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Research Article

# Fifteen Year Weight, Metabolic, and Conversion Outcomes After Primary Metabolic Bariatric Surgery in Individuals Living with Obesity and Type 2 Diabetes

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## Abstract

**Background:** Metabolic and bariatric surgery (MBS) is an established intervention for weight reduction and metabolic improvement in individuals living with obesity and type 2 diabetes mellitus (T2DM), with well described short term and medium term benefits. However, long term results extending beyond 10 years, particularly in people with T2DM, remain limited.

**Objective:** To evaluate 15 years weight, metabolic and surgical outcomes following primary MBS in individuals living with obesity and T2DM.

**Methods:** This retrospective cohort study included patients with T2DM who underwent primary MBS between 2003 and 2007 at a single tertiary centre. Long term follow up data at approximately 15 years were available for 49 individuals. Primary outcomes included changes in weight, body mass index (BMI), and diabetes related outcomes. Secondary outcomes included medication use, cardiovascular events, and secondary surgical procedures, classified as revisions or conversions according to International Federation for the Surgery of Obesity and Metabolic Disorders definitions. Analyses were descriptive, with paired comparisons performed where data completeness permitted.

**Results:** Fifteen years follow up data were available for 49 individuals with type 2 diabetes mellitus. Median body weight decreased from 143.0 kg to 101.6 kg, and median body mass index (BMI) decreased from 52.6 kg/m² to 39.6 kg/m² (both $p < 0.01$). Median percentage total body weight loss was 27.5%, and median percentage excess weight loss was 49.0%. Paired HbA1c data were available for 6 patients, with median values decreasing from 8.4% to 5.6%; six patients met criteria for diabetes remission at 15 years. Among 28 patients with medication data, oral hypoglycaemic agent use decreased from 27 to 10 patients ($p = 0.01$), and insulin use decreased from 6 to 3 patients ($p < 0.001$). Thirteen patients (26.5%) underwent secondary bariatric procedures during follow up, including 9 conversions and 4 revisions.

**Conclusions:** In this real world cohort of individuals living with obesity and T2DM, MBS was associated with durable long term weight reduction and reduced reliance on glucose lowering medications over 15 years. Secondary surgical procedures occurred in a subset of patients and should be interpreted in the context of baseline patient characteristics and evolving surgical practice. Larger prospective studies with comprehensive long term follow up are required to further define durability and metabolic outcomes beyond a decade.

***Keywords:*** *Metabolic Bariatric Surgery, Type 2 Diabetes Mellitus, Long-term Outcomes*

## Key Points

**Question**

What are the 15 years weight, glycemic, and reoperation outcomes among individuals living with obesity and type 2 diabetes mellitus who undergo primary metabolic and bariatric surgery?

**Findings**

In this retrospective cohort with available 15 years follow up, sustained long term weight reduction and reductions in diabetes medication use were observed following metabolic and bariatric surgery. Secondary bariatric procedures occurred in 26.5% of patients, including nine conversions for inadequate weight loss or weight recurrence and four revisions for procedure related complications. The frequency and type of secondary procedures varied according to the primary operation and reflected historical surgical practice patterns.

**Meaning**

These findings provide rare long term, real world data on the durability of metabolic and bariatric surgery in individuals living with obesity and type 2 diabetes. They highlight the need for long term follow up and informed patient counselling regarding the potential for secondary procedures, particularly in the context of evolving surgical practice and patient selection.

## Introduction

Metabolic and bariatric surgery is widely recognized as the most effective long term intervention for individuals living with severe obesity and type 2 diabetes mellitus (T2DM). Randomised controlled trials have consistently demonstrated significant benefits in weight reduction and glycaemic control during short and medium term follow up. In the STAMPEDE trial, Schauer et al. reported superior glycaemic outcomes at five years following MBS compared with intensive medical therapy, with a mean reduction in glycated haemoglobin (HbA1c) of 2.1% in surgically treated patients versus 0.3% with medical therapy alone [1]. Similarly, Mingrone et al. demonstrated higher rates of diabetes remission at five years following bariatric–metabolic surgery compared with conventional medical treatment in individuals with T2DM and obesity [2].

