



Is Revisional Gastric Bypass as Effective as Primary Gastric Bypass for Weight Loss and Improvement of Comorbidities?

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Abstract

Background Revisional gastric bypass (R-RYGB) surgery is utilized for the management of inadequate weight loss or weight regain observed after some cases of bariatric surgeries. Data on the mid-term effectiveness of primary gastric bypass (P-RYGB) compared with R-RYGB (e.g., post sleeve gastrectomy/gastric banding) are controversial.

Methods Retrospective chart review of all patients who received P-RYGB and R-RYGB (January 2011–June 2015) at our center. One hundred twenty patients who underwent P-RYGB and 34 R-RYGB who completed 18 months follow-up were included. We compared the effectiveness of P-RYGB with R-RYGB by assessing four anthropometric, two glycemic, and four lipid parameters, as well as the control of type 2 diabetes (T2DM), hypertension, dyslipidemia (remission, improvement, persistence, relapse, de novo), mortality and complications rates.

Results A comparison of the effectiveness of P-RYGB with R-RYGB at 18 months revealed no significant differences in patients' age, gender, and preoperative BMI between groups. However, patients who received P-RYGB had lower mean weight ($P = 0.001$) and BMI ($P < 0.001$), reflected by a higher mean delta BMI ($P = 0.02$), total weight loss percentage (TWL%) ($P < 0.0001$) and excess weight loss percentage (EWL%) ($P < 0.0001$). No differences in glycemic parameters, lipid profiles, control of T2DM, hypertension, and dyslipidemia were observed. No death is reported and complication rates were comparable.

Conclusions Although R-RYGB effectively addressed inadequate weight loss, weight regain, and recurrence of comorbidities after restrictive bariatric surgery, R-RYGB resulted in inferior weight loss compared with P-RYGB. Neither procedure differed in their clinical control of T2DM, hypertension, and dyslipidemia. Both procedures exhibited comparable complication rates.

Keywords Revisional gastric bypass · Primary gastric bypass · Weight loss outcome · Hypertension · Type 2 diabetes · Dyslipidemia

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Introduction

Restrictive bariatric procedures, such as laparoscopic adjustable gastric band (LAGB) and laparoscopic sleeve gastrectomy (LSG), are technically simple, have a low surgical risk [1, 2] and are effective in achieving weight loss and managing obesity-related comorbidities, e.g., hypertension (HTN), type 2 diabetes (T2DM) and hyperlipidemia [3, 4]. Despite these benefits, surgical revision is performed in 20–60% of LAGB patients due to insufficient weight loss or surgical complications and in 5.7% of LSG patients due to weight regain and a relapse of comorbidities [5, 6].

Revision of LAGB and LSG to Roux-en-Y gastric bypass (RYGB) is a reasonable approach when conservative treatments fail [7, 8]. The restrictive and potentially malabsorptive mechanisms of RYGB, as well as its physiological and metabolic effects resulting from the changes in gastrointestinal hormones collectively contribute to excellent weight loss and metabolic disease resolution [9]. RYGB is also less complicated than biliopancreatic diversion and duodenal switching, carries less risk of nutritional deficiencies, and is more effective than re-sleeving procedures [10, 11]. Nevertheless, the results of studies that compared the effectiveness of primary gastric bypass (P-RYGB) with revisional gastric bypass (R-RYGB) remain inconclusive.

Most studies that assessed the effectiveness of P-RYGB and R-RYGB only examined the weight loss and surgical complications [12–14]. Moreover, these studies reported inconsistent findings, suggesting comparable weight loss and complications for patients who underwent P-RYGB and R-RYGB [12–14] or inferior weight loss and higher complications in patients who received R-RYGB [15, 16]. Furthermore, few studies have assessed the evolution of comorbidities after P-RYGB and R-RYGB [8, 17, 18], despite the possibility of relapse of comorbidities after RYGB (e.g., T2DM, HTN, and dyslipidemia). Likewise, studies comparing P-RYGB to R-RYGB only reported the remission of the comorbidities, with no data provided on the improvements or relapses [19–21]. Additionally, some studies did not provide explicit definitions of a remission, improvement, or relapse [16]. Given this range of inconsistencies and deficiencies, an understanding of the effectiveness of R-RYGB will assist physicians and patients in making informed decisions as whether to proceed with R-RYGB after a failed restrictive surgery, particularly when R-RYGB is performed to treat the relapse or persistence of comorbidities rather than the correction of surgical complications [20].

Therefore, the current study assessed the effectiveness of P-RYGB and R-RYGB at 18 months by evaluating weight loss and the evolution (status and control) of three comorbidities (HTN, T2DM, and dyslipidemia) using 4 anthropometric parameters, 2 glycemic parameters, and 4 lipid parameters. The four specific objectives were to assess changes in:

- Anthropometric parameters: weight, body mass index (BMI), delta BMI, excess weight loss percentage (EWL %), and total weight loss percentage (TWL %);
- Glycemic parameters: glycosylated hemoglobin A1c (HbA1c) and fasting blood glucose (FBG) levels;
- Lipid parameters: total cholesterol (TC), low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglyceride (TG) levels; and,
- The status and control of comorbidities: remission, improvement, persistence, or relapse.

