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Anthropometric and Metabolic Changes and Comorbidity Remission Rates After Predominantly Sleeve Gastrectomy at a Referral Center in Southwestern Colombia: A Retrospective Cohort Study, 2022-2023

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Carlos Berrocal [1], Daniela Arias Echeverri [2], Jhon H. Quintana [3], Jose Luis Pineda Bocanegra [4], Víctor Alonso Carrascal Carrascal [5], Elvis Mauricio Pérez Lafont [6], María Daniela Prada Quiñones [7], Guadalupe Durango Pacheco [8], Juan Pablo Martínez Buitrago [9], Alyi Alejandro Arellano Cabeza [1], Antonio M. Zumaque Carrascal [10], Andrés Felipe García Ramos [11]

1. Internal Medicine, Hospital Universitario del Valle, Universidad del Valle, Cali, COL 2. General Practice, Hospital Universitario del Valle, Universidad del Valle, Cali, COL 3. Internal Medicine, Clínica de Occidente, Cali, COL 4. Internal Medicine, Hospital San Jerónimo de Montería, Universidad del Sinú, Montería, COL 5. General Practice, Clínica Fundación Amigos de la Salud, Monteria, COL 6. General Practice, ESE Vida Sinú, Montería, COL 7. General Practice, Hospital San Jerónimo de Montería, Universidad del Sinú, Montería, COL 8. General Practice, Clínica NEFROUROS, Bello, COL 9. General Practice, Uniremington, Medellín, COL 10. General Practice, Universidad del Sinú, Montería, COL 11. Endocrinology, Hospital Universitario del Valle, Universidad del Valle, Cali, COL

Corresponding author: Carlos Berrocal, carlos.berrocal@correounivalle.edu.co

Abstract

Background: Bariatric surgery is among the most effective interventions for weight loss and metabolic improvement; real-world evidence from Latin America, particularly for sleeve gastrectomy, remains limited.

Objective: To evaluate metabolic changes and estimate comorbidity remission rates after bariatric surgery at a referral center in southwestern Colombia (2022-2023).

Methodology: This retrospective pre-post cohort study included 315 adults. Preoperative and latest available postoperative values (up to 36 months) were compared using a paired t-test or Wilcoxon signed-rank test (Hodges-Lehmann differences with 95% confidence intervals (CIs) for nonnormally distributed variables). Remission denominators included all patients with the diagnosis.

Results: Most patients were female (300/315, 95.2%) and underwent sleeve gastrectomy (300/315, 95.2%). Median follow-up was 12.0 months; postoperative data availability ranged from 97.8% (weight/body mass index (BMI)) to 17.1% (vitamin B12). Weight (-23.0 kg; 95% CI, -24.5 to -21.5) and BMI (-10.4 kg/m^2; 95% CI, -10.8 to -9.7) decreased, as did glucose, glycated hemoglobin (HbA1c), triglycerides, total and low-density lipoprotein (LDL) cholesterol, and blood pressure; high-density lipoprotein (HDL) increased (all $P < 0.001$). Greater weight loss correlated with larger reductions in HbA1c and blood pressure. Remission rates were 55/140 (39.3%) for prediabetes, 15/67 (22.4%) for type 2 diabetes (8/67 sustained through 12 months), and 15/120 (12.5%) for hypertension. Three patients had dumping syndrome, 2 required conversion to gastric bypass, and 1 died intraoperatively.

Conclusions: In this predominantly female, sleeve gastrectomy cohort, surgery was associated with weight loss and cardiometabolic improvement. Remission rates were lower than those reported in controlled trials, possibly reflecting differences in study design and definitions. Substantial missing data limit interpretation, and the findings cannot be extrapolated to men or other procedures.

Categories: Internal Medicine, Endocrinology/Diabetes/Metabolism, Gastroenterology
Keywords: bariatric surgery, diabetes type 2, gastrectomy, gastric bypass surgery (gastrojejunostomy), metabolic syndrome (metsd), obesity, postoperative complication

Introduction

Obesity has become established as a chronic disease of high prevalence and multisystemic impact, with a sustained upward trend across most countries over recent decades. Between 1975 and 2016, the prevalence of excess weight (defined as a body mass index (BMI) ⩾ 25 kg/m^2) in adults increased from approximately 21% in men and 24% in women to roughly 40% in both sexes [1]. Over the same period, the prevalence of obesity (BMI ⩾ 30 kg/m^2) quadrupled in men - from 3% to 12% - and doubled in women - from 7% to 16% [1]. These increases have been observed across all age groups and sexes, regardless of geographic location, ethnicity, or socioeconomic status [2]. More recent data confirm the persistence of this trend: a global analysis encompassing over 222 million participants from 200 countries showed that, between 1990 and

2022, the combined burden of underweight and obesity increased in most countries, driven primarily by a sustained rise in obesity. By 2022, obesity had surpassed underweight in prevalence in the vast majority of countries, consolidating its position as the leading component of the double burden of malnutrition worldwide [3].

In Colombia, available data reflect a similar trajectory. Between 2005 and 2010, the prevalence of obesity in adults increased from 13.9% to 16.4%, with a disproportionate burden among women and individuals aged 55-64 years; additionally, overweight and obesity were more prevalent in urban areas and among lower socioeconomic groups [4]. According to the most recent National Nutritional Status Survey (ENSIN 2015), 56.4% of the adult population had excess weight - including 18.7% with obesity - representing a 5.2-percentage-point increase from 2010, with higher rates in women (22.4%) than in men (14.4%) [5]. This growing burden, compounded by the finding that only approximately half of Colombian adults meet the World Health Organization (WHO)-recommended minimum of 150 minutes per week of moderate-intensity or 75 minutes per week of vigorous-intensity physical activity [5], underscores the need for comprehensive, multidimensional public health interventions.

Beyond its rising prevalence, the clinical significance of obesity lies in its well-established association with comorbidities of high morbidity and mortality, including arterial hypertension (AHT), dyslipidemia, type 2 diabetes mellitus (T2DM), cardiovascular disease, metabolic dysfunction-associated steatotic liver disease (MASLD), and metabolic syndrome [6]. Management of obesity requires a multimodal approach encompassing dietary and lifestyle modifications, anti-obesity pharmacotherapy, treatment of associated comorbidities, and, in selected cases, bariatric surgery. Among these, bariatric surgery represents the intervention with the greatest demonstrated long-term effectiveness for sustained weight loss and remission of metabolic comorbidities in patients with class III obesity or class II obesity with high cardiovascular risk [7]. Randomized controlled trials (RCTs) and long-term cohort studies have documented its superiority over intensive medical management in reducing HbA1c, blood pressure, and major adverse cardiovascular events, with benefits persisting at 10-15 years of follow-up [8-11]. Nevertheless, effectiveness observed under real-world clinical conditions may differ from that reported in controlled settings [12, 13], particularly in Latin American contexts where follow-up intensity, population characteristics, and available resources differ from those of international referral centers [14, 15].