Despite these well established early benefits, the durability of metabolic and clinical outcomes beyond 10 years—particularly among individuals living with T2DM—remains less clearly defined. This gap is clinically important given the progressive nature of diabetes and the need for lifelong metabolic and surgical follow up after bariatric procedures. Many published studies report outcomes limited to five to ten years, leaving uncertainty regarding longer term effectiveness, durability of weight loss, and metabolic control.

Large observational and prospective cohort studies have provided important insight into longer term outcomes following bariatric surgery. Adams et al. reported substantial reductions in all cause mortality, coronary artery disease related mortality, and diabetes related mortality following gastric bypass compared with matched controls in an initial analysis with extended follow up [3]. These findings were reinforced by subsequent analyses demonstrating sustained weight loss and metabolic benefit up to 12 years after gastric bypass surgery [4]. Similarly, the Swedish Obese Subjects (SOS) study demonstrated a durable survival benefit among surgically treated individuals compared with matched controls over a mean follow up of approximately 11 years [5].

More recently, long term analyses from the Longitudinal Assessment of Bariatric Surgery (LABS) consortium reported by Courcoulas et al. have demonstrated sustained improvements in weight and cardiometabolic outcomes up to 12 years following bariatric surgery, compared with medical management, while also highlighting heterogeneity in long term responses and the potential for weight regain and metabolic relapse in a subset of patients [6]. Collectively, these studies underscore the long term benefits of MBS while also emphasising the need for extended follow up to fully characterise durability beyond one decade.

Earlier work by Pories et al. suggested that bariatric surgery may confer prolonged glycaemic improvement, with a substantial proportion of individuals maintaining normoglycaemia for more than a decade following surgery [7]. Mechanistic studies reviewed by Rubino et al. further demonstrated that MBS exerts metabolic effects independent of weight loss, supporting the biological plausibility of sustained glycaemic benefit following surgical intervention [8]. However, contemporary long term data incorporating modern definitions of diabetes remission, medication use, and evolving surgical practice remain limited.

In parallel, reoperations; including both revisions and conversions: represent an established component of long term bariatric care. Reported rates vary according to index procedure, patient selection, and historical practice patterns. Early series described substantial reoperation rates following restrictive procedures such as gastric banding, while lower revision rates have been reported following gastric bypass during extended follow up [9,10]. Understanding the balance between long term metabolic benefit and surgical durability is therefore essential for patient counselling and procedural selection.

The present study aims to evaluate 15 years outcomes following primary metabolic and bariatric surgery in a cohort of individuals living with obesity and T2DM. We assess long term changes in weight, glycaemic markers, medication use, and cardiovascular outcomes, and describe the incidence and timing of secondary surgical procedures classified as revisions or conversions according to International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) definitions. By extending follow up beyond a decade, this study provides rare real world longitudinal data on the durability and long term effects of MBS in a high risk metabolic population.

## Methods

### Study Design and Population

This was a retrospective cohort study conducted at a single tertiary metabolic and bariatric surgery (MBS) centre. All patients who underwent primary MBS between January 2003 and December 2007 were screened. Institutional databases and medical records were reviewed to extract demographic, clinical, operative, and follow up data.

A total of 106 eligible individuals with type 2 diabetes mellitus (T2DM) were identified from institutional records. Patients were excluded if they lacked sufficient documentation for baseline anthropometrics or if no follow up weight was available at or near 15 years. Fifty seven individuals were excluded, primarily due to loss to follow up or relocation (n = 34), death unrelated to surgery before 15 years of follow up (n = 12), or insufficient baseline or follow up documentation (n = 11). The final study cohort comprised 49 patients with available long term follow up data, corresponding to 15 years follow up rate of 46.2%. This inclusion patient flow diagram is illustrated in Figure 1.