The study also assessed and compared the early and late mortality and complication rates of patients who underwent P-RYGB or R-RYGB.

Materials and Methods

Study Design and Ethics

The Medical Research Center at HMC approved this retrospective study (IRB #16181/16) that was conducted at the Bariatric and Metabolic Surgery Center, Hamad Medical Corporation (HMC) in Doha, Qatar (January 2011–June 2015).

Definitions of the Status and Control of Comorbidities

This study used the standardized American Society for Metabolic & Bariatric Surgery (ASMBS) definitions of the evolution of obesity-related comorbidities after bariatric surgery [21] (Table 1).

Participants, Procedures, and Data Collection

Eligible patients were individuals aged 18–60 who had undergone P-RYGB or R-RYGB during the study period. The inclusion criteria were patients with a BMI ≥ 35 and comorbidities (e.g., HTN, T2DM, and dyslipidemia). The exclusion criteria were patients receiving steroid therapy who had undergone > 1 revisional surgery or had received R-RYGB for the correction of surgical complications (e.g., stricture or band slippage). As shown in Fig. 1, 246 patients who underwent RYGB were identified from the database, but 30 were excluded because they met the exclusion criteria. Thus, patients who received RYGB were eligible, of which another 62 patients were excluded due to incomplete follow-up data. The remaining 154 patients who received RYGB had complete follow-up data at 18 months and were subsequently included in the analysis (120 patients who received P-RYGB and 34 patients who received R-RYGB).

Data were retrieved from medical charts and electronic records of patients who received P-RYGB or R-RYGB. The

Table 1 Definitions of comorbidities status for three conditions

	T2DM	HTN	Dyslipidemia
Complete remission	Normal readings of glucose metabolism (HbA1c < 6% and FBG < 100 mg/dL (< 5.5 mmol)) in the absence of antidiabetic medications	Normotensive (BP-120/80) and off anti-hypertensive medications	Normal lipid panel (TC < 5.172 mmol/l, LDL < 2.586 mmol/l, HDL > 1.0344 mmol/l, TG < 1.6935 mmol/l) and off medications
Improvement	Reduction in HbA1c and FBG not meeting criteria for remission, or decrease in anti-diabetic medications requirement	Decrease in dosage or number of anti-hypertensive medications or decrease in systolic or diastolic blood pressure (BP) on the same medications (better control)	Decrease in number or dose of lipid-lowering agents with equivalent control of dyslipidemia or improved control of lipids on equivalent medication
Persistent status	Absence of remission or improvement	Absence of remission or improvement	No clear definition
Relapse	Recurrence of disease after complete remission with abnormal HbA1c and FBG levels and resumption of medications	Recurrence of disease after complete remission with resumption of medications	No clear definition
De novo	—	—	New cases of dyslipidemia including TC, LDL, HDL, or TG

Brethauer 2015 [22]; *FBG*, fasting blood glucose; *HbA1c*, glycosylated hemoglobin; *TC*, total cholesterol; *LDL*, low density lipoprotein lipase; *HDL*, high density lipoprotein; *TG*, triglyceride

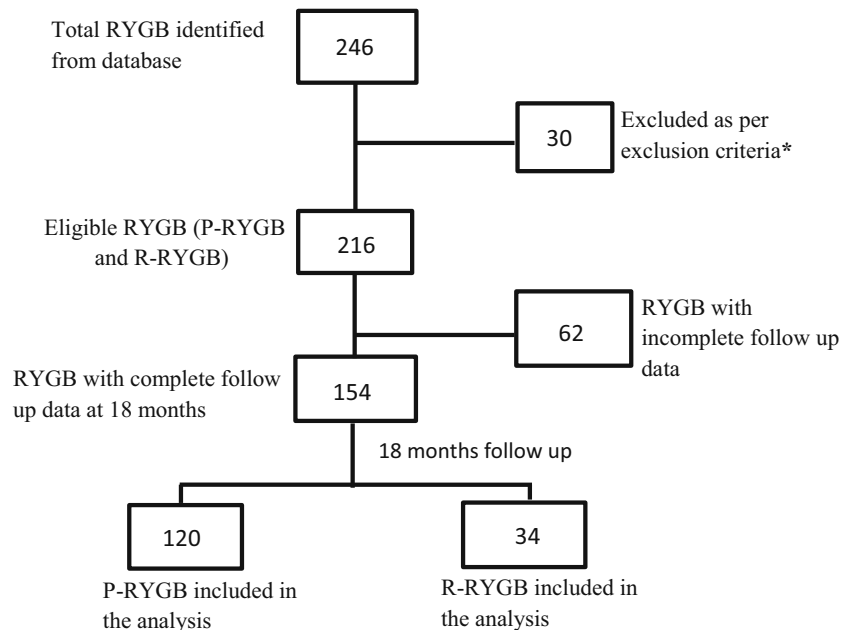
information included anthropometric (weight, BMI, EWL, EWL%, TWL%, and delta BMI), glycemic (FBG and HbA1c levels), and lipid (TC, LDL, HDL, and TG levels) parameters at baseline and 18 months. Data also included changes in the status and control of the three comorbidities (T2DM, HTN, and dyslipidemia) at 18 months. TWL%, EWL%, and delta BMI were calculated using the methods described in a previous study [23]. In addition, for patients who underwent R-RYGB, we retrieved information on the indications for R-RYGB, the initial procedure/s performed before the R-RYGB surgery, the percentage of initial procedure/s performed at HMC, and prior anthropometric

