dietetics

Review

Bariatric–Metabolic Surgery: The State of the Art and the Management of Complications

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Abstract

Bariatric surgery is a highly effective therapeutic strategy in the treatment of severe obesity, but it carries significant risks, both in the short and long terms. However, many of these complications can be avoided by appropriate patient selection, comprehensive assessment of clinical conditions, and structured follow-up including clinical, nutritional, and psychological monitoring. Achieving these objectives requires a meticulous program involving the entire multidisciplinary team and lays the foundations for proper patient compliance. Furthermore, recent studies have begun to explore the systemic effects of bariatric–metabolic surgery, with benefits extending far beyond simple weight loss and effects on both morbidity and mortality. Research has documented improvements in cardiovascular risk factors, insulin sensitivity, and hormonal balance, with substantial effects on the three main comorbidities of obesity: cardiovascular risk and hypertension, T2DM, and OSAS. In conclusion, bariatric surgery, while highly effective in treating severe obesity and its comorbidities, involves significant anatomical and physiological changes that alter nutrient absorption and digestion. These changes can lead to a number of short-, medium-, and long-term nutritional complications that require close monitoring and targeted dietary interventions.

Keywords: bariatric–metabolic surgery; obesity; surgery complications

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1. Introduction

Obesity is a chronic disease. Its definition and classification are based on the assessment of body mass index (BMI). According to the World Health Organization (WHO), first-degree (mild) obesity has a BMI between 30 and 34.9 kg/m^2, second-degree (moderate) obesity has a BMI between 35 and 39.9 kg/m^2, and third-degree (severe) obesity has a BMI equal to or greater than 40 kg/m^2 [1].

Obesity is a constantly rising global phenomenon. According to data from the World Obesity Atlas 2024, it is estimated that the global adult population with a high BMI (overweight and obese) will rise from 2.2 in 2020 to about 3.3 billion by 2035. Among these, approximately 1 billion individuals are expected to be classified as obese. The incidence of this chronic disease is particularly high in middle-income countries, with an increasing number of cases also among children and adolescents [2,3]. The increasing prevalence of obesity is attributed to multiple factors, including

- Changes in lifestyle;
- Increased consumption of energy-dense foods;
- Reduced physical activity;
- Socioeconomic and cultural factors;
- Psychological factors.

In the latest Italian projections, the obesity trend (indicated as a percentage) is slightly decreasing: from 1.4% to 0.5% for adults and from 1.6% to −0.6% for children, a sign that something is changing.

All the main obesity guidelines indicate that the first step in treatment is lifestyle changes through

- Nutritional interventions based on nutritional re-education with a balanced low-calorie or ketogenic diet depending on the patient's metabolic condition;
- Increased personalized physical activity;
- Behavioral changes (with possible psychotherapeutic support).

However, when this initial strategy is insufficient or ineffective, drug therapy may be used. Anti-obesity drugs are indicated as part of a comprehensive program that includes diet and physical activity in individuals with a body mass index (BMI) ≥ 30 kg/m^2, or in individuals with a BMI ≥ 27 kg/m^2 who have risk factors or other obesity-related conditions, including hypertension, diabetes, dyslipidemia, fatty liver disease, sleep apnea, and cardiovascular disease. Today, we have GLP-1 RA drugs such as semaglutide and tirzepatide (the latter with dual action on GLP-1 and GIP receptor sites), which require weekly administration and personalized dosages.

In cases of severe or morbid obesity and failed dietary and pharmacological interventions, bariatric–metabolic surgery (BMS) may be used [4]. In this case, the choice of surgery and subsequent post-operative follow-up by a multidisciplinary team are important. Even a successful surgical procedure will be ineffective in the long term if it is not followed by a careful follow-up [5].

The economic benefits of bariatric surgery in terms of health policy should not be forgotten but rather emphasized. The surgical procedure involves a significant expense, but it will pay off over time. In fact, compared to obese individuals who have not undergone surgery, we initially see an increase in costs one year after surgery, EUR 10,784 versus EUR 2623, respectively. Twenty years after surgery, the situation is reversed, and patients who have undergone surgery have fewer obesity-related complications and hospitalizations than obese patients who have not undergone bariatric surgery: EUR 40,247 for those who have undergone surgery versus EUR 64,819 for those who have not [6].

2. Overview of Procedures

Bariatric–metabolic surgery is a treatment aimed at reducing body weight in patients suffering from severe obesity and/or related comorbidities. Its goal is to improve quality of life and reduce or mitigate the risk of obesity-related diseases when present, hence the name metabolic surgery. Bariatric surgery, which began in the 1960s, has increased significantly since 2008 with the advent of laparoscopic surgery. This is demonstrated by the extensive bibliography of the last 15 years (Figure 1).

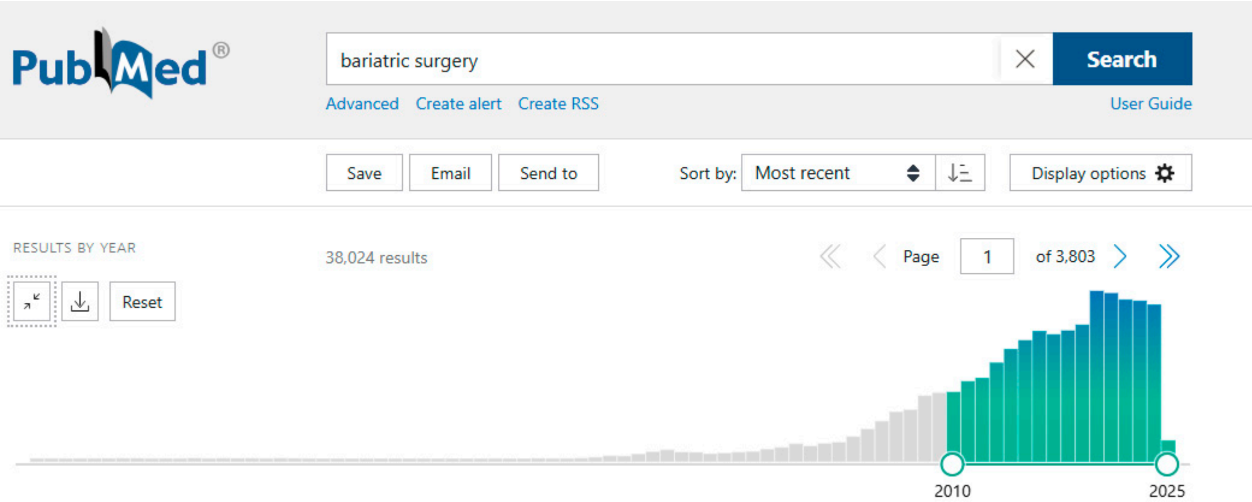


Figure 1. Timeline of the literature on bariatric surgery.

3. Surgical Treatments

Surgical treatments are divided into the following types: restrictive, malabsorptive, and restrictive–malabsorptive (Tables 1 and 2) [7].

Table 1. Classification of bariatric surgery procedures.

