



NUTRITIONAL RECALIBRATION POST-BARIATRIC SURGERY: MECHANISMS, MICRONUTRIENTS, AND METABOLIC INTERPLAY

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ABSTRACT Bariatric surgery has emerged as a highly effective and durable intervention for managing morbid obesity and its associated comorbidities such as type 2 diabetes, hypertension, and dyslipidemia. This review explores various types of bariatric procedures—including restrictive and malabsorptive surgeries—and their long-term impact on nutritional status, weight loss outcomes, and metabolic regulation. Emphasis is placed on the criteria for successful weight loss, primarily evaluated through the percentage of excess weight loss (%EWL), and the complications arising from inadequate nutrient intake or absorption. Common postoperative nutritional deficiencies include iron, vitamin B12, vitamin A, C, D, E, K, and protein, each with specific clinical manifestations and management strategies. The review also discusses altered eating behaviors post-surgery, including the emergence of eating disorders such as binge eating and their psychological underpinnings. Furthermore, the role of gut microbiota in modulating metabolic parameters and appetite regulation post-bariatric surgery is examined. Overall, this article highlights the importance of long-term nutritional monitoring, behavioral support, and microbiome-focused research to optimize surgical outcomes and patient well-being.

KEYWORDS : Bariatric Surgery, Protein Malnutrition, Roux-en-Y Gastric Bypass (RYGB), Biliopancreatic Diversion, Binge Eating Disorder (BED), Gut Microbiota, Excess Weight Loss (%EWL)

INTRODUCTION

In obese individuals, surgical intervention has already been shown to be more successful and long-lasting than non-surgical treatment [1, 2, 3, 4]. Stated differently, weight loss, improved comorbidities such as diabetes mellitus, hypertension, and hyperlipidemia, and decreased cardiovascular risk are just a few of the notable benefits of surgical treatment [1,4]. These effects are long-lasting and persistent [1]. However, a considerable number of patients may require revisional surgery as the number of bariatric and metabolic procedures and long-term patient follow-ups rises [5,6,7]. One of the main causes of revisional surgery is recognized to be failure to lose weight [5,6,7]. Failure to lose weight lowers the patient's quality of life and leads to the recurrence of comorbidities, which ultimately raise medical expenses [5,6,7,8]. The negative aspect of bariatric surgery is this extremely significant long-term consequence. Furthermore, the technical difficulties of weight reduction failure and the elevated risks of morbidity and death associated with revisional surgery itself underscore its importance for bariatric surgeons [9].

Successful weight loss following bariatric surgery is typically measured using the percentage of excess weight loss (%EWL). This is calculated using the formula:

$$\%EWL = (\text{Weight loss} / \text{Excess weight}) \times 100$$

$$\text{Excess weight} = \text{Total weight pre bariatric surgery} - \text{Ideal weight.}$$

Here, excess weight refers to the difference between the patient's pre-surgery body weight and their ideal body weight. An outcome is generally regarded as successful if the patient achieves more than 50% EWL within two years after the surgery.

Types and Effects of Bariatric Surgery

In 2008, the number of bariatric surgeries worldwide surpassed 344,000. Among these, laparoscopic adjustable gastric banding (LAGB) was frequently used in Europe, while Roux-en-Y gastric bypass (RYGB) was more common in North America. LAGB works by restricting food intake without altering the stomach or intestines, and promotes gradual weight loss primarily by decreasing appetite. [9]

Other restrictive techniques include vertical-banded gastroplasty (now obsolete) and vertical sleeve gastrectomy (VSG). To increase weight loss effectiveness, VSG is sometimes combined with malabsorptive methods such as the duodenal switch. These malabsorptive procedures work by shortening the portion of the small intestine (the common channel) where nutrients are absorbed, limiting digestion and absorption time.

Combined approaches like RYGB, duodenal switch, and biliopancreatic diversion introduce both restriction and malabsorption. When the common channel is less than 120 cm, the risk of

significant nutrient deficiencies rises. Therefore, it's important for clinicians to review surgical records to understand the patient's postoperative nutritional needs.