parameters (e.g., weight prior to the initial procedure that was performed before the revisional surgery). Early and late mortality and complication rates of patients who underwent P-RYGB and R-RYGB were also retrieved, classified according to the Clavien–Dindo classifications, and compared [24].

Operative Techniques

All surgeries were performed laparoscopically. RYGB was performed in a uniform manner by creating a 3–4 cm gastric pouch and using a linear stapled antecolic retrogastric anastomosis with a 100 cm alimentary limb and 50 cm bilio-

Fig. 1 Flow diagram of recruitment of participants. * E.g., erosion, stricture, band slippage, and two prior primary procedures



pancreatic limb, which was the standard technique performed at our center during the study period. In cases of conversion of sleeve gastrectomy to RYGB, pouch trimming was performed in selected patients when significant intraoperative pouch dilatation was observed. All patients in whom the gastric band was converted to RYGB at our institution received surgery that was performed in one stage.

Statistical Analysis

Statistical analyses were performed using the statistical packages SPSS 22.0 (SPSS Inc. Chicago, IL) and Epi-info (Centers for Disease Control and Prevention, Atlanta, GA). All *P* values presented here are two-tailed, and *P* values < 0.05 were considered statistically significant. Descriptive statistics summarized the demographic, anthropometric, clinical, biochemical, and other related characteristics of the participants. Continuous data were reported as the means and standard deviations (SD); the remaining results were reported as frequencies and percentages. The primary outcome was to compare changes in anthropometric parameters, glycemic parameters, lipid parameters, and the status and control of comorbidities (remission, improvement, persistence, or relapse) at 18 months, as well as mortality and complication rates between patients who received P-RYGB and R-RYGB. Associations between two or more qualitative variables were assessed using the Chi square (χ^2) test or Fisher's exact test, as appropriate. An unpaired *t* test or Mann–Whitney U test (depending on the normality of the data distribution) was used to compare quantitative data and outcome measures (age, anthropometric, glycemic and lipid parameters, etc.) at baseline and

18 months. In addition, we compared the same outcomes at baseline and 18 months for each individual RYGB type.

Results

Table 2 compares the preoperative characteristics of patients who were excluded from the study due to incomplete data (*n* = 62) with patients with complete data who were included in the study (*n* = 154). The comparisons were performed for the whole sample and for the P-RYGB and R-RYGB groups individually. The 62 excluded patients were not different from the 154 included patients in terms of all baseline characteristics, with two exceptions: patients included in the study were significantly older than the excluded patients (*P* < 0.0001), and the P-RYGB group generally comprised more females (*P* = 0.029).

Table 3 shows the preoperative characteristics of patients stratified by gastric bypass type. No significant differences in the preoperative characteristics of patients who received P-RYGB and R-RYGB were observed for most of the parameters examined. However, the mean HDL level was significantly lower in patients who underwent P-RYGB (*P* = 0.037). In addition, more patients were diagnosed with diabetes in the P-RYGB group compared with the R-RYGB group (*n* = 78 vs. 15 patients, *P* = 0.028). A significantly higher percentage of patients were diagnosed with hypothyroidism in the R-RYGB group.

Table 4 depicts the baseline characteristics of patients who underwent R-RYGB prior to the initial (LSG or LAGB) procedure. Patients' mean baseline weight was 128.07 ± 46.75 kg, EWL% was 55.66 ± 32.14%, and minimal weight

Table 2 Preoperative characteristics of patients excluded vs. included in the study

