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Outcomes of Bariatric Surgery

Asad Ullah

Abstract

The prevalence of obesity has increased globally. Management of obesity consists of medical and surgical interventions. The results of bariatric surgery are consistently more significant than medical therapy. Importantly, bariatric surgery achieves durable weight loss in more patients than medical therapy. Moreover, studies have reported improvement in most obesity-related complications after bariatric surgery. Improvement or remission of type 2 diabetes mellitus, hypertension and dyslipidemia is noteworthy. Due to better outcomes, the indications of bariatric surgery are expanding. In conclusion, bariatric surgery is a cost-effective and safer alternative for morbidly obese patients who fail to respond to non-surgical treatments. Some studies have raised concerns about the worsening of mental health problems after bariatric surgeries. It requires careful management of high-risk patients and further research.

Keywords: obesity, bariatric surgery, weight loss, metabolic and other outcomes

1. Introduction

The global prevalence of obesity has tripled since 1975 [1]. Obesity is managed according to the severity and associated comorbid conditions. Bariatric surgery is recommended for class II obesity with associated comorbidities and class III obesity. It confers the most effective and durable weight loss. The number of bariatric procedures in the United States has significantly increased in the last decade [2].

The primary outcome of bariatric surgery is weight loss; however, it also improves obesity-related comorbidities and overall survival.

Bariatric surgery has progressed significantly since its origin in 1954. In contemporary practice, Roux-en-Y gastric bypass surgery (RYGB), sleeve gastrectomy (SG) and adjustable gastric band (AGB) are the most performed procedures. This chapter will focus on the outcomes of these three surgical techniques.

2. Outcomes of bariatric surgery

2.1 Weight loss

Weight loss is the primary goal of bariatric surgery. Regardless of the procedure, bariatric surgery provides significant long-term weight loss compared to non-surgical therapies [3].
There is no standardized metric for reporting weight loss. In surgical literature, it is frequently reported as the percentage of excess weight loss (EWL) as shown in Eq. (1) [4]

\[
\%\text{EWL} = \left( \frac{\text{Pre bariatric surgery (BS) weight} - \text{Post BS weight}}{\text{Pre BS weight} - \text{ideal body weight}} \right) \times 100
\]  

Ideal body weight is conventionally determined by using Metropolitan Life Tables [5] or the method of the Devine [6].

Some authors used percentage excess body mass index (BMI) loss (as shown in Eq. (2)) [4],

\[
\%\text{BMIL} = \left( \frac{\text{Pre BS BMI} - \text{Post BS BMI}}{\text{Pre BS BMI} - 25} \right) \times 100
\]

In the medical literature, weight loss is reported as a percentage of total weight loss (TWL) expressed as Eq. (3) [4],

\[
\%\text{TWL} = \left( \frac{\text{Pre BS weight} - \text{Post BS weight}}{\text{Pre BS weight}} \right) \times 100
\]

These parameters have limitations; however, %TWL is most frequently reported in contemporary literature.

Weight loss post-bariatric surgery is highly variable. Initially, a rapid weight decline is observed in the first 6 months, reaching a peak at 12 months. Then it slows down and reaches a plateau between 1 and 1.5 years (see Table 1).

Weight loss after RYGB & SG is comparable. Swiss multicenter bypass or sleeve study (SM-BOSS) [8] reported similar weight loss after RYGB and SG at 2, 3 and 5 years. Improvements in metabolic outcomes such as remission of diabetes mellitus (DM), hypertension (HTN) and hyperlipidemia were also comparable.

Laparoscopic Sleeve Gastrectomy vs. laparoscopic Roux en Y gastric bypass (SLEEVEPASS) study [9] showed greater excess weight loss with RYGB compared to SG (55 vs. 47% at 7 years).

Observational studies illustrate higher weight loss with RYGB than SG [10, 11]. It is likely related to the study design.

