)	36.0–56.3	169	52 (30.8)	23.9–38.3
60	67	33 (49.3)	36.8–61.8	147	44 (29.9)	22.7–38.0

Complications, Conversion, and Readmissions

Major complications (Clavien–Dindo ≥ III) occurred more frequently after RYGB than SG (7.3% vs 1.8%; $p < 0.001$) (Table 7; Fig. 4), including one postoperative death in the RYGB group. No grade IIIa complications were recorded. Conversion to laparotomy occurred only after RYGB (1.4%), primarily due to extensive adhesiolysis related to prior non-bariatric surgery. Readmissions were more frequent after RYGB, including within 12 months (14.5% vs 6.7%; $p = 0.0010$) and 24 months (28.7% vs 15.0%; $p = 0.0002$).

Table 7
Distribution of postoperative complications according to the Clavien–Dindo classification after SG and RYGB. p-value refers to the comparison of overall complication grade distribution between groups.

Clavien–Dindo grade	SG (n = 502)	RYGB (n = 358)	p-value
No complication	467 (93.0%)	305 (85.2%)	
Grade I	25 (5.0%)	17 (4.7%)	
Grade II	1 (0.2%)	10 (2.8%)	
Grade IIIa	0 (0%)	0 (0%)	
Grade IIIb	6 (1.2%)	18 (5.0%)	
Grade IVa	3 (0.6%)	6 (1.7%)	
Grade IVb	0 (0%)	1 (0.3%)	
Grade V	0 (0%)	1 (0.3%)	
Overall			**0.0002**

Nutritional Deficiencies and Supplementation

Distinct deficiency patterns were observed, particularly within the first two years. Folate deficiency was more frequent after SG at 12 months (52.2% vs 8.1%) and 24 months (46.3% vs 4.7%) (both $p < 0.0001$). Vitamin D deficiency was also more prevalent after SG at 12 and 24 months (both $p < 0.0001$). Calcium deficiency tended to be more frequent after RYGB at 12 months (11.9% vs 7.1%; $p = 0.072$). Phosphorus deficiency was more frequent after SG at 24 months (6.8% vs 0.6%; $p = 0.0031$). Ferritin and vitamin B12 deficiencies showed comparable overall patterns between procedures.

Across procedures, reported multivitamin supplementation was associated with lower rates of several deficiencies at 12 and 24 months, particularly folate and vitamin D. At 60 months, folate deficiency (13.3% vs 69.2%; $p < 0.0001$) and ferritin deficiency (9.9% vs 35.7%; $p = 0.017$) remained less frequent among supplemented patients.

Discussion

RYGB was associated with greater and more durable weight loss than SG across longitudinal trajectories of BMI, %EWL, and %TWL. While these findings align with the trends reported in landmark randomized controlled trials such as SLEEVEPASS and SM-BOSS [5, 6], our cohort achieved remarkably high weight-loss success rates at five years. Specifically, the observed %EWL (84.0% for RYGB and 70.2% for SG) exceeds the 5-year results typically reported in these trials and recent meta-analyses [7]. This superior weight loss performance in a real-world setting underscores the effectiveness of our standardized multidisciplinary pathway and suggests that, in an optimized clinical environment, both procedures—and RYGB in particular—can achieve outcomes that surpass traditional benchmarks for long-term weight maintenance. Our findings extend this evidence to routine clinical practice, supporting the clinical relevance of procedure choice when long-term weight-loss durability is a major priority.

Beyond absolute values, the longitudinal patterns are clinically informative. SG showed an earlier weight nadir followed by progressive recurrent weight gain, whereas RYGB achieved a later nadir with greater long-term stability. These divergent trajectories may reflect differences in hormonal signaling, nutrient sensing, and adaptive metabolic responses. Procedure selection should therefore consider anticipated long-term weight stability rather than short-term weight loss alone.

GERD outcomes diverged substantially between procedures. Clinical GERD was consistently more prevalent after SG and increased over time, whereas GERD remained lower and more stable after RYGB, and remission among patients with baseline GERD strongly favored RYGB. These findings are consistent with established mechanisms: SG may exacerbate reflux through increased intragastric pressure, disruption of the angle of His and lower esophageal sphincter function, whereas RYGB diverts acid and bile away from the esophagus [10]. Clinically, our data support preferential consideration of RYGB in patients with pre-existing GERD or esophagitis.