Variable	Whole sample			P-RYGB Patients			R-RYGB		
	Excluded* <i>n</i> = 62	Included <i>n</i> = 154	<i>P</i> value	Excluded* <i>n</i> = 42	Included <i>n</i> = 120	<i>p</i> value	Excluded* <i>n</i> = 20	Included <i>n</i> = 34	<i>P</i> value
Gender ^a			0.083			0.029			0.441
Male	10 (4.6)	42 (19.4)		6 (3.7)	38 (23.5)		4 (7.4)	4 (7.4)	
Female	52 (24.1)	112 (51.9)		36 (22.2)	82 (50.6)		16 (29.6)	30 (55.6)	
Age ^b (years)	31.88 ± 8	41.44 ± 9.98	< 0.0001	30.90 ± 7.38	40.93 ± 10.41	< 0.0001	33.95 ± 9.01	43.26 ± 8.17	< 0.0001
Height ^b (m)	1.62 ± 0.08	1.63 ± 0.09	0.775	1.62 ± 0.07	1.63 ± 0.09	0.520	1.63 ± 0.10	1.61 ± 0.08	0.580
Weight ^b (kg)	121.27 ± 21.59	123.23 ± 25.93	0.600	125.57 ± 18.98	122.44 ± 20.35	0.384	112.25 ± 24.35	126.02 ± 40.18	0.171
BMI ^b (kg/m ²)	45.96 ± 6.40	46.28 ± 8.16	0.785	47.59 ± 5.74	45.89 ± 6.64	0.143	42.55 ± 6.52	47.65 ± 12.14	0.089
EW ^b (kg)	54.97 ± 18.23	56.73 ± 23.49	0.600	59.58 ± 15.78	55.48 ± 17.77	0.190	45.29 ± 19.60	61.05 ± 37.21	0.086

*Patients excluded from the study due to incomplete follow up information, EW, excess weight

^a cell values represent *n* (%), Chi Square test used for comparisons

^b cell values represent means ± standard deviation, independent sample *t* test used for comparisons. Values in italics mean that comparisons of results are statistically significant

achieved after the initial procedure was 63.33 ± 46.76 kg. After the initial procedure, the mean weight gain was 34.39 ± 29.27 kg. Table 4 also shows the type of initial procedure performed prior to R-RYGB (22 patients received LSG and 12 patients received LAGB). Forty-four percent of these initial procedures were performed at our institution (data not presented).

Table 5 illustrates the indications for R-RYGB, where 35.2% of patients underwent R-RYGB because of weight regain, 32.3% for inadequate weight loss, and 32.3% to treat GERD. Approximately, 73% had > 1 indication for R-RYGB, e.g., the persistence or relapse of T2DM or HTN, in addition to the indications listed above.

Table 6 compares the outcomes of P-RYGB with R-RYGB at 18 months. In terms of anthropometric parameters, patients

Table 3 Preoperative characteristics by gastric bypass type ($n = 154$)

Parameter	Reference range*	Gastric bypass		P value
		P-RYGB <i>n</i> = 120	R-RYGB <i>n</i> = 34	
Demographic ^a				
Age (years)		40.93 ± 10.41	43.26 ± 8.17	0.231
Gender ^b				<i>0.021</i>
Male		38 (23.5)	7 (11.18)	
Female		82 (50.6)	33 (88.2)	
Anthropometric ^a				
Height (m)		1.63 ± 0.09	1.61 ± 0.08	0.429
Weight (kg)		122.44 ± 20.35	126.02 ± 40.18	0.478
BMI (kg/m ²)		45.89 ± 6.64	47.65 ± 12.14	0.270
EW (kg)		55.48 ± 17.77	61.05 ± 37.21	0.231
Glycemic ^a				
FBG (mmol/L)	3.3–5.5	9.31 ± 4.48	8.54 ± 4.11	0.523
HbA1c (%)	4.8–6	8.20 ± 2.42	7.98 ± 2.71	0.754
Lipid profile ^a (mmol/L)				
TC	< 5.172	4.94 ± 1	4.85 ± 0.96	0.644
LDL	< 2.586	2.97 ± 0.86	2.88 ± 0.87	0.643
HDL	> 1.03	1.23 ± 0.33	1.37 ± 0.35	<i>0.037</i>
TG	< 1.69	1.68 ± 0.76	1.38 ± 0.83	0.059
Comorbidities Examined ^b				
T2DM		78 (65)	15 (44.1)	<i>0.028</i>
HTN		63 (52.5)	16 (48.5)	0.683
Dyslipidemia		46 (39.3)	8 (24.2)	0.111
Other Comorbidities ^b				
OSA		13 (10.8)	1 (2.9)	0.158
OA		15 (12.5)	8 (23.5)	0.111
Asthma		10 (8.3)	3 (8.8)	0.928
GERD		14 (11.7)	7 (20.6)	0.181
Hypothyroidism		10 (8.3)	7 (20.6)	<i>0.044</i>
Infertility		3 (2.5)	0 (0)	0.352
Depression		0 (0)	1 (2.9)	0.059
Back pain		17 (14.2)	7 (20.6)	0.362

^a cell values represent means ± standard deviation, independent sample *t* test used for comparisons (reviewer #1, comment #4)

^b cell values represent *n* (%), Chi Square test used for comparisons (reviewer 1, comment #4)

P-RYGB, primary gastric bypass; R-RYGB, revisional gastric bypass; *M*, mean; *SD*, standard deviation; *N*, number; *Normal values; *BMI*, body mass index; *EW*, excess weight; *FBG*, fasting blood glucose; *HbA1c*, glycosylated hemoglobin; *T2DM*, type 2 diabetes mellitus; *HTN*, hypertension; *TC*, total cholesterol; *LDL*, low density lipoprotein; *HDL*, high density lipoprotein; *TG*, triglyceride; *OSA*, obstructive sleep apnea; *OA*, osteoarthritis; *GERD*, gastroesophageal reflux disease; *BP*, back pain; Bolded cells indicate statistical significance. Values in italics mean that comparisons of results is statistically significant

