# Roux-en-Y gastric bypass and sleeve gastrectomy for obesity-associated hypertension

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## ABSTRACT

Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) reduce blood pressure (BP) in obese patients with hypertension (HTN). We compared the effect of RYGB and SG on BP in obese patients with HTN at a large-volume, private bariatric surgery center using a propensity score analysis. The measurement and management of BP were exclusively left to the patient's provider without any involvement of Tulane investigators. At month 1, RYGB and SG equally decreased: (1) mean body weight: 12.7 vs 13.2 kg (p=not significant (NS)) (2) systolic/diastolic BP: 8.5/5.3 vs 8.0/4.2 mm Hg (p=NS) and (3) average number of antihypertensive medications from 1.5 to 0.8 and from 1.6 to 0.6 per patient (p=NS). From month 1 to 12, BP remained unchanged after RYGB but tended to increase from month 6 to 12 after SG. Remission of HTN occurred in 52% and 44% of patients after RYGB and SG. In contrast to the full effect of RYGB and SG on BP at 1 month, body weight decreases steadily over 12 months after RYGB and SG. In conclusion, early after surgery, RYGB and SG equally reduce BP in obese patients with HTN. Thereafter, RYGB has a more sustained effect on BP than SG.

## Significance of this study

### What is already known about this subject?

- Roux-En-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) reduce blood pressure (BP) and need for antihypertensive therapy in obese patients with hypertension.
- Randomized trials comparing RYGB and SG did not evaluate BP as a primary endpoint. Further, observational and retrospective studies comparing BP outcomes after RYGB and SG have yielded variable results.
- Accordingly, we prospectively recorded BP and antihypertensive medications for 12 months in obese patients who underwent RYGB and SG.

### What are the new findings?

- At 1 month, both RYGB and SG resulted in a similar and marked reduction in BP, and antihypertensive therapy.
- From 1 to 12 months, BP remained unchanged after RYGB but tended to increase from month 6 to 12 after SG.
- Remission of hypertension (HTN) occurred in 52% and 44% of patients after RYGB and SG.

### How might these results change the focus of research or clinical practice?

- RYGB is more effective than SG for BP reduction and HTN remission in obese patients with HTN and may be preferred to SG in patients with obesity-associated HTN.

## INTRODUCTION

Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) are the two most commonly performed metabolic surgical procedures.[1] Besides reducing body weight and improving/resolving type 2 diabetes (T2D), RYGB and SG reduce blood pressure (BP) and alleviate antihypertensive therapy in obese patients with hypertension (HTN).[2–4] The effects of RYGB and SG on body weight and T2D have been directly compared in randomized trials.[5–8] However, BP was not a primary endpoint in these randomized trials. Accordingly, we prospectively recorded BP and antihypertensive medications for 12 months in obese patients who underwent RYGB and SG.

## MATERIALS AND METHODS

A propensity score analysis was performed to account for baseline demographic, clinical, and laboratory confounders. Measurement and management of BP were exclusively left to the patient's provider without any involvement of Tulane investigators.

### Patient population

The study population consisted of all patients aged >18 years who underwent RYGB or SG at the Surgical Specialists of Louisiana, Metairie, Louisiana, from January 1, 2015, to December 31, 2016. The indications for SG or RYGB were a body mass index (BMI) of >40 kg/m$^2$ or a BMI of >35 kg/m$^2$ and obesity-related comorbidity. All patients participated in a nutrition counseling and exercise program before metabolic surgery. Psychological evaluation was conducted in all potential surgical candidates. The choice of surgical procedure (RYGB or SG) was a shared decision between surgeon and