Evidence on the magnitude of clinical and metabolic changes following bariatric surgery at Colombian referral centers remains limited, and even less information is available regarding comorbidity remission rates under routine practice conditions. The present study aimed to describe changes in anthropometric, clinical, and metabolic variables and to estimate remission rates of the main associated metabolic comorbidities, including T2DM, prediabetes, and AHT, in patients who underwent bariatric surgery at the Hospital Universitario del Valle Evaristo García, a tertiary referral center in southwestern Colombia, during the period 2022-2023.

Materials And Methods

Study design

This was a retrospective cohort study with repeated measurements, using a pre-post design with an analytical component, conducted within the Obesity Program of the Hospital Universitario del Valle Evaristo García, a tertiary referral center for bariatric surgery in Cali, southwestern Colombia.

Population and sample

The study population comprised all consecutive adult patients aged ⩾18 years who underwent bariatric surgery at the institution between January 2022 and December 2023. A census approach was used, including all procedures performed during the study period (n = 315; 2022: n = 116; 2023: n = 199). Sleeve gastrectomy is the procedure of choice at our institution according to the institutional protocol, given its technical simplicity. Two patients underwent revisional procedures (Roux-en-Y refashioning with distalization and conversion of a previous sleeve gastrectomy to single-anastomosis duodeno-ileal bypass with sleeve gastrectomy (SADI-S)); their baseline measurements correspond to the time before revision.

Data collection

Data were obtained through a systematic review of electronic medical records. The following variables were collected: sociodemographic variables (age, sex), anthropometric variables (body weight, BMI), preoperative comorbidities (T2DM, AHT, prediabetes, MASLD, obstructive sleep apnea (OSA), polycystic ovary syndrome (PCOS), hypothyroidism, and heart failure with preserved ejection fraction), type of surgical procedure, postoperative laboratory and blood pressure measurements, comorbidity remission, and recorded complications (dumping syndrome, reoperation or conversion, and mortality). Postoperative follow-up was recorded as months since surgery at scheduled visits (nominally 1, 3, 6, 12, 18, 24, 30, and 36 months); exact calendar dates were not available. Implausible values identified during data cleaning were reviewed against the medical record and corrected or set to missing.

Outcome definitions

Baseline diagnoses of T2DM, AHT, and prediabetes were taken from the medical record according to the following criteria: T2DM, HbA1c ⩾6.5%, fasting glucose ⩾126 mg/dL, or use of glucose-lowering medication; AHT, blood pressure ⩾140/90 mmHg or a documented diagnosis or treatment; and prediabetes, HbA1c 5.7-6.4% or fasting glucose 100-125 mg/dL. T2DM remission was defined according to the international consensus [8] as HbA1c <6.5% measured at least 3 months after discontinuation of all glucose-lowering pharmacotherapy, including oral agents, insulin, and injectable glucose-lowering therapies. Because exact discontinuation dates were not available, the medication-free interval was inferred from the medical record: remission was considered present when postoperative HbA1c was <6.5% and no glucose-lowering pharmacotherapy was documented at that assessment. Sustained remission through 12 months was defined for this study as remission documented at both the 6- and 12-month postoperative assessments, with HbA1c <6.5% and no glucose-lowering pharmacotherapy at each assessment. T2DM remission was the primary outcome; sustained remission through 12 months was assessed as a stricter secondary analysis. Prediabetes remission was operationally defined as normalization of HbA1c (<5.7%) and fasting glucose (<100 mg/dL) on the latest available postoperative measurement (up to 36 months), without glucose-lowering treatment [9]. This definition is based on a single postoperative measurement. AHT remission was defined as blood pressure <140/90 mmHg in the absence of antihypertensive treatment, documented at two consecutive follow-up visits six months apart [10].

Statistical analysis

The statistical analysis was conducted in two phases. In the descriptive phase, categorical variables were summarized as absolute frequencies and proportions with 95% confidence intervals (CIs, Clopper-Pearson). Quantitative variables were described using medians and interquartile ranges (IQRs) or means and standard deviations (SD), as appropriate, after assessment of distributional assumptions using the Shapiro-Wilk test. In the analytical phase, for the pre-post comparisons, the postoperative value used for each patient was the most recent measurement documented in the electronic medical record up to 36 months after surgery. The interval between surgery and this measurement was calculated for each patient and outcome and is reported in Table *2* (median (IQR), in months). For body weight and BMI, two predefined follow-up windows (11-20 months and 21-30 months) were additionally described to illustrate the postoperative trajectory. Because different patients contributed to each window, paired differences were calculated within each window. Weight change between windows was assessed only in the subset of patients with measurements in both windows. For pre-post comparisons of continuous variables, a complete-case analysis was performed, including only patients with both preoperative and eligible postoperative measurements for each outcome. Comorbidity remission rates were not analyzed on a complete-case basis: the denominator comprised all patients with the corresponding baseline diagnosis, and patients without sufficient follow-up to assess remission were classified as not in remission. No formal imputation was performed because of the retrospective design. To explore selection bias, baseline characteristics (age, sex, procedure, baseline BMI, comorbidities, and baseline value of the variable) were compared between patients with and without a postoperative measurement for each outcome using the Mann-Whitney U test, chi-square test, or Fisher exact test, and standardized mean differences were calculated. Pre-post differences were calculated on a paired basis. Variables with approximately normal distributions of paired differences were analyzed using the paired Student's t-test, whereas non-normally distributed variables were analyzed using the Wilcoxon signed-rank test. Point estimates were reported as means with SD for normally distributed variables and as Hodges-Lehmann pseudomedians with 95% CIs for non-normal variables. Percentage total weight loss (%TWL) was calculated for each patient. The association between %TWL and the paired change in each metabolic variable (post - baseline) was assessed with Spearman correlation and multivariable linear regression adjusted for baseline value, age, sex, time from surgery to measurement, and procedure type. Categorical variables were compared using the chi-square test or Fisher exact test, as appropriate. A sensitivity analysis excluded patients whose latest postoperative weight measurement was obtained before 6 months. A two-sided P value <0.05 was considered statistically significant. All analyses were performed using R version 4.5.3 (R Core Team, 2025) with the coin, DescTools, and ggplot2 packages.

Ethical considerations

The study was approved by the Research Ethics Committee of the Hospital Universitario del Valle (Record No. 24, 2024). In accordance with Resolution 8430 of 1993 of the Colombian Ministry of Health, the study was classified as no-risk research because it was an observational, retrospective study based on medical record review; accordingly, the committee waived the requirement for informed consent. The study was conducted in compliance with the principles of the Declaration of Helsinki and the guidelines of the Council for International Organizations of Medical Sciences (CIOMS, 2016).