Table 4 Baseline characteristics of R-RYGB patients prior to initial procedure (reviewer 1, comment #21), (reviewer 2, comment #2)

Anthropometric parameters M ± SD	
Prior to initial procedure	
Initial Baseline weight	128.07 ± 46.75
After initial procedure and before R-RYGB	
Minimal weight (Kg)	63.33 ± 46.76
%EWL	55.66 ± 32.14
%TWL	24.67 ± 13.30
Weight gain (Kg)	34.39 ± 29.27
% of initial procedure/s performed at HMC	n (%)
LSG	13/22 (38.2)
LAGB	2/12 (5.8)

*EW, excess weight; %EWL, percentage of excess weight loss; %TWL, percentage of total weight loss; LSG, laparoscopic sleeve gastrectomy; LAGB, laparoscopic adjustable LAGB; M, mean, SD, standard deviation

who underwent P-RYGB had a significantly lower mean weight, BMI, and minimal weight compared with patients who underwent R-RYGB ($P = 0.001$, $P = 0.0001$, and $P = 0.004$, respectively). In addition, patients who received P-RYGB had a greater TWL%, EWL%, and delta BMI reduction than patients who received R-RYGB ($P < 0.0001$, $P < 0.0001$, and $P = 0.002$, respectively). No differences is observed in glycemic or lipid profile between P-RYGB and R-RYGB patients at 18 months.

Table 6 further compares the outcomes between the baseline and follow-up at 18 months for each individual RYGB type. Regarding the anthropometric parameters, patients who underwent P-RYGB exhibited a significantly lower weight and BMI at 18 months compared with baseline ($P < 0.0001$ for both), where delta BMI was -14.29 ± 5.77 kg/m², EWL% was $69.99 \pm 23.61\%$, and minimum weight was 81.87 ± 16.84 kg. Patients who underwent R-RYGB similarly achieved a significantly lower weight and BMI at 18 months compared with baseline values ($P < 0.0001$), where the delta BMI was -11.36 ± 7.41 kg/m², EWL% was $50.62 \pm 24.47\%$, and minimum weight was 94.32 ± 26.59 kg. Regarding the glycemic

Table 5 Indications for R-RYGB and stages primary LAGB operation

Indications	n (%)
Inadequate weight loss (< 50 %EWL)	11 (32.3)
Weight regain	12 (35.2)
GERD	11 (32.3)
Patients with 1 indication	9 (26.4)
Patients with >1 indications*	25 (73.5)

*Includes relapse of hypertension, diabetes or GERD (diagnosed by barium swallow and upper endoscopy); LAGB, laparoscopic adjustable gastric band (all LAGB were performed in one stage procedure)

and lipid parameters, an analysis of the glycemic parameters of patients who underwent P-RYGB showed significantly lower FBG and HbA1c levels ($P = 0.0001$ for both), and the lipid profile indicated lower TC, LDL, and TG levels ($P < 0.0001$ for each) but significantly higher HDL levels ($P = 0.006$) at 18 months compared with the baseline. In contrast, patients who underwent R-RYGB displayed a significant reduction in HbA1c levels ($P = 0.007$), but no significant improvements in the FBG level or lipid profile at 18 months compared with the baseline.

Table 7 depicts the changes in the medication use and the disease status of three comorbidities at 18 months. Regarding medication use, the P-RYGB and R-RYGB groups did not significantly differ in the percentages of patients who stopped, reduced, maintained the same dose, or resumed their medications. Regarding the disease status, again, the P-RYGB and R-RYGB groups did not differ significantly in the percentages of patients who achieved complete remission, improvement, persistence, or relapse of their T2DM, HTN, or dyslipidemia. Two patients who underwent P-RYGB and 1 patient who underwent R-RYGB developed de novo dyslipidemia.

Table 8 shows the early and late complications of patients stratified by RYGB type. Early and late mortality were not observed both in the P-RYGB and in the R-RYGB groups. Furthermore, the P-RYGB and R-RYGB groups did not display significant differences in the overall, early or late complication rates.