RYGB has been linked to deficiencies in several essential vitamins including A, C, D, thiamine (B1), riboflavin (B2), B6, and B12. The duodenal switch, due to its higher malabsorption, shows even greater risks, especially for vitamins A, D, and B1. Biliopancreatic diversion, although highly effective for weight loss, often results in severe nutrient depletion, particularly of trace minerals like zinc and copper. Because of these complications, its use has declined, and there are documented cases of birth defects in children born to women who previously underwent this surgery.[10]

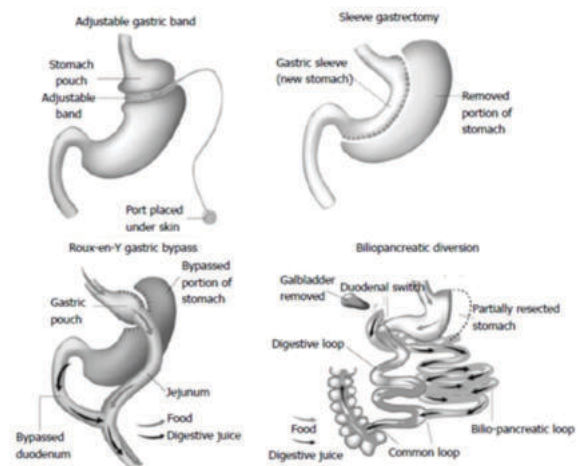


Figure 1: Infante, M., Leoni, M., Caprio, M., & Fabbri, A. (2021). Long-term metformin therapy and vitamin B12 deficiency: an association to bear in mind. *World journal of diabetes*, 12(7), 916. doi: 10.4239/wjd.v12.i7.916

Nutritional Deficiencies After Bariatric Surgery:

Anemia:

Iron insufficiency is the primary cause of post-bariatric anemia, with vitamin B12 deficiency being a minor factor. According to recent research by Alexandrou et al., iron deficiency, manifested by low serum ferritin, affects about 30% of patients five years after surgery, and the prevalence is comparable following RYGB and SG [10]. Numerous factors can contribute to iron deficiency. The main causes of iron insufficiency include reduced iron absorption from hypochloridia and skipping the duodenum and proximal jejunum, which are the main

sites of iron absorption. Significant contributing factors include changes in food preferences, such as intolerance for meat and dairy items, and a decrease in food intake following surgery.

Since serum ferritin is a more accurate and early measure of iron body capacity and becomes abnormal before serum iron concentration declines, it is the best diagnostic test for identifying iron deficiency. Ferritin and hemoglobin levels in bariatric patients should therefore be checked on a regular basis. As a preventative measure, current guidelines [11] advise oral iron supplementation for all surgical patients. However, intravenous iron treatment is necessary to rectify iron deficiency once it has developed, as dietary supplementation is insufficient.

Vitamin b12:

The prevalence of B12 insufficiency in the post-bariatric population can be fairly high, up to 65% in patients undergoing Roux-en-Y gastric bypass (RYGBP) and biliopancreatic diversion (BPD) surgeries [12]. A B12 deficiency can cause megaloblastic anemia, which is primarily asymptomatic but can be made worse by surgical blood loss, a typical side effect of post-bariatric contouring treatments. This is because B12 plays a critical role in DNA and protein stabilization. Anemia fatigue may further impair the patient's movement, raising the risk of thromboembolism, while the drastically decreased volume of blood in circulation may cause delays or issues in the healing of wounds.

Furthermore, a lower B12 level has been associated with higher plasma levels of homocysteine and methylmalonic acid (MMA), which raise the risk of thrombosis and endothelial dysfunction [13,14].