**Table 1** Baseline characteristics of the hypertensive patients who underwent laparoscopic SG and RYGB study before propensity matching

| Variable | SG (n=642) | RYGB (n=85) | P value α | Smd |
|---|---|---|---|---|
| Age (years)† | 48.5 (11.7) | 49.7 (12.9) | 0.39 | 6.3 |
| Sex* | | | | |
| Men | 161 (25.1) | 24 (28.2) | 0.51 | 7.1 |
| Women | 481 (74.9) | 61 (71.8) | 0.51 | |
| Race* | | | | |
| Caucasian | 471 (73.4) | 65 (76.5) | 0.013 | 5.6 |
| African–American | 131 (20.4) | 9 (10.6) | 0.013 | |
| Other | 40 (6.2) | 11 (12.9) | 0.013 | |
| SBP (mm Hg)† | 132.5 (15.7) | 133.4 (16) | 0.63 | 5.7 |
| DBP (mm Hg)† | 80.1 (10.9) | 80.2 (11.4) | 0.97 | 0 |
| HR (beats/min)† | 82.3 (13.8) | 81.4 (13.4) | 0.55 | 6.8 |
| Weight (kg)† | 125.6 (27) | 133.9 (36.4) | 0.01 | 25.9 |
| BMI (kg/m$^2$)† | 44.9 (7.9) | 47.5 (10.6) | 0.008 | 23.2 |
| T2D* | 197 (30.7) | 31 (36.5) | 0.32 | 12.2 |

*Categorical variables were described as frequency (percentage).
†Continuous variable represented as means (SD).
BMI, body mass index; DBP, diastolic blood pressure; HR, heart rate; RYGB, Roux-en-Y gastric bypass; SBP, systolic blood pressure; SG, sleeve gastrectomy; Smd, standardized mean difference; T2D, type 2 diabetes.

**Table 2** Baseline characteristics of the hypertensive patients who underwent laparoscopic sleeve gastrectomy (RYGB) and RYGB study after propensity matching

| Variable | SG (n=85) | RYGB (n=85) | P value* | Smd |
|---|---|---|---|---|
| Age (years)† | 49.8 (11.7) | 49.7 (12.9) | 0.97 | 3.5 |
| Sex* | | | | |
| Men | 24 (28.2) | 24 (28.2) | 1 | 0 |
| Women | 61 (71.8) | 61 (71.8) | 1 | |
| Race* | | | | |
| Caucasian | 58 (68.2) | 65 (76.5) | 0.1 | 6.9 |
| African–American | 19 (22.4) | 9 (10.6) | 0.1 | |
| Other | 8 (9.4) | 11 (12.9) | 0.1 | |
| SBP (mm Hg)† | 132.2 (18.3) | 133.4 (16) | 0.64 | 9.1 |
| DBP (mm Hg)† | 80.4 (12.3) | 80.2 (11.4) | 0.89 | 1.5 |
| HR (beats/min)† | 80.3 (12.9) | 81.4 (13.4) | 0.59 | 7.6 |
| BMI (kg/m$^2$)† | 46.8 (9.1) | 47.5 (10.6) | 0.63 | 4.5 |
| T2D* | 32 (37.6) | 31 (36.5) | 1 | 2.4 |

*Categorical variables were described as frequency (percentage).
†Continuous variable represented as means (SD).
BMI, body mass index; DBP, diastolic blood pressure; HR, heart rate; RYGB, Roux-en-Y gastric bypass; SBP, systolic blood pressure; SG, sleeve gastrectomy; Smd, standardized mean difference; T2D, type 2 diabetes mellitus.

patient. The surgical team consists of eight surgeons with each performing 10–15 RYGB and 100–150 SG per year.

## Follow up

Patients were seen at 1, 3, 6 and 12 months after the procedure. Vital signs and anthropometric measurements, including height (inches), weight (kilograms), and body mass index (BMI) in kilogram per square meter were measured at each visit. BP was measured with an automated cuff affixed to the non-dominant arm after the patient had been in seated position for a minimum of 5 min. An average of two consecutive BP measurements was recorded. Preoperative blood work included a complete blood count, metabolic panel, and lipid profile. Postoperative laboratory testing and antihypertensive therapy were at the discretion of the healthcare provider. Patients were deemed hypertensive when the BP was >130/80 mm Hg or when they were receiving antihypertensive therapy. Remission of HTN was defined as a BP of <130/80 mm Hg in the absence of antihypertensive medications. Other obesity-related comorbidities such as T2D, dyslipidemia, depression, and gastrointestinal reflux disease were assessed at each visit.