Results

Baseline cohort characteristics

A total of 315 patients who underwent bariatric surgery during the study period were included (Figure *1*). The cohort was predominantly female (300/315, 95.2%) and underwent sleeve gastrectomy in 95.2% of cases (300/315), with a median age of 39 years (IQR 31-47) and a median baseline BMI of 41.0 kg/m² (class III obesity). Baseline T2DM was more frequent in men than in women (8/15, 53.3% vs. 59/300, 19.7%; $P = 0.005$,

Fisher exact test). Detailed baseline characteristics, including the prevalence of metabolic and endocrine comorbidities, are presented in Table 1.

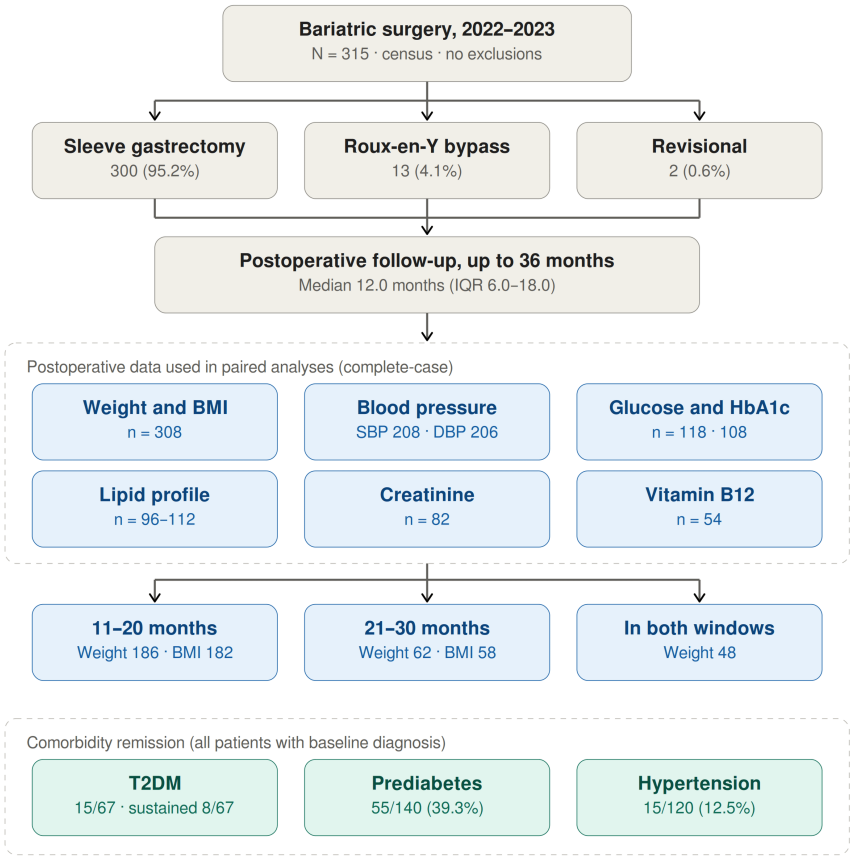


FIGURE 1: Patient flow and data availability.

Flow diagram of the 315 patients who underwent bariatric surgery at the Hospital Universitario del Valle Evaristo García (2022-2023), included by census with no exclusions. Postoperative follow-up was analyzed up to 36 months. For each outcome, the number of patients with both a baseline and a postoperative measurement is shown (complete-case analysis for pre-post comparisons); patients without a documented postoperative measurement for a given variable were excluded from the analysis of that variable. The numbers of patients with weight and BMI measurements differ because, in some patients, only one of the two measures was recorded or the recorded BMI was implausible and was excluded. The weight windows include different patients; 48 patients had weight recorded in both. For comorbidity remission, the denominator comprised all patients with the corresponding baseline diagnosis; patients without sufficient follow-up were counted as not in remission. Sustained T2DM remission was defined as HbA1c <6.5% without glucose-lowering therapy at both the six- and 12-month assessments. Figure created using Claude (Anthropic, PBC, San Francisco, CA).

T2DM, type 2 diabetes mellitus; SBP, systolic blood pressure; DBP, diastolic blood pressure

Variable	Value
Total	315 (100%)
Age (years), median (IQR)	39 (31-47)
Female sex, *n* (%)	300 (95.2%)
Male sex, *n* (%)	15 (4.8%)
Body weight (kg), median (IQR)	98 (86-113)
BMI (kg/m²), median (IQR)	41.0 (37.5-46.0)
MASLD, *n* (%)	152 (48.3%)
Prediabetes§, *n* (%)	140 (44.4%)
Arterial hypertension (AHT)§, *n* (%)	120 (38.1%)
Dyslipidemia§, *n* (%)	99 (31.4%)
Obstructive sleep apnea (OSA), *n* (%)	70 (22.2%)
Type 2 diabetes mellitus (T2DM)§, *n* (%)	67 (21.3%)
Hypothyroidism, *n* (%)	37 (11.7%)
Polycystic ovary syndrome (PCOS)†, *n* (%)	22 (7.3%)
Subclinical hypothyroidism, *n* (%)	12 (3.8%)
Heart failure with preserved ejection fraction (HFpEF), *n* (%)	1 (0.3%)
Sleeve gastrectomy, *n* (%)	300 (95.2%)
Roux-en-Y gastric bypass, *n* (%)	13 (4.1%)
Other procedures‡, *n* (%)	2 (0.6%)

TABLE 1: Baseline sociodemographic, anthropometric, and clinical characteristics of patients undergoing bariatric surgery (N = 315).

†Calculated over the total number of women in the cohort (*n* = 300).

‡Both were revisional procedures: Roux-en-Y refashioning with distalization of the alimentary limb after a previous bypass (*n* = 1) and conversion of a previous sleeve gastrectomy to SADI-S (single-anastomosis duodeno-ileal bypass with sleeve gastrectomy) (*n* = 1). Their baseline measurements correspond to the time before revision.

§Baseline diagnoses were taken from the medical record: prediabetes, HbA1c 5.7-6.4% or fasting glucose 100-125 mg/dL; AHT, blood pressure ≥140/90 mmHg or documented diagnosis or treatment; T2DM, HbA1c ≥6.5%, fasting glucose ≥126 mg/dL, or use of glucose-lowering medication; dyslipidemia, triglycerides ≥150 mg/dL, low HDL cholesterol, LDL cholesterol ≥130 mg/dL, or lipid-lowering treatment.

Age was available for 313 patients and baseline BMI for 311 patients; missing values were not imputed.