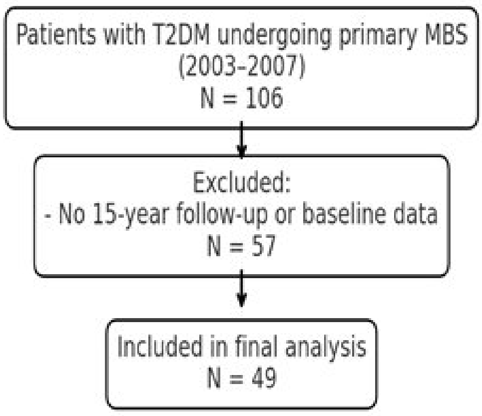


**Figure 1.** Flow Diagram of Study Participants included in 15 years follow up analysis (N=49)

**Eligibility Criteria:**

Inclusion criteria were: (1) a preoperative diagnosis of type 2 diabetes mellitus (T2DM); and (2) one of the following index procedures: laparoscopic Roux-en-Y gastric bypass (LRYGB), laparoscopic sleeve gastrectomy (LSG), laparoscopic adjustable gastric banding (LAGB), or laparoscopic duodenal switch (LDS), also referred to as biliopancreatic diversion with duodenal switch (BPD-DS).

Eligibility for surgery during the study period (2003–2007) was based on the following indications for metabolic and bariatric surgery:

BMI ≥40 kg/m², or

BMI ≥35 kg/m² with obesity associated medical problems.

These criteria were based on the NIH Consensus Statement (1991) and remained standard during the study period [11].

More recent guidelines have expanded indications to include lower BMI thresholds for selected patients with type 2 diabetes; these updated recommendations are cited for contextual reference only and were not applied retrospectively to the present cohort [12,13].

All patients underwent preoperative evaluation, weight loss efforts, and multidisciplinary team (MDT) review prior to surgery.

**Surgical Procedures**

All procedures were performed laparoscopically by experienced bariatric surgeons. Participants underwent one of four primary bariatric procedures.

Primary bariatric procedures performed during the study period included laparoscopic Roux-en-Y gastric bypass (LRYGB), laparoscopic sleeve gastrectomy (LSG), and laparoscopic adjustable gastric banding (LAGB) and laparoscopic duodenal switch (LDS). All procedures were performed according to standard techniques accepted at the time, as previously described in the literature [14-17]. Detailed step by step operative descriptions are therefore not repeated here.

During the study period (2003-2007), LSG was utilized both as a definitive procedure and as a staged first line procedure in selected patients with very high body mass index (BMI >50–60 kg/m²), reflecting emerging evidence and contemporary practice patterns at the time [18,19]. This approach was adopted at our centre to reduce operative risk in patients with severe obesity.

LSG was offered either as a definitive procedure or as the first stage of a planned two stage approach, with the option of later conversion if clinically indicated. This practice pattern explains the higher baseline BMI observed in the LSG group compared with the LRYGB and LAGB groups [18,19,20].

Laparoscopic adjustable gastric banding (LAGB) was considered a standard bariatric procedure during the early 2000s, although its use has since declined due to higher long term reoperation rates. Accordingly, LAGB was offered during the study period in line with prevailing practice at that time. All patients received standardized perioperative care, including thromboprophylaxis, antibiotic prophylaxis, and early mobilization protocols, consistent with contemporary best practices.

**Data Collection and Follow up**

Preoperative and 15 years postoperative data were extracted from electronic and paper medical records.

The primary outcomes of interest were long term weight and diabetes related outcomes. Anthropometric measures collected included body weight and body mass index (BMI).

Weight Outcomes included:

- Body weight (kg)
- Body Mass Index (BMI, kg/m²)
- Percentage total body weight loss (%TBWL = [(baseline weight – follow up weight) / baseline weight] × 100)
- Percentage excess weight loss (%EWL = [(baseline weight – follow up weight) / (baseline weight - ideal weight)] × 100, where ideal weight corresponds to BMI 25 kg/m²)

Diabetes Outcomes involved:

- Fasting plasma glucose (reported in mmol/L and mg/dL)
- Haemoglobin A1c (HbA1c, %)
- Diabetes medication use (oral hypoglycemic agents and/or insulin)
- Diabetes remission status (defined according to American Diabetes Association criteria: HbA1c <6.5% without diabetes medications for ≥3 months [21].

**Additional metabolic outcomes:**

Additional metabolic outcomes included hypertension and hyperlipidaemia, assessed based on the use of antihypertensive and lipid lowering medications, respectively, as documented in medical records. Cardiovascular events, defined as myocardial infarction, stroke, coronary revascularisation, or peripheral vascular intervention, were also recorded. These outcomes were extracted from clinical records and analysed descriptively due to limited event numbers and incomplete long term follow up.