The progressive increase in postoperative GERD after SG is notable and supports the concept that de novo or worsening reflux may emerge several years after surgery. This occurred despite systematic preoperative endoscopic assessment, suggesting that short-term reflux evaluations may underestimate long-term risk. Although GERD was assessed clinically, the magnitude and consistency of differences across time points favor a true procedure-related effect.

Early T2DM remission was higher after SG at 12 months, but differences attenuated thereafter. Given non-randomized allocation and the higher baseline metabolic burden in the RYGB group, this early difference likely reflects selection of younger patients with less advanced diabetes for SG rather than superior intrinsic metabolic efficacy. Accordingly, procedure selection should integrate baseline diabetes severity, treatment intensity, and broader cardiometabolic risk rather than early remission rates alone.

Nutritional deficiencies were common and procedure-specific. Despite preserved intestinal continuity, SG was associated with higher folate and vitamin D deficiency rates during the first two years. Even with preserved intestinal continuity, the reduced gastric acid secretion, altered dietary intake, and imperfect adherence to supplementation may contribute to these results [11]. Calcium deficiency tended to be more frequent after RYGB, consistent with bypass of primary calcium absorption sites and altered vitamin D metabolism [12]. Importantly, reported multivitamin supplementation was associated with lower prevalence of several deficiencies at mid- and long-term follow-up, emphasizing the central role of adherence and structured biochemical monitoring.

Notably, the high prevalence of nutritional deficiencies after SG challenges the perception of SG as nutritionally neutral over the long. These findings reinforce procedure-specific nutritional counseling and systematic long-term biochemical surveillance regardless of the perceived anatomic and absorptive alterations associated with the procedure.

As expected, RYGB carried higher major morbidity and readmissions. The greater anatomical complexity of RYGB exposes patients to procedure-specific complications, including internal hernia, anastomotic complications, and marginal ulcers, which may occur years after surgery [13]. Standardized closure of mesenteric defects and structured long-term surveillance for late complications remain essential components of care after RYGB. These trade-offs should be explicitly discussed during preoperative counseling, balancing superior reflux control and weight-loss durability against higher morbidity and resource use.

This study has several strengths, including a large consecutive cohort, standardized techniques within a multidisciplinary pathway, and longitudinal modeling of repeated outcomes. Limitations include the retrospective design with potential residual confounding, missing biochemical data at some time points, and differential follow-up with fewer SG patients reaching 60 months, raising the possibility of attrition bias. Procedure allocation in this real-world cohort likely reflected routine multidisciplinary practice and baseline comorbidity burden, rather than random assignment, introducing potential selection bias. In this context, use of a standardized decision-support tool such as the Metabolic Surgery Indication Score (MetSIS) could have supported a more objective alignment between patient metabolic risk and procedure choice [14]. Given the distinct profiles observed in our study such tools may help optimize individualized procedure selection. Quality of life (QoL), a key long-term outcome after bariatric surgery, was not assessed in this study. This represents an important limitation, as differences in GERD burden, nutritional deficiencies, and late complications observed between SG and RYGB are likely to translate into meaningful QoL differences over time. A validated composite framework such as the Bariatric Analysis and Reporting Outcome System (BAROS) [15], would have enabled a more patient-centered comparison. Complications were graded using Clavien–Dindo [9]; a composite metric such as the Comprehensive Complication Index could have provided a more granular assessment of overall morbidity [16]. GERD was assessed clinically using symptoms and PPI use without standardized questionnaires, systematic endoscopic grading, or functional testing. Erosive esophagitis and Barrett’s esophagus were not systematically captured, and no standardized postoperative endoscopic surveillance was implemented, despite increasing evidence supporting the importance of endoscopic follow-up after bariatric surgery [17]. Additionally, dyslipidemia and MASLD evolution were not systematically assessed, and quality of life was not measured.

Because follow-up was more complete after RYGB, attrition could have influenced long-term estimates if missingness was not at random. However, the consistency of directionality across outcomes and time points supports the robustness of the main conclusions. Future prospective studies incorporating standardized reflux phenotyping, endoscopic surveillance strategies, and patient-reported quality-of-life measures would provide a more patient-centered comparison.