Restrictive	Malabsorptive	Restrictive–Malabsorptive
Sleeve gastrectomy (SG)	Biliary pancreatic diversion with duodenal switch (BPD-DS)	Roux-en-Y Gastric Bypass (RYGB) One-Anastomosis Gastric Bypass (OAGB)
Laparoscopic gastric banding (LGB)	Ileal jejunal bypass	Single-Anastomosis Duodenal–ileal Bypass with Sleeve Gastrectomy (SADI-S).

Table 2. Mechanisms of actions of principal interventions.

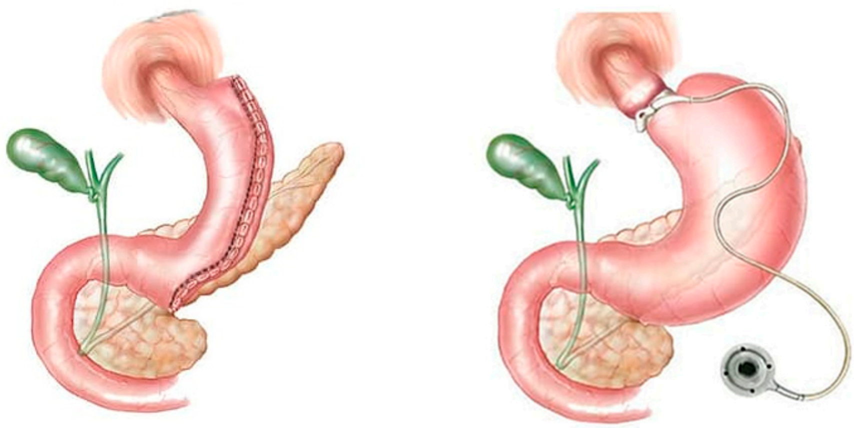
Procedure	Mechanisms	Benefits	Complications
Sleeve Gastrectomy (SG)	Restriction: resection of a significant portion of the stomach, leaving a tubular structure, similar to a "sleeve," which drastically reduces gastric capacity. Hormonal effect: a reduction in ghrelin and an increase in GLP-1, CCK, and PYY.	Simpler and less invasive procedure. Lower risk of short- and long-term complications.	Vomiting. Regurgitation or gastroesophageal reflux. Esophagitis. Suture dehiscence.
Roux-en-Y Gastric Bypass (RYGB)	Gastric partitioning with ileogastric and jejunoileal anastomosis (variable common segment): gastric restriction, malabsorption, dumping syndrome, and a reduction in ghrelin and appetite.	Significant and lasting weight loss. Improvement in comorbidities (T2DM, hypertension, and OSAS)	Infections, bleeding, intestinal obstructions, and protein malnutrition. Risk of vitamin and mineral deficiencies. Bone demineralization, diarrhea, flatulence, and chronic malabsorption. Vomiting and regurgitation.

Table 2. *Cont.*

Procedure	Mechanisms	Benefits	Complications
One-Anastomosis Gastric Bypass (OAGB)	Tubular gastrectomy (approximately 60 mL capacity) with a single gastro-jejunal anastomosis (duodenal bypass) usually 150–200 cm from the duodenum (non-standardized measurement): gastric restriction, malabsorption, and effects on metabolism (increases insulin sensitivity).	Technically simpler. Shorter procedure times. Faster recovery. Effective weight loss. Improvement in obesity-related conditions, such as T2DM.	Comparable to RYGB in the long term; inferior in the post-operative period.
Single-Anastomosis Duodenal–Ileal Bypass with Sleeve Gastrectomy (SADI-S)	It combines sleeve gastrectomy and the duodeno–ileal bypass: vertical gastric resection, resection of the duodenum at the post-pyloric level, and anastomosis of the first duodenal segment with the ileum 300 cm from the ileocecal valve. Mainly indicated for the treatment of "complex" bariatric patients (BMI $\geq$ 50 kg/m^2, metabolic patients, and revision surgery).	Billroth II duodenojejunal anastomosis results in a lower incidence of bile reflux thanks to the post-pyloric reconstruction of the single anastomosis. The presence of a single anastomosis reduces operating time, anesthesia time, and the likelihood of post-operative complications.	A low rate of early complications, provided that it is performed in referral centers. The common segment of 300 cm is associated with fewer long-term nutritional and malabsorption complications.

3.1. Restrictive Procedures (Figure 2)

They act by reducing stomach size, providing an early sense of satiety and reducing food intake (Table 2).



(a) **(b)**

Figure 2. (**a**) Sleeve gastrectomy (SG) and (**b**) laparoscopic gastric banding (LGB).

3.2. Malabsorptive Procedures

Pure malabsorptive procedures (Figure 3) in recent years have been reduced due to serious complications in the long term (Table 2).

Figure 3. Biliary pancreatic diversion with duodenal switch (BPD-DS).

3.3. Restrictive–Malabsorptive Procedures

In restrictive–malabsorptive interventions (Figure 4), weight loss occurs not only by a reduction in oral caloric intake but also by a reduction in food absorption and hormonal interference (influence on entero-hormone secretion and hypothalamic regulatory centers of hunger/satiety) (Table 2).

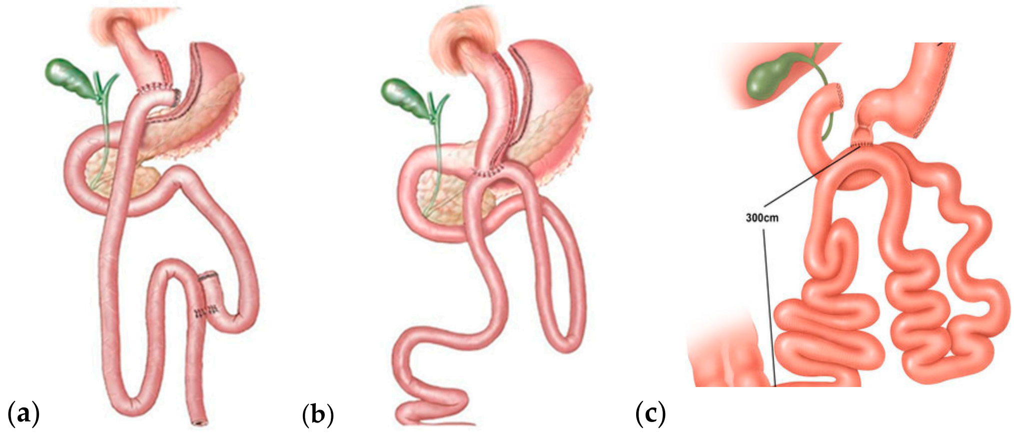


Figure 4. (**a**) Roux-en-Y Gastric Bypass (RYGB), (**b**) One-Anastomosis Gastric Bypass (OAGB), and (**c**) Single-Anastomosis Duodenal–ileal Bypass with Sleeve Gastrectomy (SADI-S).

4. Patient Selection

Patient selection requires a multidisciplinary assessment. The main objective is to identify patients who can derive maximum benefit from the procedure and who are able to ensure adequate follow-up and strict compliance. Selection criteria may vary according to the protocols of individual centers, but they are generally based on clinical, psychological, and behavioral parameters. The main factors considered in the selection process are described below [8].