BMI, body mass index; MASLD, metabolic dysfunction-associated steatotic liver disease; OSA, obstructive sleep apnea; T2DM, type 2 diabetes mellitus; PCOS, polycystic ovary syndrome; HFpEF, heart failure with preserved ejection fraction; IQR, interquartile range (P25-P75)

Follow-up and data availability

Postoperative follow-up was analyzed up to 36 months. Median follow-up was 12.0 months (IQR 6.0-18.0; range 0-36); follow-up of at least 6, 12, 24, and 30 months was available for 278/315 (88.3%), 196/315 (62.2%), 58/315 (18.4%), and 18/315 (5.7%) patients, respectively. The time from surgery to the postoperative measurement used for each outcome is shown in Table *2*. Postoperative data availability varied by outcome (Figure *1*): weight/BMI, 308 patients (97.8%); blood pressure, 206-208 (65.4-66.0%); fasting glucose, 118 (37.5%); HbA1c, 108 (34.3%); lipid profile, 96-112 (30.5-35.6%); creatinine, 82 (26.0%); and vitamin B12, 54 (17.1%). Type 2 diabetes was present at baseline in 52/108 patients (48.1%) with a postoperative HbA1c versus 15/207 (7.2%) of those without ($P < 0.0001$); patients with a postoperative HbA1c were also older (42.8 vs. 37.9 years) and had higher baseline HbA1c (6.28% vs. 5.31%). Similarly,

hypertension was present at baseline in 98/208 patients (47.1%) with postoperative blood pressure measurements versus 22/107 (20.6%) of those without ($P < 0.0001$). Baseline BMI did not differ between patients with and without postoperative weight ($P = 0.89$).

Variable	*n*	Baseline	Postoperative	Difference (95% CI)	Months from surgery, median (IQR)	*P*
Body weight (kg)	308	98.0 (86.0-113.0)	75.0 (65.0-87.0)	-23.0 (-24.5, -21.5)	12.0 (6.0-13.0)	<0.001
BMI (kg/m²)	308	41.0 (37.0-45.0)	30.8 (27.2-35.1)	-10.4 (-10.8, -9.7)	12.0 (6.0-13.0)	<0.001
Fasting glucose (mg/dL)	118	98.0 (88-118)	84.0 (78-92)	-16.0 (-22.0, -11.0)	12.0 (6.0-12.0)	<0.001
HbA1c (%)	108	5.90 (5.4-6.5)	5.30 (5.0-5.6)	-0.60 (-0.80, -0.40)	12.0 (6.0-12.0)	<0.001
Total cholesterol (mg/dL) †	112	198.5 ± 38.2	178.2 ± 32.4	-20.3 (-26.8, -13.8)	12.0 (6.0-12.0)	<0.001
LDL cholesterol (mg/dL) †	98	122.4 ± 32.1	104.1 ± 28.2	-18.3 (-24.2, -12.4)	12.0 (6.0-12.0)	<0.001
HDL cholesterol (mg/dL) †	102	44.2 ± 10.8	52.6 ± 12.4	+8.4 (+6.1, +10.7)	12.0 (6.0-12.0)	<0.001
Triglycerides (mg/dL)	96	165.0 (128-215)	105.0 (82-132)	-58.0 (-72.0, -45.0)	12.0 (6.0-12.0)	<0.001
Systolic BP (mmHg)	208	126.0 (120-138)	118.0 (110-122)	-10.0 (-12.0, -8.0)	12.0 (6.0-12.0)	<0.001
Diastolic BP (mmHg)	206	80.0 (74-88)	72.0 (70-78)	-8.0 (-10.0, -6.0)	12.0 (6.0-12.0)	<0.001
Vitamin B12 (pg/mL) †	54	412.0 ± 185.0	485.0 ± 220.0	+73.0 (+21.5, +124.5)	12.0 (6.0-12.0)	0.006
Creatinine (mg/dL)	82	0.80 (0.70-0.92)	0.70 (0.60-0.80)	-0.10 (-0.12, -0.07)	12.0 (6.0-12.0)	<0.001

TABLE 2: Paired changes in anthropometric, metabolic, and laboratory variables between baseline and the latest available postoperative measurement, and time from surgery to that measurement.

Values are median (IQR) for variables analyzed with the Wilcoxon signed-rank test (difference: Hodges-Lehmann pseudomedian) and mean ± SD for variables marked with † (paired Student's t-test; difference: mean difference). The postoperative value is the most recent measurement recorded during follow-up, up to 36 months. Follow-up was recorded as months since surgery at scheduled visits; exact calendar dates were not available. HbA1c difference is expressed in percentage points.

BMI, body mass index; BP, blood pressure; CI, confidence interval; IQR, interquartile range

Changes in body weight and BMI

Considering the latest available postoperative measurement ($n = 308$), body weight and BMI decreased significantly. The paired median difference was -23.0 kg (95% CI, -24.5 to -21.5) for body weight and -10.4 kg/m² (95% CI, -10.8 to -9.7) for BMI (both $P < 0.001$; Table 2). The median per-patient percentage total weight loss (%TWL) was 23.5% (IQR 18.2-28.6). In a sensitivity analysis excluding the 16 patients whose latest weight measurement was obtained before six months ($n = 292$), the paired differences were -24.5 kg (95% CI, -25.8 to -23.0) for weight and -10.9 kg/m² (95% CI, -11.4 to -10.2) for BMI.

In the 11- to 20-month window ($n = 186$), the paired weight difference was -26.0 kg (95% CI, -27.5 to -24.5) (median %TWL, 26.5%), and in the 21- to 30-month window ($n = 62$), it was -22.0 kg (95% CI, -24.5 to -19.5) (median %TWL, 22.4%) (Figure 2A). BMI changed by -11.9 and -10.5 kg/m², respectively (Figure 2B); all *P*-values were <0.001. These windows include different patients and were therefore not compared directly. Measurements obtained after 30 months were included in the latest available analysis but are not represented in the two windows. In the 48 patients with weight recorded in both windows, median weight increased from 72.0 kg at 11-20 months to 76.5 kg at 21-30 months (paired difference, +4.5 kg; 95% CI, 3.0 to 6.0; $P < 0.001$; Figure 2C). The number of patients with postoperative weight and BMI measurements

differed slightly within each window (186 vs. 182 and 62 vs. 58) because, in some patients, only one of the two measures was recorded in the medical record or the recorded BMI value was implausible and was excluded during data cleaning. Missing values were not imputed.