Overall, SG and RYGB offer distinct long-term risk–benefit profiles. RYGB provides better weight-loss durability and GERD control, whereas SG offers lower major morbidity but requires heightened vigilance for reflux progression and selected nutritional deficiencies.

Conclusion

RYGB provided superior five-year weight-loss durability and GERD control compared with SG, at the cost of higher major complications and readmissions. SG remained effective with a more favorable surgical safety profile but was associated with higher long-term clinical GERD prevalence and higher rates of folate and vitamin D deficiency. These findings support individualized procedure selection integrating metabolic burden, reflux disease, nutritional risk, and the patient’s ability to engage in structured long-term follow-up.

Declarations

Ethics Approval

The study was approved by the institutional ethics committee; informed consent was waived due to the retrospective design.

Conflict of Interest

The authors declare no competing interests.

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Author Contribution

A.H. and J.G. wrote the main manuscript text. All authors reviewed the manuscript.

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Data Availability

Data are available from the corresponding author upon reasonable request and subject to institutional approvals and applicable data protection regulations.

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Figures

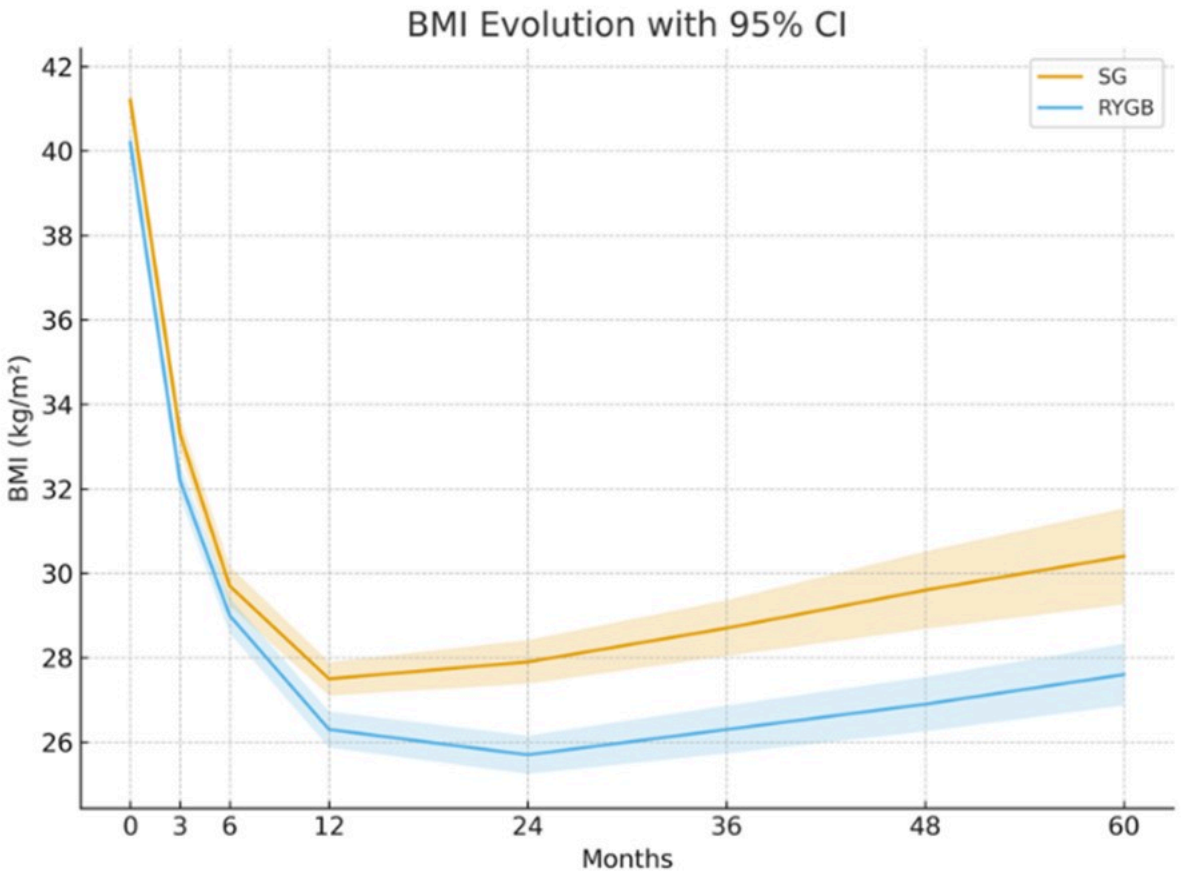


Figure 1

BMI from baseline to 60 months after SG and RYGB. Values are shown as means with 95% confidence intervals. BMI was significantly lower after RYGB compared with SG at all postoperative time points ($p < 0.05$).