4.1. Preliminary Assessments

Preliminary assessments include the following:

- Accurate medical and dietary history;
- Complete blood chemistry tests, hormone assays, and endocrinological tests;

- Psychological assessment—MMPI, SF 36, and BITE tests;
- BMI;
- Bioimpedance analysis (BIA) and calorimetry to assess body composition and basal metabolic rate;
- Abdominal ultrasound;
- Thyroid ultrasound;
- Cardio-respiratory sleep monitoring;
- Internal medicine, gastroenterology, cardiology, endocrinology, surgery, and anesthesiology assessments;
- Esophagogastroduodenoscopy (EGDS) and digestive tract X-ray;
- Ergospirometry and PFT (pulmonary function tests).

4.1.1. Body Mass Index (BMI): Indications for Surgery

The following are the criteria for surgery:

- BMI $\geq$ 40 kg/m^2;
- BMI $\geq$ 35 kg/m^2 and comorbidities: high blood pressure, type 2 diabetes mellitus (T2DM), dyslipidemia, and obstructive sleep apnea syndrome (OSAS);
- BMI $\geq$ 30 kg/m^2 in selected cases after collegial evaluation (osteoarticular pathologies of the lower limbs; T2DM not controlled with medical therapy; and at least one uncontrolled comorbidity among T2DM, arterial hypertension, dyslipidemia, and OSAS).

4.1.2. Body Mass Index (BMI): Indications for the Choice of Bariatric Procedure

The following are the indications for procedure choice:

- BMI $\geq$ 40 kg/m^2:
    - Roux-en-Y Gastric Bypass (RYGB);
    - Biliopancreatic diversion with duodenal switch;
    - One-Anastomosis Gastric Bypass (OAGB);
    - Sleeve gastrectomy;
    - Laparoscopic gastric banding.
- BMI $\geq$ 35 kg/m^2 and $\geq$ 1 comorbidity or uncontrolled T2DM:
    - RYGB;
    - Biliopancreatic diversion with duodenal switch;
    - OAGB.
- BMI $\geq$ 30 kg/m^2 and uncontrolled T2DM:
    - RYGB;
    - Laparoscopic gastric banding;
    - Sleeve gastrectomy.

4.1.3. Personalization in the Choice Based on

The choice depends on the following:

- BMI;
- Surgical experience, facility potential, and follow-up;
- Compliance;
- Comorbidities;
- Type of obesity;
- Eating habits.

4.1.4. Psychological Evaluation

Exclusion criteria include the following:

- Pathological addictions;
- Psychopathologies;
- Eating disorders.

Bariatric surgery involves significant psychological and behavioral changes, so it is essential that patients are psychologically fit.

The preoperative psychological assessment aims to

(a) Rule out untreated psychiatric disorders (such as severe depression, eating disorders, and substance abuse), which could compromise the long-term success of the surgery.
(b) Assess the patient's attitude toward change and their ability to adopt new eating and behavioral habits. For example, the ability to manage emotions without resorting to food is crucial. Post-operative psychological support is also essential to facilitate adaptation to the new lifestyle and body image and to maintain the results achieved.

4.2. Failure of Conservative Treatments

It occurs in patients who have undergone multiple failed diets and pharmacological treatments for a period of at least 6 months. It is strongly recommended that patients achieve a weight loss of at least 10% of their initial weight prior to surgery in order to reduce surgical and anesthetic risks.

4.3. Age

Although there are no universal age limits, bariatric surgery is generally recommended for adults between the ages of 18 and 65. In younger patients, it is important to consider the potential long-term risks and psychological maturity. In older patients, surgery can only be considered if there are favorable general conditions and the possibility of good post-operative recovery.

4.4. Conclusions

Patient selection for bariatric surgery is based on a thorough assessment of the above factors. It can offer significant health and quality-of-life benefits, but it is essential that patients are adequately prepared physically, psychologically, and behaviorally to cope with radical lifestyle changes that place a strain on the patient's psychological balance.

5. Comparing Surgical Procedures

These procedures are evolving, and there is still considerable room for improvement. RYGB is the oldest and most studied bariatric procedure, but its predominance has been challenged by sleeve gastrectomy. While procedures such as biliopancreatic diversion with duodenal switch (BPD-DS) are declining, newer techniques are gaining popularity, such as One-Anastomosis Gastric Bypass (OAGB) and Single-Anastomosis Duodeno–Ileal Bypass with Sleeve Gastrectomy (SADI-S), especially for the guarantees they offer in terms of long-term weight loss maintenance [9–11].

In some European countries (Turkey) and in Asia, OAGB is already the most commonly performed bariatric surgery, surpassing sleeve gastrectomy (SG). According to recent comparative studies, in fact, ten years after surgery, the results in terms of weight loss are greater with OAGB (Table 3 and Figures 5 and 6) [12–15].

Table 3. Comparison of weight loss results between RYGB, OAGB, and SADI-S. SD: standard deviation; TWL: total weight loss [12].

Weight Loss	Duration	RYGB (N Studies)	OAGB (N Studies)	SADI-S (N Studies)
%TWL (median—SD)	1 year	30.28 ± 4.12 (5)	33.69 ± 1.35 (4)	38 (1)
	2 years	33.68 ± 1.67 (5)	33.68 ± 1.67 (5)	36.8 (1)
	3 years	29.45 ± 2.55 (4)	35.82 ± 1.68 (3)	38.7 (1)
	5 years	27.67 ± 3.56 (3)	33.46 ± 1.26 (2)	37.8 (1)
	10 years	26.7 (1)	29.1 (1)	-

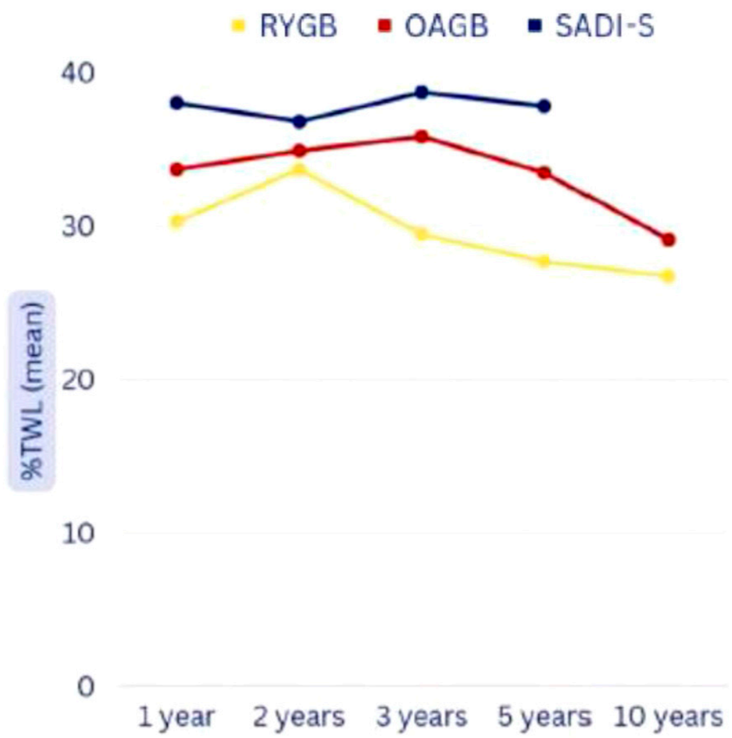


Figure 5. Weight loss trend between RYGB, OAGB, and SADI-S. Comparison of %total Weight loss [12].