Weight loss with AGB is slower, reaching a plateau at 2 years [7]. The longitudinal assessment of bariatric surgery (LABS) study [12] compared RYGB and laparoscopic AGB in a cohort of 2348 obese individuals. At seven years, the mean weight loss with

<table>
<thead>
<tr>
<th>Surgical technique</th>
<th>% Excess weight loss</th>
<th>Time for weight stabilization (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGB</td>
<td>45–55</td>
<td>2</td>
</tr>
<tr>
<td>SG</td>
<td>55–80</td>
<td>1-1.5</td>
</tr>
<tr>
<td>RYGB</td>
<td>60–85</td>
<td>1-1.5</td>
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Table 1.
Expected weight loss after bariatric surgery [7].
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RYGB was 38.2 kg (95% CI, 36.9–39.5) and 18.8 kg (95% CI 16.3–21.3) after AGB. Due to lack of efficacy, the reoperation rate was higher in the AGB group than in the RYGB group (n = 160 vs. 14).

Adjustable gastric banding has gone out of practice due to lack of efficacy. Most of the patients will regain some weight regardless of the operation commencing in the second year. It is estimated to be 5–10% of TBW in the first 10 years; e.g., in the Swedish obese subjects (SOS) study, the TWL decreased from 32 to 25% at 10 years after RYGB [13]. Similarly, in the LABS study, TWL decreased from 35 to 28% after RYGB [12].

What is the significant weight regain is not clearly defined in the literature. The risk of weight regain is lowest for RYGB (2.5 to 3.3%), followed by SG (12.5 to 14.5%) and highest for AGB (30.5 to 36%) [10, 14].

2.2 Metabolic benefits

Metabolic syndrome or insulin resistance is the co-existence of risk factors for cardiovascular diseases and type 2 diabetes mellitus (T2DM) including hypertension, central obesity, high blood glucose level and dyslipidemia. Bariatric surgery is by far the most effective treatment for metabolic syndrome. The effects of bariatric surgery on each component of metabolic syndrome are discussed below.

2.2.1 Effects on type 2 diabetes mellitus

Durable remission of T2DM is reported in 23 to 60% of cases [15]. Glycemic control improves within days after the surgery suggesting the role of weight loss independent factors. Bariatric surgery influences β-cell function, incretin responses, insulin sensitivity, gut microbiota, bile composition, intestinal glucose metabolism and brown adipose tissue metabolism [16, 17]. Weight loss contributes to better glycemic control in the long run. A French national survey study demonstrated the preventative role of bariatric surgery in T2DM [18]. The risk of developing T2DM was lower in the surgery group than medical therapy group [2 vs. 13% hazard ratio (H.R.) 0.18, 95% CI: 0.17–0.19]. Roux en Y gastric bypass and SG conferred better protection against T2DM than AGB (1.2 vs. 0.9 vs. 4.5%, respectively). Patients with a shorter duration of T2DM, better pre-operation glycemic control and significant weight loss post-surgery had higher chances of achieving remission.

Many prospective and retrospective studies have shown favorable effects of bariatric surgery on the management of T2DM. A meta-analysis [19] reported higher rates of T2DM remission with RYGB than medical therapy at 1 year [RR, 18.01; 95% CI: 4.53–71.70], 3 years (RR, 29.58; 95% CI: 5.92–147.82) and 5 years (RR, 16.92; 95% CI: 4.15–69.00). Moreover, a higher proportion of patients in the RYGB group achieved the American Diabetes Association (ADA) treatment targets at 1, 2, 3 & 5 yr.

Another meta-analysis [20] comprising mainly of observational studies reported a T2DM remission rate of 78% and an improvement rate of 87% at 1–3 years follow-up.

A prospective multi-center study [21] compared SG to RYGB and AGB. Type 2 diabetes mellitus improved or remitted in 83, 55 and 44% with RYGB, SG & AGB respectively at 1 year.