Secondary outcomes included the incidence and timing of reoperation following the index procedure. Operative records, clinical notes, and follow up documentation were reviewed to classify reoperations according to International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) definitions.

Conversion was defined as secondary bariatric procedure of a different type performed to address inadequate weight loss, defined as <25% excess weight loss at 2 years postoperatively, or weight recurrence of >10 kg from nadir weight with BMI >35 kg/m².

Revision was defined as secondary procedure of the same type performed to address technical or anatomical complications (e.g., band repositioning, hiatal hernia repair, stricture dilation).

Indications for conversion/revision were documented as:

- Inadequate weight loss or weight recurrence
- Gastroesophageal reflux disease (GERD), assessed by symptoms and/or objective testing (endoscopy or pH monitoring)
- Band related complications (slippage, erosion, port issues)
- Anastomotic complications (stricture, marginal ulcer)

Clinical documentation was reviewed to classify reoperations as being performed for procedure related complications or inadequate weight loss. Conversion surgery was considered a recognised component of long term bariatric management aimed at optimising weight and metabolic outcomes.

### Statistical Analysis

All analyses were conducted using IBM SPSS Statistics version 30 (IBM Corp., Armonk, NY, USA) and Python 3.12. Analyses were primarily descriptive and exploratory, given the retrospective design and limited sample size. Continuous paired variables (e.g., preoperative versus 15 years BMI) were analysed using the Wilcoxon signed rank test, and categorical paired variables using McNemar's test. Between group comparisons were performed using the Kruskal–Wallis test or chi square/Fisher's exact test, as appropriate.

Reoperation outcomes were analysed descriptively. The incidence, type (conversion or revision), indication, and timing of reoperations following the index procedure were summarised by primary procedure group. No time to event modelling was performed, as sleeve gastrectomy was frequently used as a staged first procedure during the study period, and subsequent conversion did not uniformly represent treatment failure. Accordingly, comparative survival analyses were considered potentially misleading and were not undertaken.

A two sided p-value <0.05 was considered statistically significant for descriptive comparisons.

## Results

***Primary Outcomes:***

### Baseline Characteristics

Baseline characteristics are shown in Table1. The median age of the cohort was 50.2 years (range 19–59.3 years). The male to female ratio was 1:2.7 (24% male; 76% female). The median preoperative body mass index (BMI) was 52.6 kg/m² (range 38.6–69.4). All participants were living with type 2 diabetes mellitus (T2DM), with varying degrees of medication dependence. A substantial proportion also required antihypertensive and lipid lowering therapy.

There were no statistically significant differences across surgical groups with respect to age (p = 0.2) or sex distribution (p = 0.5). Preoperative BMI differed significantly between groups (median BMI: LAGB 49.0 kg/m², LSG 57.4 kg/m², LRYGB 52.4 kg/m²), with the LSG Group having a higher median BMI (p < 0.05). This reflects contemporary clinical practice during the study period, whereby sleeve gastrectomy was frequently selected as a staged first line procedure for patients with severe obesity (BMI > 50–60 kg/m²) [18,19].

Table 1. Baseline Characteristics of the Study Cohort

| Characteristic | Overall* | Gastric Band (n=9) | Sleeve Gastrectomy† (n=16) | Gastric Bypass‡ (n=23) | p-value |
|---|---|---|---|---|---|
| Age, years, median (range) | 50.2 (19.8–59.3) | 50.6 | 51.3 | 49.0 | 0.2 |
| Female sex, n (%) | 35/46 (76%) | 7 (78%) | 11 (69%) | 15 (71%) | 0.5 |
| Male sex, n (%) | 11/46 (24%) | 2 (22%) | 5 (31%) | 6 (29%) | |
| Preoperative BMI, kg/m², median (range) | 52.6 (38.6–69.4) | 49.0 | 57.7 | 52.1 | <0.05 |
| Type 2 diabetes mellitus, n (%) | 49 (100%) | 9 (100%) | 16 (100%) | 23 (100%) | — |

** Baseline BMI available for 47 patients; sex recorded for 46 patients.*

*† Sleeve gastrectomy group includes one patient initially converted to open sleeve gastrectomy.*