Vitamin C

A healthy, diverse, fruit-rich diet could effectively address vitamin C insufficiency in post-bariatric individuals because it is water-soluble. To prevent microcytic anemia, however, supplements may be suggested in treatments where vitamin C is impacted, such as RYGB, as research indicates that it improves iron absorption. Oral vitamin C supplementation of 1-2 grams per day is typically coupled with ferrous sulfate 300 mg twice or three times per day in cases of confirmed iron deficiency anemia. Refractory cases may benefit from intravenous infusions [15,]. Among the low-molecular-weight antioxidants include glutathione and vitamin C. The activity of antioxidants in preventing tissue damage caused by their high reactivity is crucial for good healing, even though low levels of ROS are necessary for angiogenesis and intracellular signaling [16]. This is demonstrated by their depletion in wounded skin and impaired wound healing conditions like diabetes, advanced age, and immunodepression [17].

Vitamin A

According to reports, the prevalence of vitamin A deficiency in the post-bariatric population is approximately 69%, rising over time, and 10% resistant to supplementation. Repletion is advised to be accomplished by oral supplementation between 10 and 50,000 IU/day for one month prior to and following surgery, or by 10,000 IU/day intravenously in cases of more severe deficiencies and malnourished patients, given that its daily requirement (2700 IU) appears to increase following surgical procedures. [18]

Vitamin E

Vitamin E consists of two main groups: tocopherols and the lesser-known tocotrienols. In the typical American diet, α -tocopherol is the most prevalent form. This vitamin plays a crucial role in protecting cell membranes from lipid peroxidation due to its positioning within the membrane. Oral supplementation is generally well tolerated at doses between 400 and 1,000 mg daily (note: 1 IU of vitamin E is equivalent to 0.67 mg).

Post-bariatric surgery, vitamin E deficiency is not well documented, but symptoms such as ataxia, muscle weakness, visual disturbances, anaemia, or speech difficulties may suggest a deficiency. Initial management involves oral supplementation of 800–1,200 IU per day.[19]

Vitamin K

Vitamin K refers to a group of compounds vital for synthesizing prothrombin and other proteins involved in the blood clotting process. It is moderately absorbed (about 40–70%) in the jejunum and ileum. Due to its rapid turnover rate, the body maintains only a small reserve of vitamin K. Additionally, intestinal bacteria contribute significantly to its production in the human body.

Although reports of vitamin K deficiency following bariatric surgery are rare, it may still occur in subtle forms. Notably, cases of intracranial hemorrhage in five newborns born to mothers who had undergone RYGB indicate the possibility of undiagnosed maternal vitamin K deficiency. When deficiency is suspected, treatment may involve oral supplementation (2.5–25 mg daily) or parenteral administration (5–15 mg via intramuscular or subcutaneous injection).

Macronutrients

Following bariatric surgery, protein deficiency is the most significant macronutrient-related concern. According to the Endocrine Society, patients are advised to consume 60–120 grams of protein daily, though even reaching the lower threshold of 60 grams can be challenging without the guidance of a nutrition professional. Protein malnutrition poses a serious risk, particularly in patients with a shortened common channel, which limits the region of the small intestine where pancreatic enzymes mix with dietary protein, reducing absorption.

Research on hypoalbuminaemia a key indicator of protein deficiency has shown it occurs frequently in those undergoing biliopancreatic diversion or duodenal switch, with prevalence ranging from 3.4% to 18.0%. In many cases, hair loss is one of the earliest signs of protein deficiency. Other indicators, based on WHO criteria, include oedema, visible wasting, changes in hair texture, and lab findings such as anaemia and low serum albumin. However, since albumin is also a marker of inflammation, low levels may also reflect acute illness, liver dysfunction, or small intestinal bacterial overgrowth.