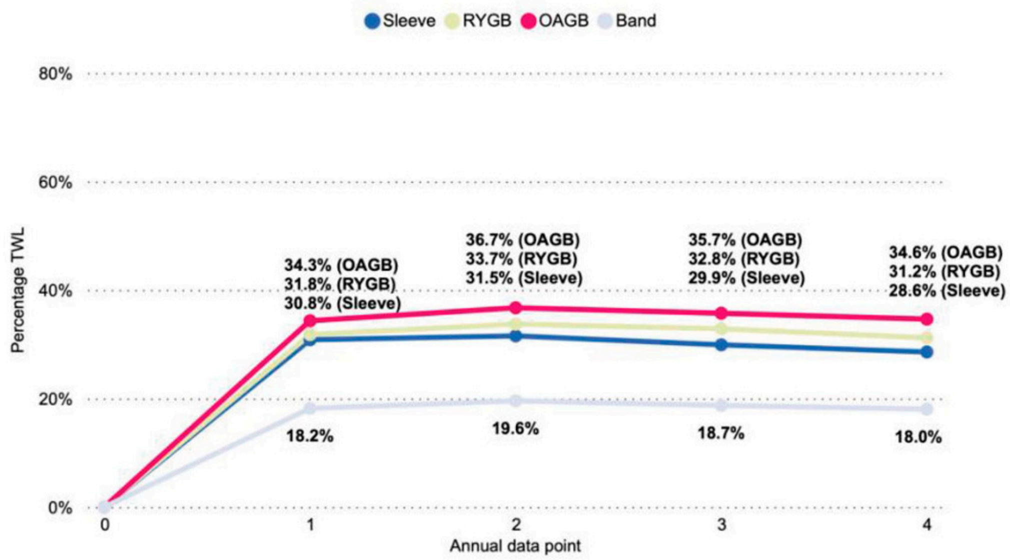


Figure 6. Mean percentage of TWL by procedure type in Australia from the 2023 report (N = 6229) [15].

However, studies show that SADI-S has higher rates of early complications (anastomotic leakage, bleeding, fistulas, intestinal obstruction, pneumonia, and sepsis). One possible explanation could be the significantly longer operating time. Additionally, the hospital readmission rate for SADI-S is also almost double that of OAGB, likely reflecting the procedure's complexity. It is important to note that SADI-S patients often present a higher BMI, which could explain the increased risk of complications (Table 4).

Table 4. Complications and mortality among RYGB, OAGB, and SADI-S. SD, standard deviation.

Complications	RYGB (N Studies SD)	OAGB (N Studies SD)	SADI-S (N Studies SD)
Early complications	8.06 ± 0.14 (5)	8.12 ± 1.50 (4)	11.8 ± 2.29 (3)
Late complications	48.94 ± 40.96 (3)	12.39 ± 4.39 (2)	22.9 (1)
Mortality	0.07 ± 0.11 (11)	0.09 ± 0.18 (8)	0.2 ± 0.28 (3)

SADI-S and OAGB have been proposed and described as "simpler" but equally effective alternatives to RYGB and BPD-DS. In recent studies, SADI-S has been shown to have greater total weight loss (TWL) than OAGB after just one year. This may be why bariatric surgeons in the United States have proposed it to patients with a higher BMI [16].

Although early complications and mortality were higher with SADI-S, late complications (marginal ulcers and internal hernias) are more common with RYGB. Ultimately, both SADI-S and OAGB are as effective as RYGB for weight loss, with OAGB offering fewer complications. However, more data are needed to evaluate the long-term safety (≥5 years) of SADI-S compared to other bariatric procedures and to determine the gold-standard procedure (Table 5) [12–15].

Table 5. Key points.

Bariatric Surgery: The State of the Art
The number of surgeries is increasing every year.
The performance of RYGB is on a downward trend.
Sleeve gastrectomy is the most commonly used procedure, but it is decreasing.
OAGB is significantly on the rise.

6. Post-Operative Follow-Up

Follow-up care for patients who have undergone bariatric surgery is key to achieving and maintaining their ideal body weight, i.e., the weight that corresponds to their optimal physical and mental well-being [17]. Therefore, long-term follow-up care should be planned to monitor

- Weight loss;
- The patient's psychological state;
- The patient's well-being in terms of quality of life and control of any associated diseases;
- Prevention and early diagnosis of surgical and non-surgical complications.

Achieving these objectives requires a meticulous program involving the entire multidisciplinary team and lays the foundation for proper patient compliance [18].

The frequency of clinical and instrumental checks that the patient undergoes after bariatric surgery depends on their characteristics, the type of surgery performed, and the severity of the comorbidities addressed. In general, clinical checks are scheduled

- After 15 and 30 days from surgery for the first three months;
- Subsequently every 3 months in the first year after surgery;
- Every 6 months in the second year after surgery;
- Annually from the third year after surgery.

6.1. Follow-Up

6.1.1. Post-Operative Dietary Visits

After surgery, the patient undergoes a specific nutritional program to prevent complications and promote adaptation to the new gastrointestinal tract. This nutritional program includes

- A liquid diet in the first two weeks after discharge, consisting of liquid foods and supplemented with normal-calorie and high-protein oral nutritional supplements, which are necessary to meet the patient's needs;
- A creamy diet for one month with the aim of increasing the consistency of foods and increasing nutrient intake until specific requirements are met, reducing the risk of anastomotic dehiscence as much as possible;
- A soft diet for about one month; the duration may be increased in the case of intolerance to solid foods;
- A personalized solid diet in the long term.

Along with the dietary treatment, the patient is provided with

- Behavioral advice to help reduce the onset of complications like eat slowly, chew well, drink between meals, and stop eating as soon as you feel full.
- Nutritional education sessions, which facilitate the long-term maintenance of achieved results.

Dietary and nutritional monitoring includes

- Assessment of patient's clinical and nutritional status;
- Monitoring of body weight and weight loss;
- Monitoring of blood chemistry tests;
- Verification of adherence to the diet and provided behavioral advices;
- Verification of compliance with the recommended physical activity plan;
- Verification of adherence to the prescription of multivitamin supplements.

6.1.2. Post-Operative Psychological Visits

Psychological support is essential for coping with the emotional and psychological changes that accompany significant weight loss. In fact, some patients may develop eating disorders, anxiety, and concerns about food, or difficulty adapting to their new body image. If well structured, the above measures offer ample guarantees for reducing the number of dropouts. Early follow-up helps in identifying the risk of dropout by recognizing the first signs of difficulty, such as

- Loss of motivation;
- The onset of psychological distress;
- The resumption of unhealthy eating habits.

In addition, it strengthens the healthcare professional–patient relationship, which is essential for promoting motivation and involvement in the lifestyle change process.