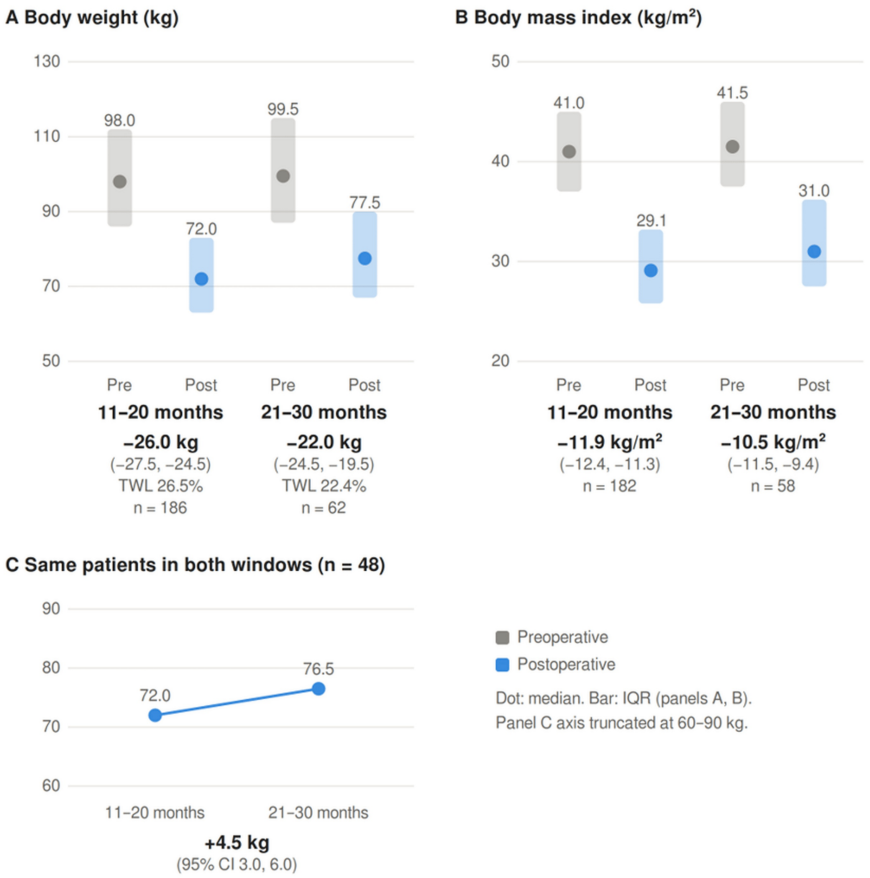


FIGURE 2: Body weight and body mass index in the 11- to 20- and 21- to 30-month postoperative windows.

(A) and (B) Median (dot) and interquartile range (bar) of preoperative and postoperative values; within each window, the preoperative value corresponds to the same patients as the postoperative value. Below each window: paired Hodges-Lehmann difference (95% CI), median per-patient percentage total weight loss (TWL; panel A), and number of patients. The two windows include different patients and were not compared directly. (C) Median weight of the 48 patients with weight recorded in both windows (paired difference, +4.5 kg; 95% CI, 3.0 to 6.0; axis truncated at 60-90 kg). The number of patients with weight and BMI measurements differs because, in some patients, only one of the two measures was recorded or the recorded BMI was implausible and was excluded.

IQR, interquartile range; CI, confidence interval

Changes in metabolic variables

Changes in clinical and metabolic variables between baseline and the latest available postoperative measurement (up to 36 months) are summarized in Figure *3* and Table *2*.

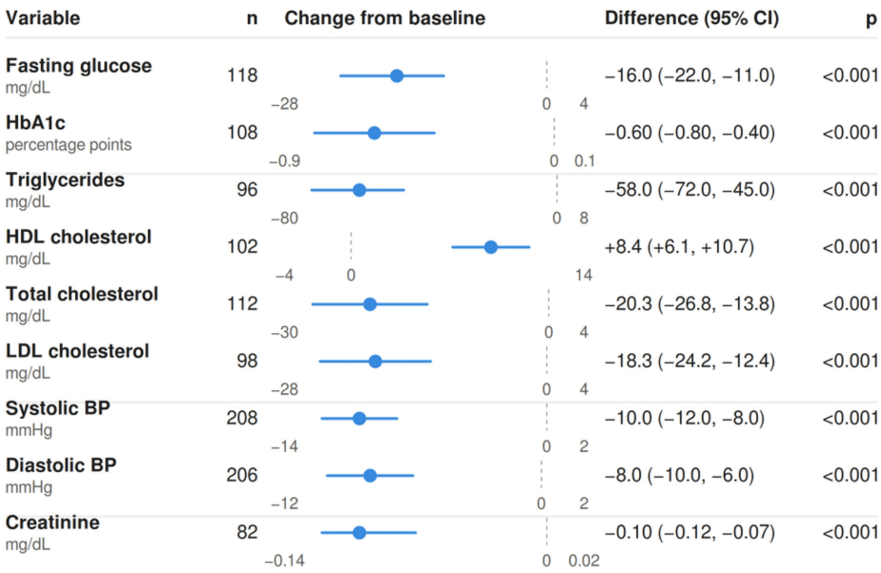


FIGURE 3: Paired changes in clinical and metabolic variables between baseline and the latest available postoperative measurement (up to 36 months).

Dots show the paired difference (postoperative - baseline), and bars show the 95% confidence interval. For fasting glucose, HbA1c, triglycerides, systolic and diastolic blood pressure, and creatinine, differences are Hodges-Lehmann pseudomedians (Wilcoxon signed-rank test); for total, LDL, and HDL cholesterol, they are mean differences (paired Student's t-test). The dashed vertical line marks no change. Each row has its own scale, so interval lengths are not comparable across variables.

LDL, low-density lipoprotein; HDL, high-density lipoprotein; BP, blood pressure; HbA1c, glycated hemoglobin

n, number of patients with paired measurements; BP, blood pressure

Glycemic Control

Fasting glucose (*n* = 118) and HbA1c (*n* = 108) decreased significantly (paired differences, -16.0 mg/dL (95% CI -22.0 to -11.0) and -0.60 percentage points (95% CI -0.80 to -0.40), respectively; both *P* < 0.001).

Lipid Profile

Triglycerides decreased (-58.0 mg/dL; 95% CI -72.0 to -45.0; *n* = 96), and HDL cholesterol increased (+8.4 mg/dL; 95% CI +6.1 to +10.7; n = 102). Total cholesterol (*n* = 112) and LDL cholesterol (*n* = 98) also decreased (mean differences, -20.3 mg/dL (95% CI -26.8 to -13.8) and -18.3 mg/dL (95% CI -24.2 to -12.4), respectively). All changes in lipid variables were significant (*P* < 0.001).

Blood Pressure

Systolic (*n* = 208) and diastolic (*n* = 206) blood pressure decreased significantly (-10.0 mmHg (95% CI -12.0 to -8.0) and -8.0 mmHg (95% CI -10.0 to -6.0), respectively; both *P* < 0.001).

Vitamin B12 and Renal Function

In the 54 patients with paired vitamin B12 measurements, mean B12 increased from 412 to 485 pg/mL (paired difference, +73.0 pg/mL; 95% CI +21.5 to +124.5; *P* = 0.006); deficiency (<200 pg/mL) was present in 4 (7.4%) before and 2 (3.7%) after surgery. Supplementation was not recorded. Serum creatinine (*n* = 82) decreased from a median of 0.80 to 0.70 mg/dL (paired difference, -0.10 mg/dL; 95% CI -0.12 to -0.07; *P* < 0.001).