## Statistical analysis

Patients with baseline missing covariate data were excluded from the study. Propensity scores representing the estimated probabilities of patients undergoing SG or RYGB surgery were developed based observed baseline covariates in a logistic regression model with procedure group as the dependent variable (variables listed include age, sex, race, BMI, heart rate (HR) and systolic blood pressure (SBP) or diastolic blood pressure (DBP)). Highly skewed data such as SBP, DBP, age, HR and BMI were log transformed. The nearest neighbor-matching algorithm was employed to find as many 1:1 match between the surgical approaches based on the propensity scores to produce two balanced patient cohorts. We assessed the balance between the two cohorts using a standardized mean difference. Differences

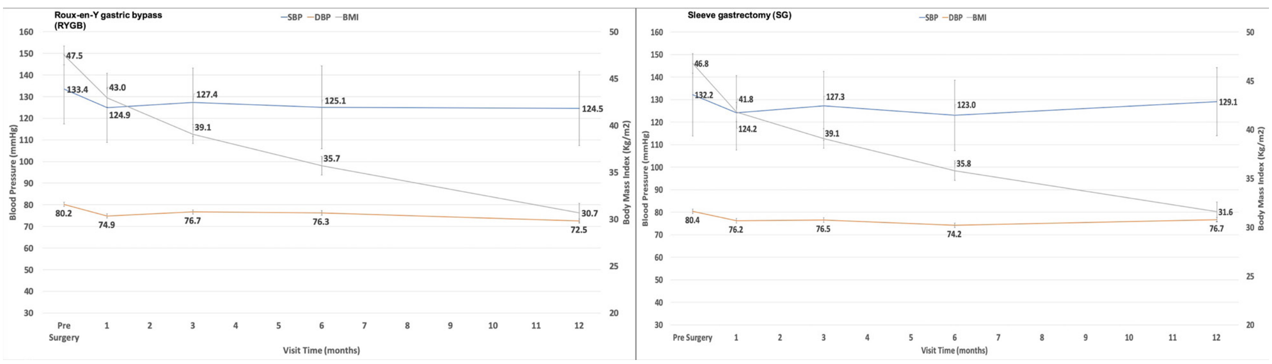


**Figure 1** Mean SBP, DBP and BMI in hypertensive patients after (A) RYGB and (B) SG. Significant decline in BP is noted 1 month after RYGB/SG. BP remains steady until 12 months after RYGB but increases between 6 and 12 months after SG. BMI decreases steadily over 12 months after RYGB/SG. Error bars indicate SD. BMI, body mass index; BP, blood pressure; DBP, diastolic blood pressure; RYGB, Roux-en-Y gastric bypass; SBP, systolic blood pressure; SG, sleeve gastrectomy.

**Table 3** Changes in hemodynamic, anthropometric parameters and BP medications in hypertensive patients over 12 months (propensity matched data)

| Parameter | | Preoperative | 1 month | 3 month | 6 month | 12 month | Mean difference | P value | Between-group difference at 12 months (mean difference (95% CI)) | P value for difference in means between groups at 12 months |
|---|---|---|---|---|---|---|---|---|---|---|
| SBP (mm Hg) | RYGB | 133.4 (16) | 124.9 (16) | 127.4 (15.8) | 125.1 (19.1) | 124.5 (17.1) | 8.9 (3) | 0.003 | −4.6 (−9.5 to 0.3) | 0.07 |
| | SG | 132.2 (18.3) | 124.2 (16.5) | 127.3 (15.3) | 123.0 (15.7) | 129.1 (15.1) | 3.1 (3.2) | 0.34 | | |
| DBP (mm Hg) | RYGB | 80.2 (11.4) | 74.9 (11.6) | 76.7 (11.1) | 76.3 (10.8) | 72.5 (8.4) | 7.7 (1.9) | <0.001 | −4.2 (−7.1 to −1.3) | 0.01 |
| | SG | 80.4 (12.3) | 76.2 (10.4) | 76.5 (9.1) | 74.2 (10.9) | 76.7 (10.5) | 3.7 (2.2) | 0.08 | | |
| HR (beats/min) | RYGB | 81.4 (13.4) | 76.3 (12) | 73.5 (11.1) | 70.6 (11.2) | 73.1 (12.1) | 8.2 (2.4) | 0.001 | 2.4 (−1.2 to 6) | 0.2 |
| | SG | 80.3 (12.9) | 77.2 (14.3) | 71.5 (13.8) | 69 (11.9) | 70.7 (11.4) | 9.6 (2.3) | <0.001 | | |
| Weight (kg) | RYGB | 134.2 (36.5) | 121.5 (34.6) | 110.4 (33.4) | 99.1 (31) | 86.7 (24.9) | 47.5 (6) | <0.001 | −2.3 (−9.3 to 4.7) | 0.5 |
| | SG | 130.7 (30.3) | 117.2 (26.1) | 109 (27.2) | 100.5 (25.7) | 89.0 (21.3) | 41.7 (5.1) | <0.001 | | |
| BMI (kg/m$^2$) | RYGB | 47.5 (10.6) | 43 (10.1) | 39.1 (10.4) | 35.1 (9) | 30.7 (7) | 16.8 (1.7) | <0.001 | −0.9 (−2.9 to 1.1) | 0.4 |
| | SG | 46.8 (9.1) | 41.8 (7.8) | 39.1 (8.0) | 35.8 (7.6) | 31.6 (6.1) | 15.2 (1.5) | <0.001 | | |
| BP meds | RYGB | 1.5 (1.4) | 0.8 (1.1) | 0.6 (1) | 0.7 (1.1) | 0.5 (0.9) | 0.9 (0.2) | <0.001 | NA | 1 |
| | SG | 1.6 (1.3) | 0.6 (0.8) | 0.7 (0.9) | 0.5 (0.8) | 0.5 (0.8) | 1 (0.2) | <0.001 | | |