6.1.3. Multidisciplinary Consultations

Specialist valuations included in multidisciplinary follow-up are

- Internal medicine: Management of dyspepsia and infectious complications and support in monitoring other obesity-related conditions, such as diabetes, hypertension, and heart disorders;
- Cardiology consultation: Monitoring of drug therapy for heart conditions associated with obesity;

- Endocrinology consultation: Monitoring of type 2 diabetes and any endocrine disorders associated with obesity (e.g., thyroid dysfunction, polycystic ovary syndrome or PCOS, and osteoporosis);
- Surgical consultation: Monitoring and management of any post-bariatric complications such as dehiscence, anastomotic leaks, or adhesions.

7. Benefits on Major Comorbidities

Recent studies have begun to explore the systemic effects of bariatric/metabolic surgery, with benefits extending far beyond simple weight loss and with effects on morbidity and mortality related to severe obesity. Research has documented improvements in cardiovascular risk factors, insulin sensitivity, and hormonal balance. Below, we will attempt to clarify, in light of the most recent literature, the long-term effects of bariatric/metabolic surgery on the three main comorbidities of obesity: cardiovascular risk and hypertension, T2DM, and OSAS [19].

7.1. Cardiovascular Risk and Hypertension

Changes in cardiac function after bariatric surgery are attributable to actual "structural changes": size and weight reductions of the left ventricle (estimated by imaging) are parameters directly related to cardiovascular mortality [20].

The metabolic effect of bariatric surgery is therefore to improve the patient's hemodynamic parameters and reverse cardiac remodeling by reducing systemic inflammation, a key mechanism of ventricular hypertrophy that causes diastolic dysfunction (a sort of chronic overload), with consequent reduced systolic contractile capacity and a higher risk of developing ventricular arrhythmias. However, the effect is not limited to the ventricles alone: in fact, the reduction in volume not only affects the left atrium, which is long known as the site of origin of atrial fibrillation, but is also directly related to the risk of developing obstructive sleep apnea syndrome (OSAS) [21].

Bariatric surgery induces remodulation in the secretion of enteric hormones that play an active role in proper cardiac function: for example, glucagon and GIP behave as inotropes, while GLP-I and PYY cause a reduction in systemic vascular tone and an increase in the contractile capacity of cardiomyocytes [22].

All this has a significant effect on the incidence of mortality and major heart diseases related to obesity. It has been shown that surgery, whether restrictive and/or malabsorptive, reduces the likelihood of a cardiovascular event by 25–58% and overall cardiovascular mortality by 35–40%. The effects are mainly due to weight loss, but they are also determined by an alteration in the secretion of enteric hormones, an improvement in insulin sensitivity, and a lasting change in the intestinal microbiota.

Bariatric surgery also has a significant effect on improving high blood pressure typically associated with obesity; in fact, a recent review has shown that the reduction in systolic and diastolic values is comparable to monotherapy with antihypertensive drugs (e.g., sartans or ACE inhibitors). Furthermore, the effect is significant during the first 12 months after surgery, and then it is significantly reduced; this is not only linked to rapid weight loss (and therefore to a reduction in afterload) but also to a change in the secretion of adipokines, such as omentin-1, which is secreted by visceral adipose tissue but in an inverse proportion to waist circumference and insulin resistance. Omentin-1 levels increase following bariatric surgery, leading to improved diastolic function and a reduction in cardiovascular risk (Figure 7) [23].

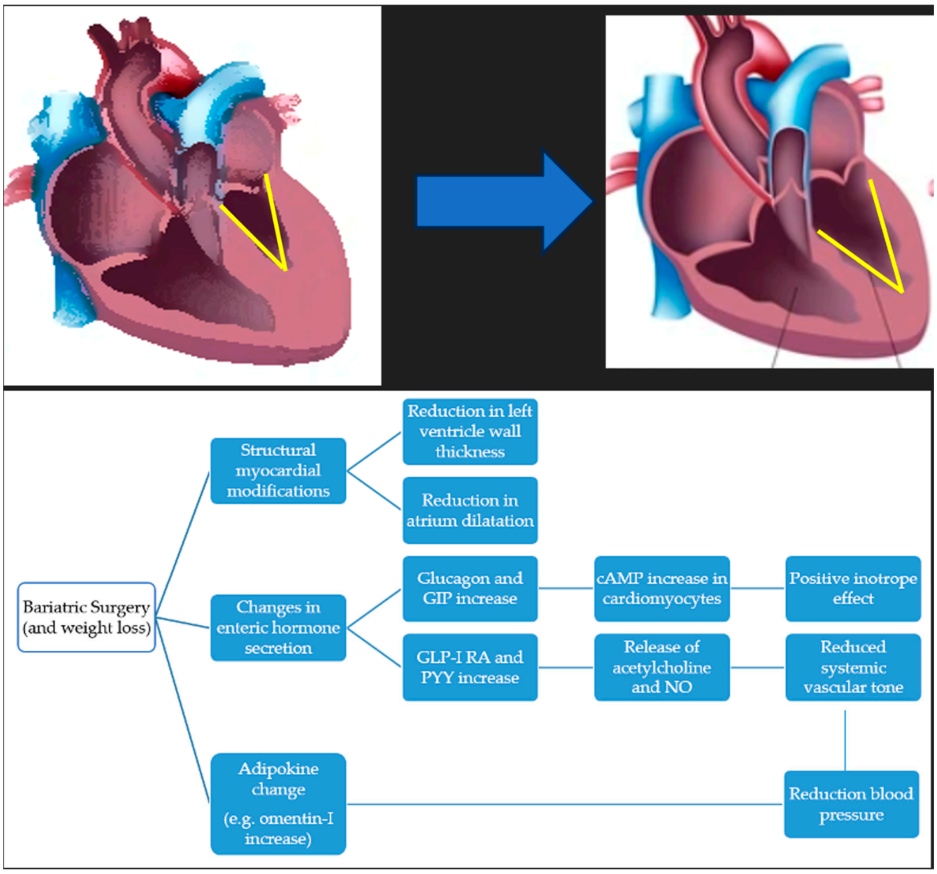


Figure 7. Cardiovascular effects of bariatric surgery.

7.2. Type 2 Diabetes Mellitus

After bariatric surgery, there is an immediate improvement in type 2 diabetes mellitus (T2DM) within the first two weeks after surgery, regardless of weight loss (Figure 8) [24].