Association between weight loss and metabolic changes

Greater %TWL was correlated with larger reductions in HbA1c (r_s = -0.48, *n* = 108), fasting glucose (r_s = -0.42, *n* = 118), triglycerides (r_s = -0.39, *n* = 96), systolic blood pressure (r_s = -0.31, *n* = 208), and diastolic

blood pressure (r_s = -0.28, *n* = 206), and with larger increases in HDL cholesterol (r_s = +0.35, *n* = 102) (all *P* < 0.001; Table 3). In adjusted models, each additional 10 percentage points of %TWL was associated with an additional reduction of 0.38 percentage points in HbA1c (95% CI 0.21-0.55), 3.2 mmHg in systolic blood pressure (95% CI 1.6-4.8), and 2.1 mmHg in diastolic blood pressure (95% CI 0.9-3.3).

Variable	*n*	Spearman r_s	*P*
HbA1c	108	-0.48	<0.001
Fasting glucose	118	-0.42	<0.001
Triglycerides	96	-0.39	<0.001
HDL cholesterol	102	+0.35	<0.001
Systolic blood pressure	208	-0.31	<0.001
Diastolic blood pressure	206	-0.28	<0.001

TABLE 3: Correlation between percentage total weight loss (%TWL) and the paired change in metabolic variables.

Paired change = postoperative - baseline. A negative correlation indicates that greater %TWL was associated with a larger reduction in the variable; for high-density lipoprotein (HDL) cholesterol, a positive correlation indicates a larger increase. Adjusted regression estimates are reported in the text.

Comorbidity remission

Remission rates were calculated using all patients with the baseline diagnosis as the denominator; patients without sufficient follow-up were counted as not in remission, so these figures may underestimate the true remission rate. Remission of prediabetes, assessed on a single postoperative measurement, was documented in 39.3% (55/140, 95% CI 31.1-47.9%) of patients. T2DM remission was documented in 22.4% (15/67, 95% CI 13.1-34.2%), and 8 patients (11.9% of all patients with T2DM, 95% CI 5.3-22.2%) met the definition of sustained remission through 12 months. AHT remission was documented in 12.5% (15/120, 95% CI 7.2-19.8%) (Figure 1).

Adverse events and mortality

Postoperative dumping syndrome was recorded in 3/315 patients (0.95%). One intraoperative death occurred (1/315, 0.32%), and no further deaths were recorded during follow-up. Two patients (0.6%) required conversion to Roux-en-Y gastric bypass for refractory gastroesophageal reflux after sleeve gastrectomy. Other complications (e.g., leak, stricture, bleeding, hernia, or readmission) were not systematically recorded.

Discussion

The findings of this retrospective cohort from a referral center in southwestern Colombia, composed predominantly of women (300/315, 95.2%) who underwent sleeve gastrectomy (300/315, 95.2%), show that surgery was associated with weight loss accompanied by improvement in the cardiometabolic profile at the latest available follow-up. However, remission rates for T2DM, prediabetes, and arterial hypertension were lower than those reported in clinical trials and large international cohorts, a difference likely attributable to varying operational definitions, follow-up intensity, and outcome ascertainment methods. Because postoperative data were missing for a large proportion of patients, the results describe mainly the patients with available measurements and should be interpreted with caution. Contemporary evidence supports bariatric and metabolic surgery as an effective intervention for sustained weight loss and cardiometabolic risk improvement, with the need for prolonged follow-up given the risks of weight regain, metabolic recurrence, and nutritional deficiencies [11].

Anthropometric changes: magnitude and trajectory

Body weight and BMI decreased substantially after surgery (median paired weight loss of 23.0 kg, median %TWL 23.5%), with paired differences of -26.0 kg (26.5% TWL) at 11-20 months and -22.0 kg (22.4% TWL) at 21-30 months (Figure 2). Because these windows include different patients, the difference between them cannot be interpreted as weight regain. In the 48 patients with weight recorded in both windows, median weight increased from 72.0 to 76.5 kg (+4.5 kg), suggesting modest regain between the first and second postoperative years. This pattern is consistent with the literature, which documents that the greatest weight loss occurs during the first year and tends to stabilize thereafter, with marked interindividual heterogeneity [16, 17]. However, this subgroup represents 48/315 (15.2%) of the cohort, and only 58/315 (18.4%) had at least 24 months of follow-up, which limits the assessment of long-term outcomes.

The near-exclusive predominance of sleeve gastrectomy is relevant to interpreting the magnitude of weight loss. In the SLEEVEPASS trial (RCT, *n* = 240, five-year follow-up), both techniques achieved substantial and sustained weight loss, although Roux-en-Y gastric bypass tended toward greater excess weight loss than sleeve gastrectomy (57% vs. 49% at five years) [18]. This difference persisted at 10 years (50.7% vs. 43.5% excess weight loss, respectively), although both techniques maintained clinically significant reductions [19]. In this context, the 26.5% TWL observed in our cohort at 11-20 months is consistent with expected outcomes for sleeve gastrectomy under real-world conditions.

Sleeve gastrectomy is generally considered less effective than Roux-en-Y gastric bypass (RYGB) in terms of weight loss, remission of type 2 diabetes, improvement of dyslipidemia, and antihypertensive discontinuation [18, 19]. This difference is attributed to mechanisms beyond restriction in RYGB, including duodenal exclusion and greater changes in gut hormones (GLP-1, PYY), whereas sleeve gastrectomy acts mainly through gastric volume reduction and lower ghrelin levels. At our center, sleeve gastrectomy is the procedure of choice according to institutional protocol, given its technical simplicity, which explains its predominance in our cohort (300/315, 95.2%). Therefore, our results reflect the expected outcomes of sleeve gastrectomy and may underestimate the benefits achievable with RYGB. Because only 13/315 patients (4.1%) underwent RYGB and 2/315 patients (0.6%) underwent other procedures, no comparison between techniques was possible.

Glycemic control: significant improvement with remission rates below those of controlled trials

Fasting glucose and HbA1c decreased significantly (-16.0 mg/dL and -0.60 percentage points, respectively; Figure *3*; Table *2*). The direction of effect is consistent with evidence from clinical trials demonstrating the superiority of surgery over intensive medical therapy in reducing HbA1c over the medium and long term. In ARMMS-T2D (pooled RCT analysis with observational follow-up, *n* = 262, median 11 years), surgery maintained greater HbA1c reductions than medical management at 7 and 12 years (between-group difference: -1.4% at 7 years, -1.1% at 12 years) [20]. Consistently, the STAMPEDE trial confirmed at three and five years a higher probability of achieving glycemic targets with bypass or sleeve gastrectomy compared with intensive medical therapy (RCT, *n* = 150, retention approximately 90%) [21, 22], findings replicated at 10-year follow-up [23]. However, postoperative HbA1c was available for only 108/315 patients (34.3%), and those patients more often had T2DM at baseline (48.1% vs. 7.2%) and higher baseline HbA1c. The average glycemic improvement therefore reflects mainly patients with greater baseline dysglycemia and may overestimate the effect in the whole cohort.