It remains uncertain whether simply increasing dietary protein intake can fully prevent protein malnutrition after surgery. There is a lack of high-quality studies evaluating the effectiveness of liquid protein supplements in managing this issue. Due to potential complications of total parenteral nutrition (TPN), enteral feeding with liquid protein supplements should be the first option. In severe cases marked by widespread oedema and muscle wasting patients should be assessed for the possibility of surgical revision. [20]

Eating Techniques

Eating habits are another issue that bariatric patients must deal with in order to maximize their weight loss. Patients need basic instructions to help them get used to their new eating habits after bariatric surgery. In order to become more aware of their body's cues and be able to recognize when to stop eating, when they feel comfortable or satisfied, and how to avoid feeling full or overfull, patients must learn to eat slowly and in a relaxed manner while avoiding distractions like television, work, or reading. Patients should give themselves 20 to 30 minutes to eat, and then they should throw away the rest of their food. [21]

Eating Disorders

There has been a growing recognition of eating disorders such as anorexia nervosa, bulimia nervosa, and unspecified eating disorders developing in individuals after bariatric surgery. Research by de Man Lapidot et al. found that those who underwent bariatric procedures were more likely to experience eating disorders post-surgery compared to those who pursued conventional weight loss approaches. Often, these disorders reflect a resurgence or persistence of preoperative disordered eating behaviors. In some cases, obesity or the surgical changes themselves may conceal the symptoms, making diagnosis more challenging. Therefore, it's critical for healthcare professionals to closely monitor patients' eating patterns, mental health, and weight changes during follow-ups.

Binge eating disorder (BED) involves consuming unusually large quantities of food in a short span of time, often accompanied by a feeling of loss of control. Identifying patients with BED before surgery is vital. While bariatric procedures physically limit food intake due to reduced stomach size, the psychological patterns behind binge eating often remain. Postoperatively, patients may compensate by frequent snacking (grazing) or, in some cases, develop behaviors such as purging, often driven by emotional distress.

Patients identified with BED before surgery are more prone to problematic eating habits afterward, including increased vomiting frequency and weight regain. According to Kalarchian et al., about 43% of bariatric patients reported episodes of loss of control over eating post-surgery, and these individuals often experienced less successful long-term weight loss outcomes. [22]

Correlations Between the Gut Microbiota and Metabolic Parameters:

One study by Kong et al. found notable shifts in 14 bacterial genera following Roux-en-Y gastric bypass (RYGB), with 13 of these showing significant positive or negative associations with changes in total calorie intake after surgery. Among their key findings was a link between alterations in plasma leptin levels and seven major bacterial genera in the gut. Specifically, leptin was positively associated with *Bifidobacterium*, *Blautia*, *Dorea*, and *Lactobacillus*, and negatively associated with *Bacteroidetes*, *Alistipes*, and *Escherichia*. A separate study also reported similar negative correlations involving leptin.

Despite multiple observed relationships between the gut microbiome and various clinical variables, no association was found between gut microbiota changes and resting energy expenditure.

Only one study focused on the connection between the gut microbiota and shifts in appetite and food preferences following bariatric surgery. This study reported three notable correlations: a higher feeling of hunger was linked to increased levels of *Enterococcus* and *Odoribacter*, while a lower desire for sweet foods was linked to a greater presence of *Akkermansia*.

CONCLUSION

Bariatric surgery offers significant and sustained benefits in terms of weight reduction and the resolution of obesity-related comorbidities. However, the long-term success of these procedures extends beyond the surgical intervention itself. Nutritional deficiencies particularly of iron, vitamin B12, and fat-soluble vitamins are common and can lead to serious clinical consequences if not identified and treated early. Protein malnutrition, in particular, remains a critical concern, especially in malabsorptive procedures like biliopancreatic diversion. Additionally, maladaptive eating behaviors and the resurgence of eating disorders such as binge eating can compromise weight loss outcomes and psychological well-being. Emerging evidence also suggests a strong interaction between gut microbiota composition and metabolic parameters post-surgery, pointing toward future therapeutic targets. Given these complexities, a multidisciplinary approach involving dietitians, mental health professionals, surgeons, and primary care providers is essential for monitoring, educating, and supporting bariatric patients. Continued research and individualized patient care will be key in enhancing long-term outcomes and minimizing complications. [24]

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