(**a**)

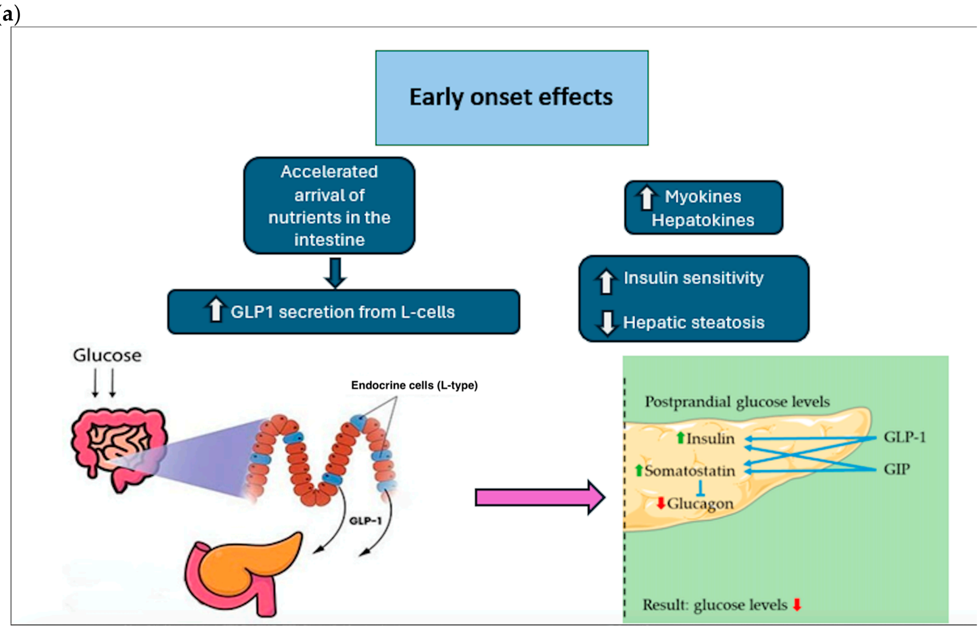


Figure 8. *Cont.*

(b)

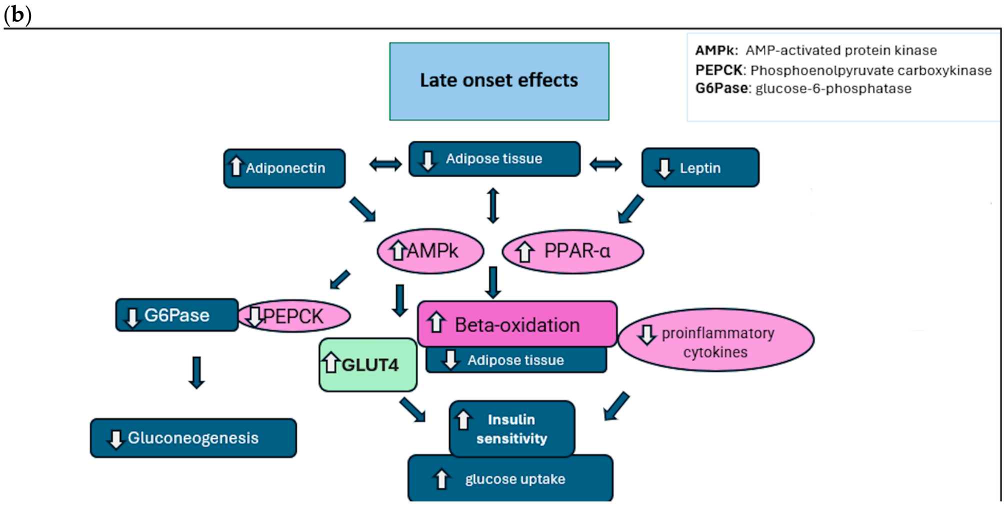


Figure 8. T2DM after bariatric surgery: (**a**) immediate effects and (**b**) late effects.

The various mechanisms that appear to underlie this improvement are as follow:

- Improvement of insulin secretion: A rapid increase in insulin secretion in the first few days/weeks after surgery, regardless of weight loss. The effect is linked to changes in the flow of nutrients through the gastrointestinal tract.
- Improved insulin sensitivity: Increased cellular responses to insulin, improving blood glucose management.
- Changes to the gastrointestinal tract: An alteration of gastrointestinal physiology (e.g., gastric bypass and SG), which promotes better glucose regulation thanks to changes in hormonal signals.
- Hormonal changes (GLP-1, PYY): Increased production of hormones such as GLP-1 and PYY, which improve insulin sensitivity and stimulate insulin secretion.
- Reduction in hepatic glucose production: A reduction in excessive glucose production by the liver, contributing to improved blood sugar levels.

In addition, metabolic changes occur and involve adipokines, myokines, and hepatokines [25]:

- Adipokines (e.g., adiponectin): Increased circulation of adiponectin, which improves insulin sensitivity and reduces inflammation. In addition, there is a decrease in pro-inflammatory interleukins (IL-1, IL-6, and IL-8).
- Myokines: Muscles exhibit an enhanced capacity to utilize nutrients, leading to a decrease in inflammation and better glucose metabolism.
- Hepatokines: The liver experiences improved lipid utilization and reduced hepatic inflammation, aiding in metabolic regulation.
- Synergistic interactions: Metabolic adaptations result from the interaction between adipokines, myokines, and hepatokines, which work together to improve metabolic regulation and reduce inflammation.

To date, there are no standardized criteria for defining remission of diabetic disease. Most authors lean toward partial or complete remission depending on whether, after at least two years of follow-up, glycated hemoglobin is less than 6.5 or 6%, respectively, or fasting blood glucose is less than 126 or 100 mg/dL, respectively, in the absence of hypoglycemic therapy for at least one year [26,27].

7.3. Obstructive Sleep Apnea Syndrome (OSAS)

There is a two-way relationship between body weight and OSAS severity: a 1% increase in BMI corresponds to a 3% worsening in AHI (Apnea–Hypopnea Index).

Foster et al. found that with a 10% reduction in initial weight one year after metabolic surgery, the AHI improved by 20%. The underlying mechanisms are not entirely clear, as numerous factors are involved. Sleep apnea is not only related to excess fat mass; in fact, the resolution rate following weight loss by metabolic surgery is only 65% [28].

The improvement/resolution of OSAS in patients who have undertaken metabolic surgery can be attributed to both weight loss-related and weight loss-independent mechanisms (Figure 9).

MECHANICAL FACTORS:
1) < adiposity in the upper airways increases the trachea transverse area and reduces collapse of the pharynx;
2) < visceral adiposity favors descent of diaphragm → increased chest volume → < airway resistance → lung function improvement.

BIOCHEMICAL-METABOLIC FACTORS:
1) improvement of oxidative stress and chronic inflammatory state by reducing some cytokines (TNF-α, IL-6);
2) improvement of pharynx neuromuscular control;
3) Increase of mitochondrial activity (pgc-1α expression increased) → greater efficiency of respiratory muscles.

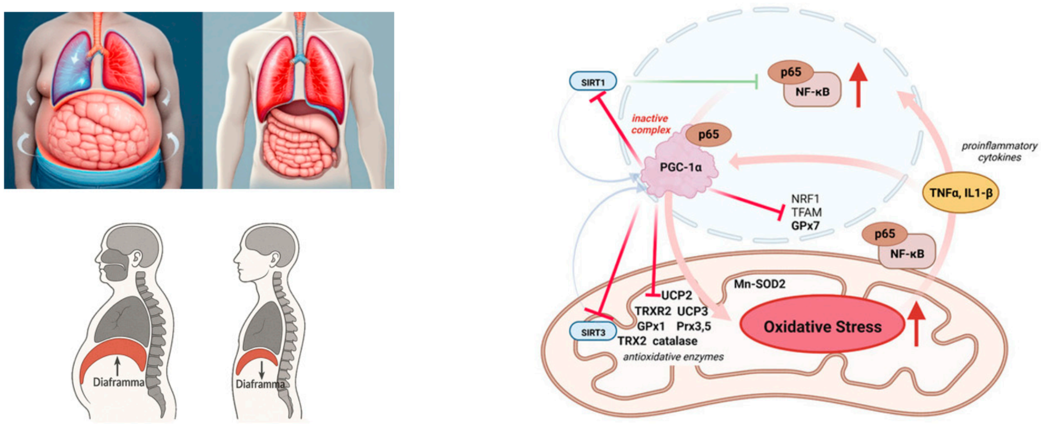


Figure 9. Mechanisms underlining OSAS improvement after bariatric surgery.