The T2DM remission rate observed in this cohort was 22.4% (15/67), and 11.9% (8/67) when remission was required at both the 6- and 12-month assessments. Both figures are considerably lower than those reported in protocolized prospective studies. In the SOS study (prospective controlled study, *n* = 303 surgical patients with T2DM), remission at two years reached 72.3%, with progressive decline to 30.4% at 15 years, illustrating the dynamic and potentially reversible nature of metabolic remission [24]. In ARMMS-T2D, remission was 37.5% after surgery versus 2.6% with medical management [20]. These differences may be explained by longer T2DM duration and greater follow-up heterogeneity in real-world cohorts, as well as methodological differences: the SOS study used fasting glucose <110 mg/dL without systematic HbA1c assessment as a remission criterion, which may have overestimated the rate relative to more stringent contemporary definitions (international consensus: HbA1c <6.5% for at least three months without antidiabetic therapy) [8]. Additionally, assessment at the peak of metabolic effect (two years) in SOS contrasts with the variable follow-up of a retrospective cohort, limiting direct comparability. Two features of our analysis act in opposite directions: patients without sufficient follow-up were counted as not in remission, which likely underestimates remission among patients who were followed, whereas the medication-free interval of at least three months required by the consensus definition was inferred from medication status at scheduled visits because exact discontinuation dates were not available, which may overestimate it.

Remission of prediabetes was observed in 55/140 patients (39.3%). Although no universally accepted consensus definition for prediabetes remission after bariatric surgery exists, limiting direct comparison with other series, this rate is consistent with the expected early metabolic response to caloric restriction and substantial weight loss. Because remission was defined on a single postoperative measurement, this figure may overestimate sustained remission. The relatively high remission rate compared with T2DM likely reflects the greater reversibility of the prediabetic state, in which beta-cell function is better preserved. Standardization of prediabetes remission criteria in future bariatric registries would facilitate cross-study comparisons.

Lipid profile: Improvement in triglycerides and HDL cholesterol, with reductions in LDL and total cholesterol

Triglycerides decreased (-58.0 mg/dL), and HDL cholesterol increased (+8.4 mg/dL); total and LDL cholesterol also decreased (-20.3 and -18.3 mg/dL, respectively) (Figure *3*; Table *2*). The triglyceride and HDL changes are consistent with the typical metabolic response to weight loss and improvement in insulin resistance, and they were correlated with the magnitude of weight loss in our data. In STAMPEDE (RCT, *n* =

150, five-year follow-up), surgery achieved greater triglyceride reductions and HDL increases than intensive medical therapy [22]. A meta-analysis of 73 RCTs (n = 32,496) documented that each kilogram of weight lost was associated with a reduction in triglycerides (-0.33 mg/dL/kg) [25]. The reduction in LDL cholesterol should be interpreted with more caution: in real-world data from PCORnet, LDL reduction was more pronounced with gastric bypass than with sleeve gastrectomy [26]. In our cohort, lipid-lowering treatment was not analyzed, so changes in pharmacological therapy may have contributed. In addition, lipid measurements were available for only about one third of patients.

Blood pressure: Clinically relevant reduction with limited remission

Significant reductions were documented in systolic and diastolic blood pressure (-10.0 and -8.0 mmHg, respectively; Figure *3*; Table *2*), in line with the average effect of bariatric surgery on blood pressure control reported in a recent systematic review and meta-analysis [27]. However, AHT remission, defined as blood pressure below 140/90 mmHg without antihypertensive treatment at two consecutive visits six months apart, was modest (15/120, 12.5%). This finding is expected in a real-world setting, where the outcome depends on active deprescription, clinical documentation, and the timing of measurement.

In trials with structured follow-up, higher remission rates have been described, particularly after bypass. In SLEEVEPASS, antihypertensive discontinuation at five years was 29% after sleeve gastrectomy versus 51% after bypass (P = 0.02), and remission at 10 years was 8% versus 24% (P = 0.04), respectively [18,19]. In the ENGAGE CVD cohort (n = 4,964 with AHT), although approximately 42%-43% experienced some episode of remission within five years, only 17%-18% remained in sustained remission when relapses were considered, with no significant differences between techniques [28]. These data reinforce that AHT remission is a dynamic and unstable outcome. Although the rate observed in this cohort was lower than the sustained remission rate reported in ENGAGE CVD, it is compatible with the real-world effectiveness of sleeve gastrectomy under non-protocolized conditions.

Relationship between weight loss and metabolic improvement

Greater %TWL was correlated with larger reductions in HbA1c (r_s = -0.48), fasting glucose (r_s = -0.42), triglycerides (r_s = -0.39), and systolic (r_s = -0.31) and diastolic blood pressure (r_s = -0.28), and with larger increases in HDL cholesterol (r_s = +0.35). In adjusted models, each additional 10 percentage points of %TWL was associated with an additional reduction of 0.38 percentage points in HbA1c and 3.2 and 2.1 mmHg in systolic and diastolic blood pressure, respectively. These associations support weight loss as a contributor to the observed metabolic improvement. However, these associations are observational, are based on patients with available measurements (who more often had diabetes or hypertension), and may be influenced by regression to the mean and weight-independent effects of surgery that this study design cannot distinguish.

Vitamin B12 and renal function

Among the 54 patients with paired measurements, mean vitamin B12 increased from 412 to 485 pg/mL, and the proportion with deficiency decreased from 7.4% to 3.7%. Because supplementation was not recorded, this change cannot be attributed to the surgery itself, and it may reflect postoperative supplementation and/or correction of an undocumented baseline deficiency. Its interpretation should also be made with caution, as only 54/315 patients (17.1%) had a postoperative measurement available, introducing a risk of selection bias. From a comparative standpoint, the risk of B12 malabsorption is greater with bypass than with sleeve gastrectomy: in a Swedish national cohort (RYGB, n = 7,294 vs. sleeve gastrectomy, n = 1,105), bypass was associated with a twofold risk of micronutrient deficiency (adjusted HR = 2.00) [29], a finding consistent with a meta-analysis of RCTs (RR = 1.86, P = 0.012) [30]. The predominance of sleeve gastrectomy in this series would imply a lower relative risk of deficiency, although subclinical deficiency cannot be excluded in the absence of systematic nutritional follow-up [31].

Serum creatinine decreased from a median of 0.80 to 0.70 mg/dL (Figure *3*; Table *2*). This decrease should not be interpreted as an improvement in renal function, because serum creatinine falls with the loss of muscle mass that accompanies substantial weight loss; at most, it suggests no deterioration of renal function during follow-up. Previous evidence indicates that bariatric surgery does not impair and may improve renal function [32,33], but markers independent of muscle mass, such as cystatin C or albuminuria, were not available in our data.