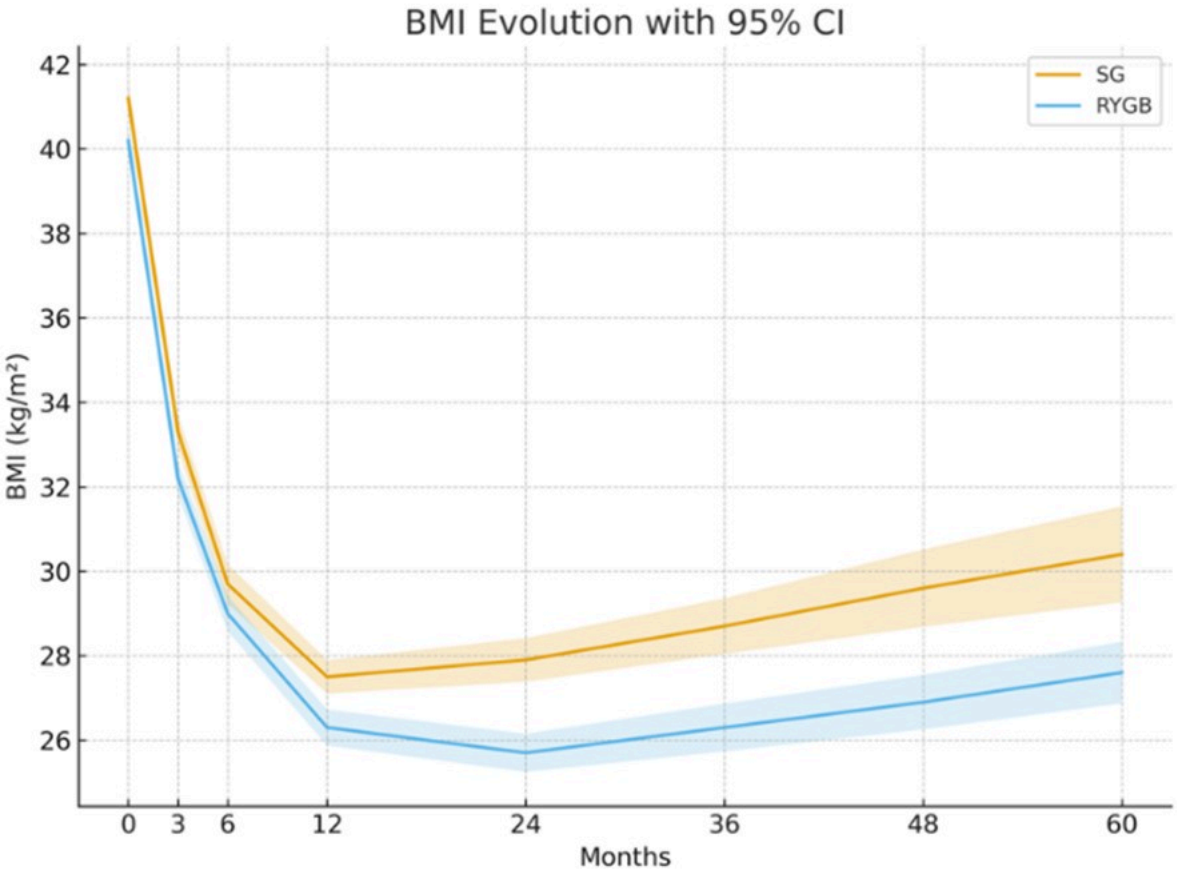


Figure 2

%EWL from 3 to 60 months after SG and RYGB. Values are shown as means with 95% confidence intervals. RYGB resulted in significantly greater %EWL at all time points except 6 months ($p < 0.05$).