Weight loss

- Reduces adiposity in the upper airway by increasing the transverse area of the trachea and reducing pharyngeal collapse;
- Reduces visceral adiposity that is associated with lower intra-abdominal pressure, diaphragm descent, increased thoracic volume, and lower airway resistance, resulting in improved lung function.

Mechanisms independent of weight loss, i.e., related to the type of intervention, are

- Amelioration of oxidative stress and the chronic inflammatory state typical of obesity through the reduction in certain cytokines (e.g., TNF-α and IL-6). A reduction in these mediators could contribute to improved neuromuscular control of the pharynx and have an effect at the CNS level;
- Increased mitochondrial activity compared to preoperative levels, alleviating the symptoms of hypoxia [29].

These effects are related to the type of surgery (malabsorptive, restrictive, or restrictive–malabsorptive): those with a higher remission rate in the short term are RYGB (89.2%) and SG (81.2%) [30].

8. Complications

Bariatric–metabolic surgery, while highly effective in the treatment of severe obesity, involves significant anatomical and physiological changes that alter nutrient absorption and digestion. These changes can lead to a number of short-, medium-, and long-term nutritional complications that require close monitoring and targeted dietary interventions. Nutritional complications mainly result from reduced dietary intake capacity and alterations in the intestinal absorption process (Tables 6 and 7) [31].

Table 6. Complications by type of intervention.

Type of Surgery	Main Complications
Sleeve Gastrectomy	Gastroesophageal reflux disease (GRD), vomiting, and dumping syndrome.
Roux-en-Y Gastric Bypass (RYGB), One-Anastomosis Gastric Bypass (OAGB), and Single-Anastomosis Duodenal–Ileal Bypass with Sleeve Gastrectomy (SADI-S)	Protein malnutrition. Lipid malabsorption, chronic diarrhea, and flatulence. Bone demineralization. Dumping syndrome and GRD. Iron deficiency anemia or megaloblastic anemia due to folate and/or vitamin B12 deficiency. Dysvitaminosis with Wernicke's encephalopathy (thiamine deficiency), neuropathy (B-group deficiency), and night blindness (vitamin A deficiency). Intestinal dysbiosis and alterations in the microbiota.

Table 7. Complications: prevention and treatment.

Late Complications	Prevention	Treatment
GRD	Dietary precautions (avoid large meals and limit fatty or spicy foods).	Antisecretory therapy.
Dumping syndrome	Dietary and behavioral modifications (small, frequent meals).	Fractionated diet without simple sugars.
Protein malnutrition	High-protein diet.	Oral protein supplementation or parenteral nutrition.
Lipid malabsorption and chronic diarrhea	Dietary modifications to limit excessive fat intake.	Pancreatic enzymes to improve lipid digestion (pancrelipase).
Gut dysbiosis and alterations in microbiota	Dietary adjustments and probiotics.	Probiotics and prebiotics to restore gut microbiota balance.
Iron deficiency anemia	Regular intake of a multivitamin supplement specific for bariatric surgery plus periodic oral or intravenous martial supplementation if necessary (18–60 mg/die).	Oral supplementation should be increased to provide 150–200 mg of elemental iron daily to amounts as high as 300 mg 2–3 times daily (intravenous iron infusion if oral administration is insufficient or poorly tolerated).
Megaloblastic anemia caused by folate and/or vitamin B12 deficiency	Regular intake of a multivitamin supplement specific for bariatric surgery plus periodic oral or im supplementation if necessary. - B12 supplementation: 350–500 mcg/day per os sublingual; 1000 mcg/month im. - Folic acid supplementation: 0.4–0.8 mg/day per os.	Administration of oral supplements or intramuscular injections of vitamin B complex: cobalamin 1000 mcg/day and/or folate 1000 mcg/day to achieve normal levels and then resume recommended dosages to maintain normal levels.

Table 7. *Cont.*

Late Complications	Prevention	Treatment
Bone demineralization	Monthly monitoring of ionized calcium, serum 25 OH vitamin D, 24 h calcium, and phosphate excretion; annual BMD evaluation; and serial PTH testing. Supplementation of vitamin D with 3000 IU/day until blood levels of 25 (OH) D are greater than sufficient (30 ng/mL). The appropriate dose of daily calcium from all sources varies by surgical procedure: BPD-DS: 1800–2400 mg/day; LGB, SG, and RYGB: 1200–1500 mg/day.	Administration of vitamin D per os and/or calcium supplementation per os/iv with the following doses: Vitamin D3 at least 3000 IU/day and as high as 6000 IU/day, or 50,000 IU vitamin D2 1–3 times weekly. Repletion of calcium deficiency varies by surgical procedure: BPD-DS: 1800–2400 mg/day calcium; LGB, SG, and RYGB: 1200–1500 mg/day calcium.
Dysvitaminosis with Wernicke's encephalopathy (thiamine deficiency), neuropathy (group-B deficiency), and night blindness (vitamin A deficiency)	Serial monitoring of serum values and regular intake of a multivitamin supplement specific for bariatric surgery.	Corrective intravenous infusion (oral supplementation at the maximum dosage in less severe forms).

8.1. Deficiency of Vitamins and Minerals

Patients undergoing bariatric surgery may experience nutritional deficiencies (vitamins, oligo elements, and electrolytes) [32–34] in

- Iron: Its deficiency is one of the most common nutritional complications post-bariatric surgery. Limited absorption capacity, combined with a possible reduced dietary intake of iron-rich foods, can result in sideropenic anemia, a condition that may manifest with fatigue, weakness, and, in severe cases, cardiac changes. Oral iron supplementation (30 mg/day) is frequently necessary, but in the presence of reduced intestinal surface area, this may be inadequate or insufficient. In these cases, intravenous iron supplementation is calculated as follows: (Kg body weight $\times \uparrow$ desired Hb $\times$ 2.5 + 10 mg pro Kg body weight).
- Folic acid: Its deficiency exposes individuals to megaloblastic anemia. Regular supplementation is essential to prevent deficiency (0.4–0.6 mg/day per os).
- Vitamin B12: Anatomical alterations can impair intestinal absorption of vitamin B12, leading to megaloblastic anemia, peripheral neuropathy, and cognitive deficits. Treatment involves oral supplements or intramuscular injections of vitamin B12 (per os: 250–1000 mcg/day, i.m.: 1000 mcg/3 months).
- Vitamin D: Reduced intestinal absorption of vitamin D, combined with limited sun exposure and reduced physical activity, may promote vitamin D deficiency, with an increased risk of osteoporosis and fractures. Vitamin D oral supplementation is often necessary to maintain adequate levels.
- Calcium: Bariatric surgery can alter calcium absorption, increasing the risk of osteopenia and osteoporosis. Supplementation with calcium supplements and regular monitoring of serum levels are essential.
- Vitamins A, E, and K: Deficiencies of these fat-soluble vitamins are less common but can occur, especially in the presence of lipid malabsorption.