Perioperative safety

Dumping syndrome occurred in 0.95% of cases (3/315), and one intraoperative death was recorded (0.32%; 1/315). Two patients (0.6%) required conversion to Roux-en-Y gastric bypass for refractory gastroesophageal reflux after sleeve gastrectomy. The low frequency of dumping is clinically plausible given the predominance of sleeve gastrectomy [34,35], although passive record review likely underestimates milder symptoms, which are often underreported [35]. Other complications were not systematically recorded, so an overall complication rate could not be estimated. In comparative effectiveness cohorts with longitudinal follow-up (PCORnet; n = 33,560), the cumulative incidence of reoperation at five years was 8.94% for sleeve gastrectomy and 12.27% for bypass [36]. The 0.6% reoperation rate observed in our series, with a median

follow-up of 12 months and passive record review, likely underestimates the true cumulative incidence. The overall perioperative mortality estimated in a large-scale meta-analysis (>3.6 million procedures) was 0.05% for sleeve gastrectomy and 0.08% for gastric bypass [37,38]. Accordingly, the rate observed in this series (0.32%) should be interpreted with caution given the small sample size and the intraoperative nature of the single event recorded.

Strengths and limitations

This study provides real-world evidence from a referral center in southwestern Colombia, with a considerable sample size for a single-center analysis (n = 315), from a geographic region historically underrepresented in the bariatric literature. The evaluation integrates multiple cardiometabolic domains - anthropometry, glycemia, lipids, blood pressure, and nutritional markers - allowing a comprehensive assessment of clinical impact. The use of nonparametric tests (Wilcoxon signed-rank) with Hodges-Lehmann pseudomedian estimation and 95% CI is methodologically appropriate for the observed distributions, and the explicit reporting of data availability, the timing of measurements, and the comparison of patients with and without postoperative data improve transparency.

The principal limitations are as follows. The retrospective pre-post design without a control group does not allow causal inference or separation of the surgical effect from concomitant changes in pharmacological treatment, diet, or physical activity. Use of antidiabetic, antihypertensive, and lipid-lowering medications before and after surgery was not analyzed, so changes in metabolic parameters cannot be separated from changes in pharmacological treatment. The variable availability of postoperative measurements across variables (range: n = 54-308) introduces a risk of selection bias: patients with diabetes or hypertension were more likely to have postoperative laboratory and blood pressure measurements, so the observed improvements may not be representative of the whole cohort and may be overestimated. The reasons for missing data were not recorded. Follow-up was recorded as months since surgery at scheduled visits rather than exact dates. The median follow-up was 12 months, and only 58/315 patients (18.4%) had at least 24 months of follow-up, limiting the assessment of long-term outcomes. The 11- to 20- and 21- to 30-month windows included different patients, so weight regain could be assessed only in the 48 patients with measurements in both windows. Complications other than dumping syndrome, conversion, and death were not systematically recorded, and two patients underwent revisional procedures whose baseline measurements preceded the revision rather than the first bariatric surgery. Serum creatinine is an imperfect marker of renal function after substantial weight loss, and vitamin B12 supplementation was not recorded.

The operational definitions of prediabetes and AHT remission, developed for this study in the absence of uniform consensus criteria (with prediabetes remission based on a single postoperative measurement), limit direct comparability with other cohorts. For T2DM, exact dates of medication discontinuation were not available, so the medication-free interval required by the consensus definition was inferred from the medical record, and only 8 of the 15 patients classified in remission had HbA1c < 6.5% at both the 6- and 12-month visits. Additionally, remission rates were calculated using all patients with a baseline diagnosis as the denominator, regardless of follow-up availability; patients without sufficient follow-up were counted as not in remission, which likely underestimates the true remission rate among those who completed follow-up. Finally, the marked predominance of female sex (300/315, 95.2%) and sleeve gastrectomy (300/315, 95.2%) restricts the generalizability of results to men, to other bariatric procedures, and to bariatric surgery as a whole.

Clinical implications

The results of this cohort suggest a favorable association of sleeve gastrectomy-predominant surgery with body weight, glycemic variables, lipid profile, and blood pressure in this predominantly female population, although the substantial missing postoperative data call for caution. Given the limitations described, these results should not be extrapolated to men or to other bariatric procedures. The T2DM and AHT remission rates, which were lower than those reported in controlled trials, highlight specific areas for improvement: standardizing postoperative measurements at predefined fixed time points (e.g., 12 and 24 months), recording the dates of medication discontinuation, implementing institutional deprescription and remission documentation algorithms, and characterizing predictors of remission and recurrence (T2DM duration, insulin use, and baseline HbA1c), as described in cohorts with prolonged follow-up [39]. The development of a prospective registry of adverse events, reoperations, medication changes, and nutritional deficiencies would substantially improve external comparability with large-scale comparative effectiveness studies.

Conclusions

In this retrospective cohort from a referral center in southwestern Colombia, composed predominantly of women who underwent sleeve gastrectomy, surgery was associated with substantial weight loss (median 23 kg; median %TWL 23.5%) and improvement in glycemic, lipid, and blood pressure parameters among patients with available measurements, up to 36 months of follow-up. Greater weight loss was correlated with larger reductions in HbA1c and blood pressure. Remission rates of prediabetes (39.3%), type 2 diabetes (22.4%; 11.9% when required at both the six- and 12-month assessments), and hypertension (12.5%) were lower than those reported in clinical trials and protocolized cohorts, which probably reflects differences in definitions, follow-up intensity, and missing data inherent to real-world practice. The high proportion of

missing data, the short follow-up (median 12.0 months), the absence of a control group, and the lack of analysis of medication changes call for cautious interpretation and limit extrapolation to men and to other procedures. Prospective registries with measurements at fixed time points, documentation of medication discontinuation, and long-term follow-up are needed to characterize more reliably the remission, recurrence, and safety of bariatric surgery in our setting.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Carlos Berrocal, Jhon H. Quintana, Jose Luis Pineda Bocanegra, Víctor Alonso Carrascal Carrascal , Elvis Mauricio Pérez Lafont , María Daniela Prada Quiñones , Guadalupe Durango Pacheco, Juan Pablo Martínez Buitrago, Alyi Alejandro Arellano Cabeza, Antonio M. Zumaque Carrascal, Andrés Felipe García Ramos

Acquisition, analysis, or interpretation of data: Carlos Berrocal, Daniela Arias Echeverri

Drafting of the manuscript: Carlos Berrocal

Critical review of the manuscript for important intellectual content: Carlos Berrocal, Daniela Arias Echeverri, Jhon H. Quintana, Jose Luis Pineda Bocanegra, Víctor Alonso Carrascal Carrascal , Elvis Mauricio Pérez Lafont , María Daniela Prada Quiñones , Guadalupe Durango Pacheco, Juan Pablo Martínez Buitrago, Alyi Alejandro Arellano Cabeza, Antonio M. Zumaque Carrascal, Andrés Felipe García Ramos

Supervision: Carlos Berrocal

Disclosures

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