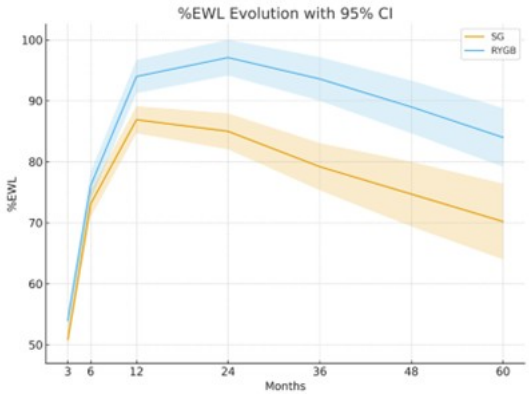


Figure 3

%TWL from 3 to 60 months after SG and RYGB. Values are shown as means with 95% confidence intervals. From 12 months onward, %TWL was significantly greater after RYGB compared with SG ($p < 0.05$).

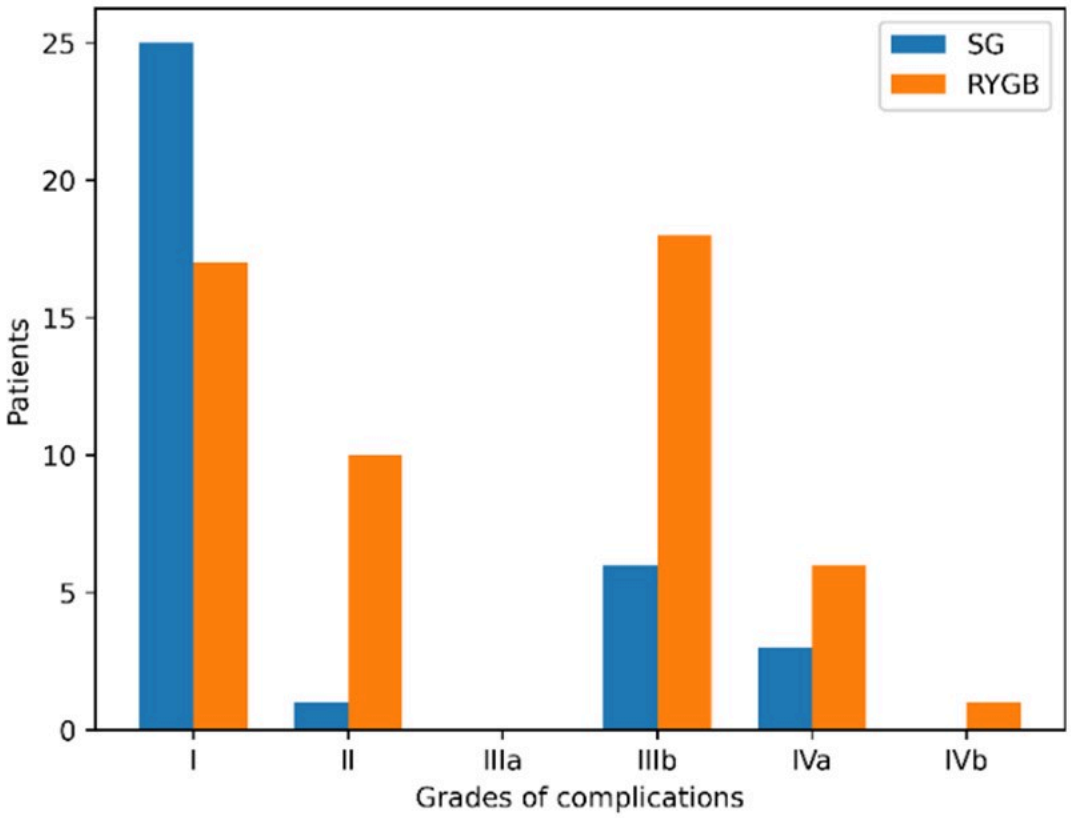


Figure 4

Distribution of postoperative complications according to the Clavien–Dindo classification after SG and RYGB.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- VisualAbstractFiveYearOutcomesofLaparoscopicSleeveGastrectomyandRouxenYGastricBypassAComparativeStudyofWeightLossandN