- Vitamin B1 or thiamine: Deficiency of this vitamin can lead to a neurological syndrome known as Wernicke's encephalopathy (confusion, amnestic deficits, tinnitus, dizziness, and hearing loss).

8.2. Dumping Syndrome and Reactive Hypoglycemia

A significant nutritional complication is rapid gastric emptying syndrome (dumping syndrome). The accelerated transit of food from the stomach to the small intestine can induce excessive insulin release, resulting in reactive hypoglycemia. This phenomenon is most common after the ingestion of high-sugar meals and is manifested by profuse sweating, tremors, weakness, disorientation, and, in severe cases, loss of consciousness. Introducing small, frequent meals that are low in simple sugars throughout the day helps prevent such complications.

8.3. Lipid Malabsorption and Chronic Diarrhea

Lipid malabsorption is a common complication, particularly in patients undergoing gastric bypass. Reduced ability to absorb lipids can lead to chronic diarrhea, malnutrition, and, in some cases, steatorrhea. Treatment involves the use of supplements to improve lipid digestion and dietary modifications to limit excessive fat intake.

8.4. Gastrointestinal and Digestive Disorders

Some patients develop chronic dyspepsia, nausea, and vomiting due to physiological changes in the gastrointestinal tract. The regurgitation syndrome may occur when gastric contents reflux into the esophagus, causing chest pain and discomfort. The use of gastric acid secretion inhibitors may be necessary, but dietary modifications, such as avoiding large meals and limiting fatty or spicy foods, are crucial for symptom management.

8.5. Protein-Calorie Malnutrition

Rapid weight loss can induce protein-calorie malnutrition, especially if protein intake is insufficient. Protein deficiency can result in edema, muscle atrophy, and delayed healing. Adequate protein intake is imperative, and specific protein supplements are often recommended early post-bariatric surgery.

8.6. Gut Dysbiosis and Microbiota Alterations

Reduced gastric capacity and changes in intestinal transit can alter intestinal bacterial flora, resulting in digestive disorders, malabsorption, and an increased risk of infection. Gut dysbiosis has been associated with an increased risk of metabolic complications, and therapy may include the use of probiotics and prebiotics to restore the balance of the gut microbiota [35].

9. Weight Regain

There are multiple risk factors for weight regain after bariatric surgery [36,37]:

- Anatomical and surgical: Enlargement of the gastric sac and site of anastomosis, as well as gastro–gastric fistula formation, is among the main structural causes of weight regain (WR);
- Endocrine and metabolic: Changes in hormones levels such as ghrelin, GLP-1, and peptide YY, which regulate appetite and satiety, may contribute to WR;
- Behavioral and lifestyle: Patients may resume unhealthy eating habits and reduce physical activity, negatively affecting maintained weight loss;

- Psychological: Untreated eating disorders or psychological disorders during follow-up such as binge eating disorder, anxiety, depression, and other mental health problems are associated with an increased likelihood of WR.

To address WR, several strategies can be implemented [38,39]:

- Lifestyle modifications: Programs combining diet, physical activity, and behavioral support can improve post-surgical outcomes;
- Pharmacotherapy: The use of medications that reduce appetite and improve satiety is an effective option for patients with WR (GLP-1 RA);
- Sequential bariatric surgery: It may be necessary in cases of WR.

10. Public vs. Private

In bariatric surgery, a multidisciplinary approach is essential: before surgery, it ensures proper patient selection and procedure choice, and after surgery, it ensures adequate follow-up. This approach is only possible in highly specialized facilities. The use of BMS should be carefully evaluated and entrusted to professionals with undoubted professionalism and experience who can guarantee multi-specialty cross-sectionality that amplifies the outcome of the surgery.

There are significant differences among Italian regions in the procedures performed [10]. In southern regions, characterized by bariatric centers with relatively low numbers and volume, sleeve gastrectomy (SG) (39%) and OAGB (38%) prevail. In contrast, there is a very high number of bariatric centers in northern regions, which mainly perform OAGB and SG (about 80%) with very short waiting times (Table 8) [40].

Table 8. Private vs. public health in bariatric surgery.

	Public Health	Private Clinics
Access to care	Patient choice often not in line with guidelines (GLs).	Compliance with LG.
Waiting times	Waiting times in the private sector are generally shorter.	Waiting times are longer.
Quality of facilities and care	It does not guarantee a multidisciplinary approach to candidate selection and, above all, to post-operative follow-up.	It ensures a multidisciplinary intervention both before and after surgery.

11. Conclusions

BMS represents a highly effective therapeutic strategy in the treatment of severe obesity, but it carries significant risks, both in the short and long terms [41].

However, many of these complications can be avoided by appropriate patient selection, comprehensive assessment of clinical conditions, and structured follow-up including clinical, nutritional, and psychological monitoring.

Before embarking on such a course, the need for plastic-reconstructive surgery, once the ideal body weight achieved has been stabilized, should be considered in the risk–benefit ratio.

This aspect, which is not always economically feasible in the private sector and associated with long waiting periods in the public sector, is nevertheless necessary and therefore should be ensured at the end of the course to support the process of adaptation to the new body image that patients face after BMS.

In conclusion, bariatric surgeries should be performed in highly specialized hospitals that can guarantee the intervention of multiple specialists as part of a diagnostic therapeutic care pathway to prevent or resolve complications early, ensure adequate follow-up, and avoid/contain drop-outs in order to achieve satisfactory results especially in the long term.

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Abbreviations

The following abbreviations are used in this manuscript:

T2DM	Type 2 diabetes mellitus
OSAS	Obstructive sleep apnea syndrome
BMI	Body mass index
WHO	World Health Organization
GLP-1	Glucagon-like peptide-1
GLP-1 RA	Glucagon-like peptide-1 receptor agonist
GIP	Gastric inhibitory polypeptide
BMS	Bariatric–metabolic surgery
SG	Sleeve gastrectomy
BPD-DS	Biliary pancreatic diversion with duodenal switch
RYGB	Roux-en-Y gastric bypass
OAGB	One-anastomosis gastric bypass
LGB	Laparoscopic gastric banding
SADI-S	Single-anastomosis duodenal–ileal bypass with sleeve gastrectomy
CCK	Cholecystokinin
PYY	Peptide YY
MMPI	Minnesota Multiphasic Personality Inventory
SF 36	Short-Form Health Survey 36
BITE	Bulimic Investigatory Test Edinburgh
BIA	Bioelectrical impedance analysis
EGDS	Esophagogastroduodenoscopy
PFTs	Pulmonary function tests
TWL	Total weight loss
PCOS	Polycystic ovary syndrome
ACE	Angiotensin-converting enzyme
AHI	Apnea–hypopnea index
CNS	Central nervous system
GRD	Gastroesophageal reflux disease
Iv	Intravenous
Im	Intramuscular
BMD	Bone mineral density
PTH	Parathyroid hormone
WR	Weight regain

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