*‡ Gastric bypass group includes one anastomosis gastric bypass performed in a patient with situs inversus.*

*One patient underwent primary duodenal switch and is included in overall counts but excluded from between group statistical comparisons due to sample size.*

*p-values reflect unadjusted between group comparisons and should be interpreted in light of confounding by indication.*

**Weight and BMI Outcomes at 15 years**

Sustained long term weight reduction was observed at 15 years following MBS. Median body weight decreased from 143.0 kg (range: 102-173kg) preoperatively to 101.6 kg (range: 88 – 118.0kg) at long term follow up ($p < 0.01$), and median BMI decreased from 52.6 kg/m² (range: 38.6-69.4) to 39.5 kg/m² (range: 23-48) ($p < 0.01$). BMI distribution at Baseline and at 15 years post MBS are shown in Figure 2.

At 15 years, the median percentage total body weight loss (%TBWL) was 27.5% (range –0.9% to 50.3%), and the median percentage excess weight loss (%EWL) was 49.0% (range –2.6% to 116.5%), where values >100% EWL reflect weight loss beyond BMI 25kg/m².

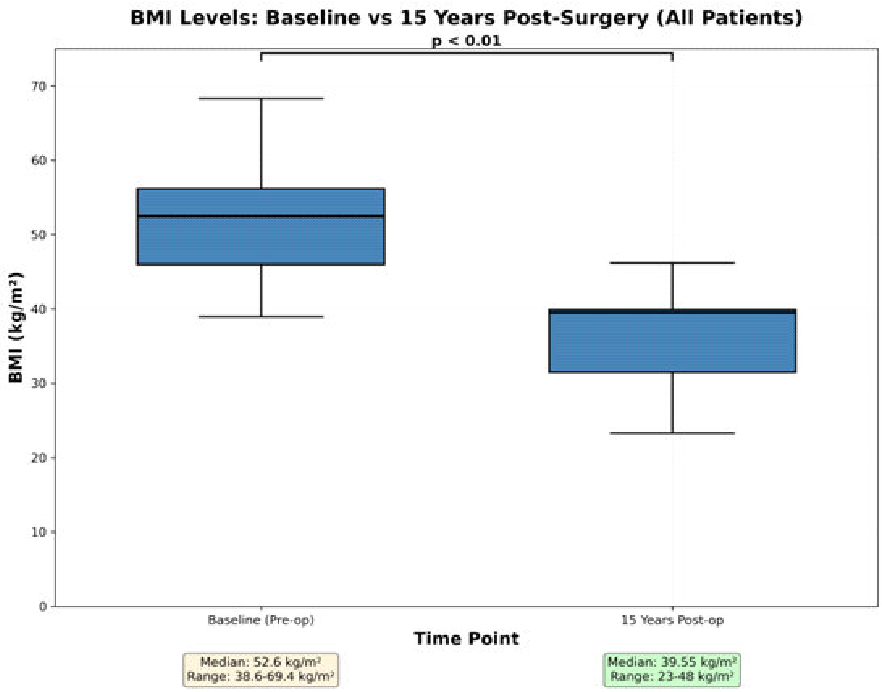


**Figure 2.** Distribution of body mass index (BMI) values at baseline and at 15 years following primary metabolic bariatric surgery.

*Boxes represent the median and interquartile range, with whiskers indicating the observed range. All patients with available BMI measurements at both time points are included.*

**Glycemic Outcomes at 15 Years**

Paired HbA1c measurements (DCCT%) were available for 10 patients. Median HbA1c decreased from 8.4% pre operatively to 5.6% at 15 years follow up (n = 6 with paired data). This reduction did not reach statistical significance, reflecting limited sample size and incomplete long term biochemical follow up.

When glycemic control was assessed using a categorical threshold, data on HbA1c ≤6.0% were available for 17 patients. At baseline, 2 patients met this criterion compared with 6 patients at 15 years ($p = 0.07$), indicating a trend toward improved glycemic control that did not reach statistical significance.

Paired fasting plasma glucose measurements were available for 5 patients. Median fasting plasma glucose decreased from 6.5 mmol/L (117 mg/dL) pre operatively to 4.6 mmol/L (82 mg/dL) at 15 years follow up. Owing to the very small sample size, these findings are presented descriptively without formal statistical testing.