Mean difference: mean change within subjects from baseline (presurgery) to follow-up (12 months).
P value for baseline to 12 months of follow-up mean difference (two-tailed).
Continuous variables described as absolute means (SD). Mean difference reported with SE in parentheses.
BMI, body mass index; BP, blood pressure; DBP, diastolic blood pressure; HR, heart rate; NA, not applicable; RYGB, Roux-en-Y gastric bypass; SBP, systolic blood pressure; SG, sleeve gastrectomy.

Table 4 Change in weight and blood pressure over 12 months after RYGB and SG

| Variable | Type of surgery | Preop–1 month* | P value* | 1–3 months | 3–6 months | 6–12 months | Preop–12 months† | P value† |
|---|---|---|---|---|---|---|---|---|
| Weight (kg) | RYGB | −12.7 | 0.024 | −11.1 | −11.3 | −12.4 | −47.5 | <0.001 |
| | SG | −13.5 | 0.004 | −8.2 | −8.5 | −11.5 | −41.7 | <0.001 |
| SBP (mm Hg) | RYGB | −8.5 | 0.001 | +2.5 | −2.3 | −0.6 | −8.9 | 0.003 |
| | SG | −8 | 0.006 | +3.1 | −4.3 | +6.1 | −3.1 | 0.34 |
| DBP (mm Hg) | RYGB | −5.3 | 0.024 | +1.8 | −0.4 | −3.8 | −7.7 | <0.001 |
| | SG | −4.2 | 0.004 | +0.3 | −2.3 | +2.5 | −3.7 | 0.08 |

DBP, diastolic blood pressure; RYGB, Roux-en-Y gastric bypass; SBP, systolic blood pressure; SG, sleeve gastrectomy.

of absolute value>10% were considered to indicate significant covariate imbalance.

Descriptive statistics were calculated for each parameter and expressed as mean and SD or median and IQR for continuous variables (based on the normality of distribution), and as frequencies and percentages for categorical variables. Paired-samples t-test was used to assess mean differences in changes from baseline to follow-up (12 months) in normally distributed continuous hemodynamic and anthropometric parameters, whereas the Wilcoxon signed-rank test was used when normality of distribution was not satisfied. Independent categorical parameters were compared using the $\chi^2$ test. Statistical significance was assessed at the two-sided, $\alpha=0.05$ level. Analyses were performed using the SPSS statistical software package V.25.0.

## RESULTS

Over 12 months, 85 and 642 obese patients with HTN underwent RYGB and SG, respectively. Their clinical characteristics are summarized in table 1. Mean body weight and T2D prevalence were greater in patients who underwent RYGB than SG. Clinical characteristics after propensity score matching are detailed in table 2. Follow-up data at 12 months were available for 55.3% of patients. The time course of BP and body weight from baseline to month 12 after RYGB and SG are depicted in figure 1.