Most observational studies show better remission rates of T2DM with RYGB than SG. However, prospective studies demonstrate comparable efficacy of RYGB and SG inducing T2DM remission [8, 22]. The effectiveness of AGB is low in this regard.
Remission of T2DM induced by bariatric surgery is more durable than medical management. A French population-based cohort study illustrated that a greater proportion of patients in the surgery group (RYGB, SG & AGB) were able to discontinue antidiabetic medications at 6 years than medical therapy alone (−49.9% vs. −9.0%, P < .001) [23]. Roux-en-Y gastric bypass surgery was more effective in discontinuation of antidiabetic medication than SG and AGB.

A single center study [24] randomly assigned 150 obese participants with uncontrolled T2DM were assigned to either intensive medical therapy alone or medical therapy + RYGB or SG. The primary endpoint was lowering HbA1c to <6% at 12 months. More patients in RYGB and SG groups achieved the primary endpoint than medical therapy alone (42, 37 and 12%, respectively).

Another study randomly assigned obese patients with poorly controlled T2DM to medical therapy alone or RYGB or biliary pancreatic diversion (BPD) [25]. The primary aim was remission of T2DM (fasting blood glucose <5.6 mmol/l and HbA1c < 6.5% without medication) was achieved by 0, 75 and 95% of participants with medical therapy alone, RYGB and BPD, respectively. Type 2 diabetes mellitus remained in remission at 10 years in 5.5, 25 and 50% with medical treatment alone, RYGB and BPD, respectively.

2.2.2 Effects on diabetic mellitus complications

Several retrospective studies illustrate the beneficial effects of bariatric surgery on macrovascular and microvascular complications of T2DM.

A retrospective study reported lower composite macrovascular events in the surgery group than in the medical therapy group [2.1 vs. 4.3%, HR 0.60 (95% CI: 0.42–0.86)] at median 5 years follow-up [26].

Another large retrospective study [27] looked at the extended major adverse cardiovascular event (MACE) in diabetic obese individuals who underwent bariatric surgery or medical therapy. At 8 years, the cumulative incidence of MACE was 30.8% (95% CI: 27.6%–34.0%) in the surgical group vs. 47.7% (95% CI: 46.1%–49.2%) in medical treatment group.

A meta-analysis [28] of 19 studies concluded lower mortality [OR 0.34; 95% CI: (0.25–0.46)] and T2DM macrovascular complications [OR 0.38, (95% CI: 0.22–0.67)] with bariatric surgery compared to medical treatment.

A large cohort study [29] reported a lower incidence of microvascular complications in patients who had bariatric surgery than medical treatment at a median follow-up of 4.3 years [16.9 vs. 34.7% HR 0.41 (95% CI: 0.29–0.58)]. Diabetic neuropathy improved the most among microvascular complications [72 vs. 21.4% HR, 0.37 (95% CI: 0.30–0.47)].

In summary, bariatric surgery plus medical therapy induces sustainable remission of T2DM in a significant proportion of patients than medical therapy alone. Bariatric surgery also has favorable effects on the complications of T2DM. Remission of T2DM has a ‘legacy effect’ or ‘metabolic memory’ [30], which protects against microvascular complications even after relapse of T2DM.

Most of the guidelines recommend bariatric surgery for patients with class III obesity (BMI ≥ 40 kg/m²) or class II obesity (BMI 35–39.9 kg/m²) with significant comorbidities. However, clinicians have a growing consensus to consider bariatric surgery for uncontrolled T2DM with medical therapy even with less severe obesity. Bariatric surgery with the primary intent to treat the metabolic syndrome of T2DM is called metabolic surgery. The Diabetes Surgery Summit
(DSS-II) consensus conference guidelines [31] recommend metabolic surgery for patients with poorly controlled T2DM with oral or injectable treatments and class I obesity [BMI 30–34.9 kg/m\(^2\) (27.5–32.4 kg/m\(^2\) for the Asian population)]. DSS-II recommendations are endorsed by American Diabetes Association and many other organizations [32].