Reductions in diabetes medication use were observed over long term follow up. Among 28 patients with available medication data, 27 were treated with oral hypoglycemic agents at baseline compared with 10 at 15 years (p = 0.01). Insulin use decreased from 6 of 28 patients preoperatively to 3 of 28 patients at 15 years (p = 0.2).

Glycemic outcomes at baseline and at 15 years are illustrated in Figure 3. Given incomplete long term biochemical follow up and small sample sizes for several glycemic parameters, all glycemic outcomes are presented descriptively and should be interpreted with caution.


**Figure 3.** Fasting plasma glucose level comparison between fasting and 15 years post primary metabolic bariatric surgery (units: mmol/l).

**Additional Metabolic Outcomes:**

Changes in non diabetes cardiometabolic medication use were observed over the 15 years follow up period. Among patients with available data, use of antihypertensive medications decreased from 29 individuals at baseline to 7 individuals at 15 years. Similarly, use of lipid lowering therapy decreased from 22 individuals pre operatively to 4 individuals at long term follow up. Given incomplete follow up and the descriptive nature of the analysis, no formal statistical comparisons were performed for these outcomes.

Cardiovascular events, defined as myocardial infarction, stroke, coronary revascularisation, or peripheral vascular intervention, were documented in 4 patients at baseline and 1 patient at 15 years follow up. Owing to the small number of events and retrospective data collection, cardiovascular outcomes are reported descriptively without statistical inference.

**Secondary Outcomes:**

**Reoperations, Revisions and Conversion Procedure**

Over the 15 years follow up period, 13 of 49 patients (26.5%) underwent a secondary bariatric procedure. Secondary procedures were classified as conversion procedures or revisions according to predefined criteria.

Conversion procedures were defined as secondary bariatric procedures of a different type performed for inadequate weight loss or weight recurrence. Inadequate weight loss was defined as <25% excess weight loss at 2 years postoperatively, while weight recurrence was defined as >10 kg regain from nadir weight with a body mass index >35 kg/m². Revision procedures were defined as secondary procedures of the same type undertaken to address technical or anatomical complications.

Of the 13 secondary procedures, 9 (69.2%) were classified as conversion procedures performed for inadequate weight loss or weight recurrence, while 4 procedures (30.8%) were classified as revisions performed for procedure related complications (Table 2).

**Table 2.** Indications for secondary bariatric procedure over 15 years follow up (n=13).

| Indication category | No. (%) |
|---|---|
| Procedure related Complications | 4 (30.8%) |
| Inadequate weight loss / weight recurrence | 9 (69.2%) |
| Total secondary procedures | 13 (100%) |

*Percentages are calculated among patients undergoing secondary procedures.*

*Procedure related complications include revisions performed for technical or anatomical issues documented in clinical records.*

*One revision following Laparoscopic Roux-en-Y gastric bypass (LRYGB) involved placement of a Fobi ring and was classified as a revision, not a conversion.*

Among the four revision procedures performed for complications, two occurred following primary laparoscopic adjustable gastric banding (LAGB) and two following primary laparoscopic sleeve gastrectomy (LSG). Indications for revision were identified from operative records and clinical documentation. However, detailed subclassification of complication type was not consistently available across all cases in this retrospective dataset and is therefore reported descriptively. Baseline and post operative GERD status was not consistently documented and therefore could not be analysed as a selection factor.

The distribution of secondary procedures by destination operation was as follows: 7 patients were converted to biliopancreatic diversion with duodenal switch (BPD-DS), 4 to laparoscopic Roux-en-Y gastric bypass (LRYGB), 1 to laparoscopic sleeve gastrectomy (LSG), and 1 patient who had previously undergone LRYGB underwent a revision involving placement of a Fobi ring. The latter was classified as a revision rather than a conversion, as it represented a restrictive modification of the existing gastric pouch rather than a change in bariatric procedure type.

When examined by index procedure, 3 of 9 patients (33%) who initially underwent LAGB required secondary surgery. Among patients who underwent LSG as the primary procedure, 9 of 16 (56%) required secondary surgery, most commonly conversion to BPD-DS (7 cases) and less frequently conversion to LRYGB (2 cases). In contrast, 1 of 23 patients (4%) who initially underwent LRYGB required a subsequent revision (Fobi ring placement). No patients who underwent primary BPD-DS required secondary surgery during follow up.