Discussion

The rapidly increasing number of bariatric procedures performed is likely to be accompanied by increasing numbers of revisional procedures when other treatment modalities fail. At our bariatric center, RYGB accounted for 9.7% (246/2529) of all bariatric surgeries performed during the study period. In the current study, weight regain was the most frequent indication for R-RYGB, consistent with other authors who reported that 46.15% of their R-RYGB surgeries were due to weight regain [25]. Weight regain is attributed to anatomical, physiological, psychosocial, and behavioral (nonadherence to healthy lifestyle) factors [22]. Likewise, 41.02% of our patients underwent R-RYGB due to inadequate weight loss, consistent with another study in which 32.3% of revisions were performed due to inadequate weight loss [26]. A total of 32.3% of patients in the current study underwent R-RYGB as a treatment for GERD, supporting the findings of other studies in which 11 of 81 patients received R-RYGB for GERD [17]. GERD is a common long-term sequela of LAGB and LSG [26, 27], and RYGB is an effective procedure when other modalities fail [27]. Notably, 26.4% of our patients underwent R-RYGB for one indication and 73.5% for > 1 indication. Documenting the number of indications for

Table 6 Changes from baseline to 18 months by gastric bypass type

Parameters	P-RYGB			R-RYGB			<i>P</i> value ^b
	Baseline	18 Months	<i>P</i> value ^a	Baseline	18 Months	<i>P</i> value ^a	
Anthropometric							
Weight (kg)	122.15 ± 20.36	84.07 ± 15.51	< 0.0001	126.93 ± 40.44	96.24 ± 24.97	< 0.0001	0.001
BMI (kg/m ²)	45.95 ± 6.70	31.71 ± 5.79	< 0.0001	47.88 ± 12.25	36.52 ± 8.10	< 0.0001	< 0.0001
Delta BMI (kg/m ²)	—	- 14.29 ± 5.77	—	—	- 11.36 ± 7.41	—	0.020
TWL (%)	—	30.60 ± 10.31	—	—	22.53 ± 11.14	—	< 0.0001
EWL (%)	—	69.99 ± 23.61	—	—	50.62 ± 24.47	—	< 0.0001
Minimal weight (kg)	—	81.87 ± 16.84	—	—	94.32 ± 26.59	—	0.004
Glycemic							
FBG(mmol/L)	10.58 ± 4.61	6.11 ± 2.75	< 0.0001	8.93 ± 3.80	6.58 ± 2.01	0.122	0.646
HbA1c (%)	8.64 ± 2.28	6.07 ± 0.79	< 0.0001	8.47 ± 2.47	6.84 ± 1.45	0.007	0.282
Lipid profile(mmol/L)							
TC	5.05 ± 1.02	4.51 ± 0.76	< 0.0001	4.54 ± 0.85	4.50 ± 0.59	0.833	0.970
LDL	3.08 ± 0.87	2.49 ± 0.61	< 0.0001	2.56 ± 0.78	2.67 ± 0.95	0.739	0.481
HDL	1.23 ± 0.33	1.35 ± 0.27	0.006	1.35 ± 0.29	1.39 ± 0.21	0.476	0.668
TG	1.72 ± 0.74	1.06 ± 0.44	< 0.0001	1.82 ± 0.87	1.23 ± 0.31	0.084	0.288

^a Paired samples *t* test for changes from baseline vs. 18 months

^b P-RYGB vs. R-RYGB at 18 months, independent sample *t* test used for comparisons

M, mean; *SD*, standard deviation; *m*, month; *BMI*, body mass index; *TWL (%)*, total weight loss percentage; *EWL (%)*, excess weight loss percentage; *FBG*, fasting blood glucose; *HbA1c*, glycosylated hemoglobin; *TC*, total cholesterol; *LDL*, low density lipoprotein lipase; *HDL*, high density lipoprotein; *TG*, triglyceride, bold cells indicate statistical significance

Values in italics mean that comparisons of results is statistically significant

revisonal bariatric surgery is important, as indications for revisonal surgery usually do not exist in isolation and are interrelated, e.g., weight regain after primary surgery that eventually leads to the recurrence of HTN and T2DM.

In terms of anthropometric parameters, some studies have not observed differences in EWL% between patients who received P-RYGB and R-RYGB [12, 13]. Conversely, patients who underwent P-RYGB have been reported to achieve significantly better EWL% [16, 18], consistent with the findings of the current study. Likewise, the patients who received P-RYGB in our study had a significantly higher TWL% than patients who received R-RYGB, similar to the findings from other studies [20, 28]. In the current study, patients who underwent P-RYGB achieved a significantly lower mean BMI and higher delta BMI, consistent with other studies [17, 18]. The inferior weight loss we observed in the R-RYGB group is likely attributed to complex factors but we could speculate that the characteristics of the patients and/or surgical technique are likely the main factors. Regarding patient characteristics, patients who undergo R-RYGB are likely to have advanced/ refractory obesity due to genetic causes [8], and lifestyle/psychological factors after repeated surgery also potentially reduce the efficacy of R-RYGB [29, 30]. In addition, the reduced efficacy of R-RYGB might be attributed to changes in bile flow and the modulation of enteric hormone levels. This is based on

evidence suggesting that patients who achieved a sustained weight loss after RYGB had higher leptin, glucose-dependent insulinotropic polypeptide, and glucagon-like peptide 1 levels than patients who experienced weight regain [31, 32]. Regarding the characteristics of the surgical technique, the inferior weight loss observed in the R-RYGB group may be due to the lack of precise measurements of the stomach pouch size during revisonal surgery, resulting in a larger stomach pouch [16]. However, recent study suggests that pouch size does not play a critical role in weight regain unless the pouch is very large [33]. There is also a growing evidence suggesting that the differences in the total alimentary limb length (TALL) and the length of the biliopancreatic (BPL) could play a role [34, 35]. At the time of the current study, the standard procedure at our institution was RYGB performed without consideration of total bowel length and TALL (a point seen today as a shortcoming). Future research would benefit from assessing these factors and their effects.