2.2.3 Hypertension (HTN)

Hypertension improves with weight loss. The role of bariatric surgery in managing HTN was best demonstrated by the Gastric bypass to treat obese patients with steady hypertension (GATWAY) trial [33]. The study population randomly received medical therapy alone or RYGB + medical therapy. The primary aim was to reduce antihypertensives by \(\geq 30\%\) compared to baseline. More patients in RYGB + medical therapy group achieved the primary endpoint than medical therapy alone at 1 year (84 vs. 13\%) and 5 years (73 vs. 11\%). A significant proportion of patients in the RYGB group achieved remission of HTN at 1 (46 to 0\%) and 5 years (31 to 2\%) compared to medical therapy. Moreover, variability in ambulatory blood pressure was low in the RYGB group compared to medical treatment.

A Norwegian cohort study reported HTN remission in 31.9\% of individuals who underwent bariatric surgery + medical therapy versus 12.4\% in the medical treatment alone group at 6.5 years [34].

What surgical procedure is more efficacious in inducing HTN remission is not clear [21, 35].

2.2.4 Dyslipidemia

Dyslipidemia improves with weight loss. Two meta-analyses showed improvement in serum lipids after bariatric surgery in the short term (< 3 years) [36, 37]. Studies with longer follow-up are required.

A multi-center observational study reported improvement in serum lipids with RYGB compared to baseline (14 vs. 33\% for high low-density lipoprotein (LDL) cholesterol; 5 vs. 24\% for high triglycerides (TG); 6 vs. 35\% for low high-density lipoprotein (HDL) cholesterol) at 7 years. Other observational studies illustrated similar results [38, 39].

2.3 Risk of cancer

Obesity increases the risk of certain cancers such as colon, breast, endometrial, pancreatic, prostate and renal cancers [40, 41]. The outcomes of some malignancies are worse in obese individuals [42].

A database study [43] reported a lower incidence of hormone-related cancers in those who had bariatric surgery (OR 0.23, 95\% CI: 0.18–0.30). Roux-en-Y gastric bypass surgery resulted in a higher reduction in hormone-related cancers than SG & AGB. However, the risk of colorectal cancer was higher (OR 2.63, 95\% CI: 1.17–5.95) in the RYGB group. Other studies did not report this finding consistently [44]. Another database study showed a 34\% higher risk of rectal cancer in obese individuals compared to the general population. The risk of colorectal cancer in obese individuals after bariatric surgery was like the general population [45].

Bariatric surgery has favorable effects on the incidence of all skin cancers (adjusted sub-hazard ratio 0.59, 95\% CI: 0.35–0.99) [46].
2.4 Long-term survival

Studies have shown improved all-cause mortality in obese individuals who underwent bariatric surgery; however, it remains higher than in the general population. A prospective study looked at life expectancy in over 5000 patients from the SOS study cohort [47]. After a median follow-up of 20 years, the hazards for deaths due to cardiovascular disease was 0.70 (95% CI: 0.57–0.85), death from cancer was 0.77 (95% CI: 0.61–0.96) and all-cause mortality was 0.77 (95% CI: 0.68–0.87). The median life expectancy was 3.0 years (95% CI: 1.8–4.2) longer in the bariatric surgery group than in controls but 5.5 years shorter than the general population.

Another large observational cohort study reported lower all-cause mortality rate in bariatric surgery group than control group 0.68 (95% CI: 0.57–0.81) [48] at 4.9 yr. Cardiovascular 0.53 (95% CI: 0.34–0.84) and cancer morality 0.54 (95% CI: 0.36–0.80) were also lower in bariatric surgery group.

Another case-control study reported 40% lower adjusted all-cause mortality in a case-control study (376 versus 57.1 deaths per 10,000 person-years p < 0.001) at 7 years [49]. However, interestingly the rate of deaths due to suicide and accidents were higher in the RYGB group compared to the control group (11.1 versus 6.4 per 10,000 person-years, p = 0.04).