At 1 month, mean body weight, BMI, and systolic/diastolic BP decreased by 12.7 kg (p=0.024), 4.5 kg/m$^2$ (p=0.005) and 8.5/5.3 mm Hg (p=0.001/p=0.024) after RYGB and 13.5 kg (p=0.004), 5.0 kg/m$^2$ (p<0.001) and 8.0/4.0 mm Hg (p=0.006/p=0.004) after SG (table 3). Mean percent excess weight loss (% EWL) was 20% after RYGB and 22% after SG. The average number of antihypertensive medications decreased from 1.6 to 0.8 per patient (p<0.001) after RYGB and from 1.5 to 0.6 per patient (p<0.001) after SG.

At month 12, mean body weight and BMI decreased by 47.5 kg (p<0.001) and 16.8 kg/m$^2$ (p<0.001) after RYGB and by 41.7 kg (p<0.001) and 15.2 kg/m$^2$ (p<0.001) after SG (table 4). Mean % EWL was 74% after RYGB and after SG. SBP/DBP decreased by 8.9/7.7 mm Hg (p=0.003/p<0.001) after patients underwent RYGB and by 3.1/3.7 mm Hg (p=0.34/p=0.08) after patients underwent SG. Remission of HTN occurred in 52% and 44% after RYGB and SG, respectively (table 5).

## DISCUSSION

The time course of BP decline and weight loss differ after RYGB and SG. Both yield their full effect on BP within the first month of the procedure. At 1 month, SBP/DBP decreased by 8.5/5.3 mm Hg (p=0.001/p=0.024) and by 8.0/4.0 mm Hg (p=0.006/p=0.004) after SG. Thereafter, BP remains stable from month 1 to 12 after RYGB, and it increases from month 6 to 12 after SG. In contrast to BP, body weight decreases steadily throughout the 12 months after RYGB and SG (figure 2).

The rapid BP decline in our patients after RYGB and SG is congruent with previous reports.[9–14] Ahmed *et al* noted an immediate BP reduction of 9/7 mm Hg within 1 week of RYGB.[10] Similarly, Hawkins *et al* observed a decrease in mean BP of 4.5 mm Hg 2 weeks after RYGB or SG in obese patients with HTN.[11] Prompt lessening of antihypertensive

Table 5 Distribution of blood pressure medications by visit (expressed as percent of total hypertensive patients)

| Meds | Surgery type | Baseline (%) | 1 month (%) | 3 months (%) | 6 months (%) | 12 months (%) |
|---|---|---|---|---|---|---|
| 0 | RYGB | 32.9 | 56 | 60.3 | 61.6 | 68.2 |
| | SG | 30.6 | 60.8 | 55.9 | 66.7 | 60.9 |
| 1 | RYGB | 21.2 | 23.8 | 23.1 | 19.2 | 16.7 |
| | SG | 16.5 | 23 | 23.5 | 20.6 | 28.3 |
| 2 | RYGB | 21.2 | 10.7 | 10.3 | 8.2 | 9.1 |
| | SG | 25.9 | 14.9 | 16.2 | 9.5 | 6.5 |
| 3 | RYGB | 17.6 | 7.1 | 5.1 | 9.6 | 4.5 |
| | SG | 20 | 1.4 | 4.4 | 3.2 | 4.3 |
| 4 | RYGB | 4.7 | 2.4 | 1.3 | 1.4 | 1.5 |
| | SG | 5.9 | 0 | 0 | 0 | 0 |
| 5 | RYGB | 2.4 | 0 | 0 | 0 | 0 |
| | SG | 1.2 | 0 | 0 | 0 | 0 |

RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

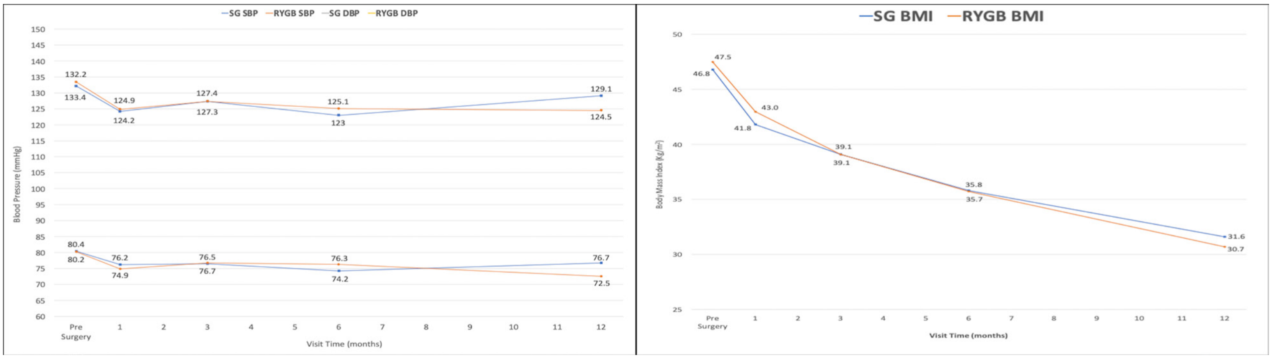


**Figure 2** (A) Mean SBP and DBP after RYGB and SG. Significant decline noted in SBP/DBP from baseline to 1 month after RYGB (p=0.001/p=0.024) and after SG (p=0.006/p=0.004). At 12 months, SBP/DBP remains lower compared with baseline after RYGB (p=0.003/p<0.001) but not after SG (p=0.34/p=0.08). (B) Mean BMI after RYGB and SG. A steady weight loss is noted throughout the 12 months after RYGB (p<0.001) and SG (p<0.001). BMI, body mass index; DBP, diastolic blood pressure; RYGB, Roux-en-Y bypass surgery; SBP, systolic blood pressure; SG, sleeve gastrectomy.

therapy was also previously reported after metabolic surgery.[14 15]

The underlying mechanisms of early BP reduction after RYGB and SG are being investigated.[16] Calorie intake is typically very low in the preoperative and early postoperative periods. Adherence to a very low-calorie diet for 1–2 weeks significantly reduces BP.[17 18] Prompt inhibition of sympathetic overdrive after metabolic surgery may also contribute to BP reduction immediately after the procedure.[19–21] Circulating levels of gut hormones such as glucagon-like peptide-1 (GLP-1) and peptide YY (PYY) increase rapidly after RYGB and SG.[22] In addition to maintaining glucose homeostasis, GLP-1 and PYY modulate sympathetic tone and renal sodium handling and thereby partly account for early BP reduction after bariatric surgery.[23]

The sustained effect of RYGB on BP is corroborated by a greater HTN remission with RYGB than SG. The HTN remission rate of 52% is similar to that reported in the Gastric Bypass to Treat Obese Patients with Steady Hypertension trial, the only randomized trial that evaluated BP as a primary endpoint.[15] A higher HTN remission rate at 1 year after RYGB compared with SG (71% vs 56%) was also previously noted among 264 obese patients with HTN.[24] Recently, a meta-analysis of studies reporting long-term HTN outcomes found that the 5-year HTN remission rate is 26% greater with RYGB than SG.[25] The extended 10-year follow-up data from the Swedish Obese Subjects study also indicate that RYGB results in a greater control of BP than purely restrictive procedures.[26] Long-term BP effect of metabolic surgery may depend on weight maintenance over time. Immediate and sustained effects of metabolic surgery are clearly mediated through different mechanisms.

The overt limitations of the present study are its single center and short duration nature, as well as the lack of ambulatory BP measurement. Further, as antihypertensive therapy is de-escalated after metabolic surgery, one does not capture the full antihypertensive impact of a given procedure. Lessening of antihypertensive therapy after the procedure may more accurately reflect the full antihypertensive effect of metabolic surgery than BP reduction. In this regard, changes in the dosage of antihypertensive medications need to be reported.

## CONCLUSIONS

One year after the procedure, RYGB is more effective than SG for BP reduction and HTN remission in obese patients with HTN. It may be preferred to SG in patients with obesity-associated HTN.

**Contributors** RS and TLJ planned the study. EMJ, JC and GS performed data collection. GS and EMJ performed the statistical analysis. RS and TLJ interpreted the data and drafted the manuscript. All authors contributed to editing the text.

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