We examined each type of RYGB individually by comparing the parameters at baseline and 18 months. At 18 months, patients who underwent P-RYGB in the present study achieved a BMI and EWL% that were consistent with another study [8]; similarly, patients who underwent R-RYGB achieved a BMI and EWL% comparable to other studies [8, 36].

Table 7 P-RYGB vs. R-RYGB: changes in the status of three comorbidities at 18 months

	Gastric Bypass		P value
	P-RYGB n (%)	R-RYGB n (%)	
Type 2 diabetes medications ^a			
Off Medications	42 (53.8)	9 (60)	0.661
Reduced	27 (34.6)	4 (26.7)	0.550
Same	8 (10.3)	2 (13.3)	0.725
Resumed	1 (1.3)	0 (0)	0.659
Status			
Remission	42 (53.8)	10 (66.7)	0.360
Improved	27 (34.6)	4 (26.7)	0.550
Persistent	8 (10.3)	1 (6.7)	0.667
Relapsed	1 (1.3)	0 (0)	0.659
Hypertension medications ^a			
Off Medications	32 (51.6)	6 (37.5)	0.314
Reduced	16 (25.8)	6 (37.5)	0.354
Same	14 (22.6)	4 (25)	0.838
Resumed	0 (0)	0 (0)	NA
Status			
Remission	32 (51.6)	6 (37.5)	0.314
Improved	16 (25.8)	6 (37.5)	0.354
Persistent	14 (22.6)	4 (25)	0.838
Relapsed	0 (0)	0 (0)	NA
Dyslipidemia medications ^a			
Off Medication	41 (80.4)	8 (88.9)	0.544
Reduced/same dose	10 (19.6)	1 (11.1)	0.544
Status			
Remission	13 (27.1)	2 (22.2)	0.761
Improvement	8 (16.7)	0 (0)	0.187
Persistence	25 (52.1)	6 (66.7)	0.420
De novo	2 (4.2)	1 (11.1)	0.392

^a Medications were employed to derive status of the given comorbidity, Chi square test used for comparisons

In terms of comorbidities, the T2DM remission rate in the current study was not significantly different between the P-RYGB and R-RYGB groups (53.8% vs. 62.5%), similar to the data reported in a previous study (23.1% vs. 50.1%) [37]. Although other studies have compared P-RYGB with R-RYGB exclusively by measuring T2DM remission [8, 20], we also compared T2DM evolution (improvement, persistence, or relapse) between patients who received the two procedures and no significant differences were observed. Regarding HTN, the P-RYGB and R-RYGB groups displayed similar HTN remission rates, consistent with studies employing shorter (1.5 years) and longer (3–5 years) follow-up durations [8, 19, 37]. However, another 3-year follow-up study found that patients who underwent P-RYGB experienced a significantly better HTN remission rate than patients

Table 8 Early and late complications by gastric bypass group

Complication	P-RYGB n (%)	R-RYGB n (%)	P value
All mortality	0 (0)	0 (0)	—
All complications	10 (10.8)	2 (5.9)	0.406
Early (< 3 months)			
Mortality	0 (0)	0 (0)	—
Complications	9 (9.7)	2 (5.9)	0.501
Major (Clavien–Dindo ≥ IIIb)	6 (6.5)	2 (5.9)	0.907
Anastomotic leak	1 (1.1)	2 (5.9)	0.114
Perianastomotic abscess	0 (0)	0 (0)	—
Biliary peritonitis (Traumatic Injury)	0 (0)	0 (0)	—
Hematoma	0 (0)	0 (0)	—
Intra-abdominal bleeding	2 (2.2)	0 (0)	0.389
Port-site herniation	0 (0)	0 (0)	—
Anastomotic stricture	3 (3.2)	0 (0)	0.289
Minor (Clavien–Dindo ≤ IIIa)	3 (3.2)	0 (0)	0.289
Marginal ulcer	0 (0)	0 (0)	—
Deep vein thrombosis	0 (0)	0 (0)	—
Minor wound infection	3 (3.2)	0 (0)	0.289
Late (> 3 months)			
Mortality	0 (0)	0 (0)	—
Complications	1 (0.08)	0 (0)	0.544
Major (Clavien–Dindo ≥ IIIb)	1 (1.1)	0 (0)	0.544
Peritonitis due to ulcer perforation	1 (1.1)	0 (0)	0.544
Intractable biliary reflux	0 (0)	0 (0)	—
Bowel obstruction	0 (0)	0 (0)	—
Incisional hernia	0 (0)	0 (0)	—
Minor (Clavien Dindo ≤ IIIa)	0 (0)	0 (0)	—
Excessive weight lost	0 (0)	0 (0)	—
Marginal ulcer	0 (0)	0 (0)	—