2.5 Functional outcomes.

2.5.1 Obstructive sleep apnea (OSA)

Weight loss improves OSA. An RCT explored the role of RYGB and usual medical care on OSA in grade 1 & 2 obesity [50]. At 3-year follow-up, the apnea-hypoxia index (AHI) was reduced to −13.2 in the RYGB group and increased by +5 events/h in the usual care group. The risk of persistent moderate and severe OSA was also lower in the RYGB group.

A meta-analysis reported comparable improvement or remission rate in OSA with RYGB, AGB & SG (79 vs. 77 vs. 86% for, respectively) [51].

Contrary to the above findings, a meta-analysis demonstrated persistent OSA in patients after bariatric surgery despite improvement in AHI score [52]. It is possibly due to a lack of uniformity in respiratory events scoring in the studies. Detailed assessment for OSA is recommended before discontinuing continuous positive pressure airway therapy.

2.5.2 Gastroesophageal reflux disease (GERD)

Gastroesophageal reflux disease is prevalent in the obese population [53]. The influence of bariatric surgery on GERD is variable and depends on the technique. Gastroesophageal reflux disease improved or remitted in 70% of cases at 1-year follow-up after RYG [21]. Another prospective study investigated the role of RYGB on pre-existing GERD [54]. At 6 months follow-up, the risk of GERD was lower than before surgery (33 versus 64%). The use of anti-reflux medications and total acid exposure also decreased. De novo reflux symptoms occurred in 10% of the cases.

The effect of SG on GERD is not clear. A retrospective study [55] of the Bariatric longitudinal database (BOLD) showed that GERD symptoms persisted in 84% of the individuals after SG. De novo GERD symptoms manifested in 8.6% of cases. Fifty
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per cent of patients with pre-existing GERD reported remission or improvement of GERD in another database study [21]. A systematic review [56] reported a lack of consensus in the studies. Gastroesophageal reflux disease and Barrett’s esophagus are not absolute contraindications for SG; however, there is no consensus about performing SG in patients with pre-existing GERD [57].

There are conflicting data about the influence of AGB on GERD [21]. A systematic review [58] reported a decline in the prevalence of postoperative GERD compared to preoperative GERD (7.7 vs. 32.9%) after AGB. The need for anti-reflux medications (9.5 versus 27.5%), pathologic reflux (29.4 versus 55.8%), and lower esophageal pressure (16.9 versus 12.9 mmHg), all decreased in patients who underwent AGB. Fifteen percent of the individuals reported de-novo reflux symptoms.

In short, RYGB is a better option in individuals with uncontrolled severe GERD or Barrett’s esophagus.

2.5.3 Joint pain and physical activity

Bariatric surgery could ease joint pain and improve physical activity by reducing weight and inflammation. An observational cohort study reported significant improvement in body pains [57.6% (95% CI, 55.3%–59.9%)], physical function [76.5% (95% CI, 74.6%–78.5%)], and walk time [59.5% (95% CI, 56.4%–62.7%)] at 1 year [59]. However, most of the above symptoms relapsed between 1 and 3 years.

A systematic review showed knee pain improvement in 73% of patients after bariatric surgery [60]. An increase in the intervertebral disc height after successful bariatric surgery was reported in a prospective study [61].

A small prospective study demonstrated a reduction in pro-inflammatory markers (Interleukin 6, C-reactive protein and fibrinogen) after bariatric surgery [62]. This effect could be partly responsible for the improvement in arthritis pain.

2.6 Polycystic ovary syndrome (PCOS)

Obesity is associated with PCOS. Observational studies have reported improved PCOS symptoms (hirsutism, menstrual irregularities and hyperandrogenemia) after bariatric surgery [63, 64].