The median time to secondary surgery was 2.6 years (range 0.8–12.4 years). Median time to secondary surgery was 2.34 years following LSG and 6.10 years following LAGB; the median time to secondary surgery was not reached for patients undergoing primary LRYGB within the 15 years follow up period.

The higher frequency of secondary procedures following LSG reflects historical clinical practice during the study period (2003–2007), when LSG was frequently utilised as a staged first line procedure in patients with very high baseline body mass index, rather than as a definitive operation. Given the retrospective design, small sample size, incomplete long term biochemical follow up, and confounding by indication, these findings are reported descriptively, without comparative statistical inference.

## Discussion

This 15 years follow up study provides insight into the long term metabolic and clinical outcomes of metabolic and bariatric surgery among individuals living with type 2 diabetes. The sustained reductions in weight, medication use, and cardiovascular events observed in this cohort are consistent with long term metabolic benefits reported in literature. These findings align with earlier studies reporting favourable outcomes up to 5–10 years postoperatively. Large observational studies, including those by Adams et al. and Sjöström et al. provide broader context regarding long term mortality benefits, demonstrating lower all cause and diabetes related mortality following bariatric surgery [3,5]. Additional large scale observational and prospective cohort studies, including long term analyses from the Longitudinal Assessment of Bariatric Surgery (LABS) consortium reported by Courcoulas et al., have demonstrated sustained improvements in weight and cardiometabolic outcomes up to 10–12 years following metabolic and bariatric surgery [6]. Extensive observational studies have similarly associated metabolic surgery with reduced risk of major adverse cardiovascular events (MACE), including coronary artery disease, cerebrovascular disease, heart failure, atrial fibrillation, and diabetic nephropathy in individuals living with obesity and type 2 diabetes [3,9]. Reported findings include a 40% reduction in all cause mortality, a 56% reduction in coronary artery disease–related mortality, and a 92% reduction in diabetes related mortality following gastric bypass [3]. The cumulative incidence of MACE at eight years has also been shown to be significantly lower among individuals undergoing surgery (30.8%) compared with those receiving medical therapy alone (47.7%) [22].

The reduction in pharmacologic therapy observed in this study suggests sustained improvements in insulin sensitivity and β cell function over time. These changes may reflect both weight dependent and weight independent mechanisms. As discussed by Rubino et al., metabolic surgery influences gut hormone secretion, including increased glucagon like peptide-1 (GLP-1) and peptide YY (PYY), and reduced ghrelin levels, with glycaemic improvements often occurring within days—well before significant weight loss takes place [8,23]. These early effects differ from those of purely restrictive procedures, such as laparoscopic adjustable gastric banding, where improvements in glycaemic control are largely attributable to weight loss alone [6]. Additional mechanisms—such as changes in duodenal signalling (foregut hypothesis) or enhanced insulin independent glucose transport via hindgut pathways—have been proposed to explain the rapid postoperative improvement in insulin resistance [8,23].

The secondary procedure rate of 26.5% in this cohort reflects the complex, multifactorial nature of long term obesity and diabetes management. Weight recurrence following primary metabolic surgery affects approximately 15–30% of individuals and may necessitate further intervention, although definitions and clinical relevance vary across studies [24-26]. Factors contributing to weight regain include anatomical issues (e.g., pouch dilation, fistulas, or anatomical adaptation over time) and non anatomical contributors such as behavioural patterns, hormonal adaptations, and metabolic responses [27]. Variation in conversion rates is also influenced by patient selection, procedural choice, and practice patterns.

An important consideration is the baseline BMI difference between procedure groups. The LSG group had significantly higher median baseline BMI (median 57.35 kg/m²) compared to LRYGB (median 52.4 kg/m²) and LAGB (median 49.0 kg/m²) ($p < 0.05$). The preferential selection of LSG for patients with higher baseline BMI in our cohort reflects the contemporary clinical practice during the study period (2003-2007). During the study period (2003-2007), LSG was increasingly recognized as an appropriate staged first line procedure for super obese patients (BMI >50-60 kg/m²) based on emerging evidence at that time from landmark studies by Gagner et al. and Silecchia et al. [18,19,20]. These studies demonstrated that LSG could be performed safely as a first stage procedure in high risk individuals, either as definitive treatment or as preparation for subsequent malabsorptive procedures.