Chi square test used for comparisons

who underwent R-RYGB [16]. In terms of the remission of dyslipidemia, remission rates in the P-RYGB group were not different from the R-RYGB group, although our rates were much lower than the values reported in another study [18], which was probably attributed to their longer follow-up duration (3 years) that may have facilitated the resolution of dyslipidemia [18]. Although other studies have assessed the effectiveness of P-RYGB and R-RYGB by evaluating dyslipidemia remission alone [17, 20], the current study also compared the effectiveness of the two procedures in improving dyslipidemia, and again no significant differences were observed between groups. Likewise, no previous studies have reported the emergence of de novo dyslipidemia, but the present study observed two de novo cases in the P-RYGB group and one case in the R-RYGB group at 18 months. Collectively, the findings of improvements in comorbidities support the hypotheses that although R-RYGB is associated with inferior weight loss, it successfully manages obesity-

associated comorbidities, e.g., T2DM and HTN, and displays the same potential as P-RYGB.

We also examined each type of RYGB individually by comparing the resolution of comorbidities (baseline vs. 18 months). Although P-RYGB produced a significant improvement in HbA1c levels, consistent with a previous study [38], it did not improve the lipid profile, in contrast to another study [39]. Patients in the R-RYGB group achieved a significant improvement in HbA1c levels, consistent with a previous study showing that R-RYGB significantly improved HbA1c levels at 1 year after LAGB, but not after LSG [20]. Although R-RYGB improved the FBG levels at 18 months, this difference was not statistically significant, similar to other studies [20]. The probable explanation is our small sample size.

In terms of complications of P-RYGB and R-RYGB, R-RYGB is reported to be a safe procedure, with similar early and late complication rates to P-RYGB, supporting the findings of the current study [37]. No patients died in the present study, whereas other studies reported a low mortality rate in patients who underwent P-RYGB and R-RYGB (0.2% and 1.3%, respectively) [40].

The study has limitations. We included fewer patients in the R-RYGB group than in the P-RYGB group (34 vs. 120), which reflects the observation that revisional surgeries are generally less common than primary surgeries; the inclusion of equal numbers of patients might have provided more precise estimates. Due to the smaller number of patients in the R-RYGB group, we combined patients who underwent the two initial procedures (LSG and LAGB) in the R-RYGB group, and although both LSG and LAGB are restrictive surgeries, LSG has some metabolic component that differentially affects the resolution of comorbidities than the purely restrictive LAGB [41]. A longer follow-up period would have been beneficial in terms of assessments of weight regain because the nadir weight loss is usually achieved after approximately 2–3 years, after which weight regain takes place. A longer follow-up period would have also allowed an extended assessment of the resolution, improvement, relapse or persistence of comorbidities. We did not compare the effects of the two procedures on the patients' nutritional status and quality of life; this information would have provided a more comprehensive assessment of the effects of each procedure.

The study also has strengths. Studies comparing the effects of P-RYGB and R-RYGB on comorbidities (T2DM, HTN, and dyslipidemia) have only focused on remission [19, 20], falling short of assessing the effects of the procedures on the improvement, persistence, and relapse of these comorbidities. The study was also novel in assessing the de novo rates of these comorbidities in patients who underwent each of the two procedures, a point that is usually omitted [18], despite the importance of continued follow-up of de novo cases. Previous studies did not use explicit definitions for remission, improvement, and relapse [16]; we employed international

ASMBS definitions for the disease status in the comparison of P-RYGB with R-RYGB. Furthermore, the current study is the first to compare the anthropometric, glycemic, and lipid parameters for each individual type of RYGB at baseline and 18 months and explore the effectiveness of each type of RYGB per se, where no other study performed this type of analysis [8, 17]. We also assessed the complications of both procedures for an impartial comparison of P-RYGB with R-RYGB. Finally, due to incomplete follow-up data, 62 patients were excluded from the analysis. Although these excluded patients were significantly younger than the included group, their exclusion might not have affected our findings, as reports advocate that improvements in obesity-associated comorbidities after RYGB are similar across age groups [42].

Conclusions

Based on the findings of the current study, R-RYGB results in an inferior outcome in terms of weight loss. However, R-RYGB is similar to P-RYGB in the clinical effects on the control of T2DM, hypertension, and dyslipidemia (remission, improvement, persistence, relapse, and de novo rates). Therefore, R-RYGB potentially represents an effective approach to address the relapse of comorbidities following restrictive bariatric surgeries (e.g., LAGB & LSG). An understanding of the outcomes of R-RYGB after restrictive bariatric surgeries in terms of its potentially lower weight loss but comparable resolution of comorbidities will assist physicians and patients in making appropriate decisions.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Informed Consent Informed consent was waived (IRB-approved, HIPAA-compliant retrospective study).

Ethical Approval All procedures reported in this study were performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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