2.7 Renal disorders

Obesity-related renal impairment could be due to hyperfiltration or other comorbidities such as T2DM, HTN, etc. Another prospective study showed improvement in eGFR 12 months after bariatric surgery [65].

A randomized trial of 100 patients with diabetic nephropathy reported remission of nephropathy in 82 with RYGB vs. 48% with medical therapy at 2 years [66].

Obesity-related urinary incontinence improved after bariatric surgery in the longitudinal assessment of bariatric surgery study [67]. Improvement was maintained at 3 years follow up (24.8%, 95% CI, 21.8%–26.5% among females and 12.2%, 95% CI, 9.0%–16.4% among male).

2.8 Non-alcoholic fatty liver disease (NAFLD)

The prevalence of NAFLD is high in obesity. Non-alcoholic fatty liver disease is treated by lifestyle changes and weight loss [68]. However, bariatric surgery could be
considered in cases that failed to improve with medical therapy. A retrospective study of biopsy-proven fibrotic non-alcoholic steatohepatitis reported a lower cumulative incidence of major adverse liver outcomes at 10 years was 2.3% (95% CI, 0%–4.6%) in the surgery group vs. 9.6% (95% CI, 6.1%–12.9%) in the control group [69]. Another database study [70] reported a lower risk of developing cirrhosis in non-alcoholic fatty liver disease patients who underwent bariatric surgery (HR 0.31, 95% CI: 0.19–0.52).

### 2.9 Mental health issues

Depression (19%) and binge eating disorder (17%) are the most common mental health conditions in the obese population. Studies have shown improvement in mental health after bariatric surgery. A systematic review [71] reported a decrease in prevalence (8–74%) and severity (40–70%) of depression after bariatric surgery compared to before surgery. Studies show contradictory reports about the influence of bariatric surgery on eating disorders. A retrospective study reported a durable decline in the loss of control of eating (5.4% post-RYGB vs. 16.2% before surgery), picking/nibbling (7.0% post-RYGB vs. 32.4% before surgery) and craving (19.4% 7 years post-RYGB vs. 33.6% before surgery) [72].

Another study [73] showed a decrease in binge eating disorder in the first two years from 6.1 to 1.3%, but it increased to 3.1% in 3 years.

A large retrospective study [49] reported a higher rate of suicides after RYGB (11.1 vs. 6.4 per 10,000 person-years, P = 0.04). Another large longitudinal cohort study [74] reported a 5-fold increase in deliberate self-harm (incidence rate ratio 4.7; 95% CI, 3.8–5.7). Suicide was reported in 9.6% of cases.

Moreover, studies have shown a high prevalence of alcohol and illicit drug abuse after bariatric surgery. King and Chen [75] observed higher incident alcohol use disorder (AUD) symptoms, substance use and illicit drug abuse after RYGB. Interestingly, the risk of incident AUD was twice higher with RYGB than LAGB.

### 2.10 Cost-effectiveness

Bariatric surgery is cost-effective in the long run. The cost is higher in the first year than medical treatment and lifestyle changes; however, it is amortized after 3.5 years of surgery [76].

A cost-effective analysis [77] comparing five different weight management programs concluded that in the National Health Service (NHS), RYGB is the most cost-effective surgery.

### 3. Conclusion

Bariatric surgery is a cost-effective, durable and safe option for managing severe obesity. It confers significant and lasting weight loss. Moreover, the benefit of bariatric surgery extends beyond weight loss. Most obesity-related comorbidities improve after bariatric surgery; remission of T2DM is noteworthy. The indications of bariatric surgery are widening. Some centers advocate bariatric surgery in cases with milder obesity and comorbidities, especially metabolic syndrome. For the long-term success of bariatric surgery, it is essential to couple it with lifestyle changes. Studies
have raised concerns about the worsening of mental health problems. It needs close monitoring of high-risk patients and further research.

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Conflict of interest

The authors declare no conflict of interest.

Notes/thanks/other declarations

None.

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