This historical practice pattern explains the higher frequency of secondary procedures observed following LSG in this cohort and the predominance of conversions to biliopancreatic diversion with duodenal switch (BPD-DS). These findings should therefore be interpreted in the context of staged surgical decision making rather than as definitive procedure failure. The choice of BPD-DS reflected the evidence based options available at the time; although single anastomosis duodeno ileal bypass with sleeve gastrectomy (SADI-S) had been described toward the end of the study period, it was not yet established in routine clinical practice [28]. Recent meta analytic data indicate that SADI-S and duodenal switch procedures provide the most substantial weight loss outcomes among revisional operations [29]. Consequently, conversion to BPD-DS represented appropriate escalation of care for patients with super obesity and inadequate response to an initial restrictive procedure. Despite the possibility of glycaemic relapse over time, many individuals continue to experience prolonged periods of remission or improved glycaemic control.

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The observed reduction in antihypertensive, lipid lowering, and glucose lowering medications observed in this cohort aligns with previous studies demonstrating long term improvements in cardiometabolic risk factors following surgery [1,2]. These reductions, together with sustained improvements in weight and glycaemia, contribute to the evidence supporting the cost effectiveness of metabolic surgery for individuals living with type 2 diabetes. Economic analyses indicate that metabolic procedures may be cost saving over a lifetime, reducing healthcare expenditure by €17,064–€24,384 and increasing quality adjusted life years (QALYs) by 1.36–1.50 [33]. These projections, combined with improved life expectancy and delayed onset of diabetes complications, reinforce the role of metabolic surgery as an important component of contemporary diabetes care algorithms. Current expert consensus recommends metabolic surgery for individuals with class III obesity (BMI ≥40 kg/m²) or class II obesity (BMI 35.0–39.9 kg/m²) with inadequately controlled hyperglycaemia and considers it appropriate for individuals with BMI 30.0–34.9 kg/m² when medical therapy alone does not achieve adequate glycaemic control [30].

## Limitations

The present study has several limitations. Its retrospective design inherently restricts the ability to establish definitive causality, and the relatively small sample size may limit the generalizability of the findings. Missing data for specific biochemical markers—such as glycated haemoglobin (HbA1c) and fasting glucose—precluded statistical testing for part of the cohort and limit the strength of conclusions regarding long term glycemic control. The single center nature of the study may further restrict the broader applicability of the results, as patient selection patterns, surgical practice, and perioperative protocols may differ across centers. Additionally, baseline BMI differed across procedure groups in this cohort, which may have influenced long term outcomes and conversion rates. These limitations collectively underscore the need for larger, multicenter, prospective studies with standardised data collection and extended follow up to validate and expand upon our findings.

## Conclusions

In summary, this 15 years follow up study suggests that metabolic and bariatric surgery is associated with sustained long term benefits for individuals living with obesity and type 2 diabetes mellitus (T2DM). These benefits include durable weight reduction, substantial decreases in the need for glucose lowering and cardiovascular medications, and a reduced incidence of cardiac events over extended follow up. Secondary procedures occurred in a subset of patients and were influenced by historical surgical practice and baseline patient characteristics. Fewer secondary procedures were observed following Roux-en-Y gastric bypass in this cohort, although these findings should be interpreted descriptively. Larger prospective studies with comprehensive long term follow up are required to further define the durability of metabolic outcomes and to guide optimal procedural selection.

## Declarations

### Ethics Approval and Consent to Participate

This study was reviewed by the Institutional Review Board / Research Ethics Committee and was deemed exempt from full ethical review due to its retrospective nature, use of de identified data, and absence of patient contact or intervention The study was conducted in accordance with the Declaration of Helsinki and complied with local data protection regulations. The requirement for informed consent was waived given the retrospective design and use of anonymized data.

### Consent for Publication

Not required.

### Availability of Data and Materials

Anonymized data is available upon reasonable request to corresponding author.

### Competing Interests

The authors declare no conflicts of interest.

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