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BRIEF REPORT

# Brazilian guide to nutrition in bariatric and metabolic surgery

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## Abstract

**Purpose** Brazilian nutrition recommendations for bariatric and metabolic surgery aim to provide knowledge, based on scientific evidence, on nutritional practices related to different surgical techniques in the surgical treatment of obesity and metabolic diseases.

**Materials and methods** A systematic literature search was carried out with the appropriate MeSH terms using Medline/Pubmed/LiLACS and the Cochrane database, with the established criteria being based on the inclusion of articles according to the degree of recommendation and strength of evidence of the Classification of Recommendations, Evaluation, Development, and Evaluation System (GRADE).

**Results** The recommendations that make up this guide were gathered to assist in the individualized clinical practice of nutritionists in the nutritional management of patients with obesity, including nutritional management in the intragastric balloon; pre and postoperative nutritional treatment and supplementation in bariatric and metabolic surgeries (adolescents, adults, elderly, pregnant women, and vegetarians); hypoglycemia and reactive hyperinsulinemia; and recurrence of obesity, gut microbiota, and inflammatory bowel diseases.

**Conclusion** We believe that this guide of recommendations will play a decisive role in the clinical practice of nutritionists who work in bariatric and metabolic surgery, with its implementation in health services, thus promoting quality and safety in the treatment of patients with obesity. The concept of precision nutrition is expected to change the way we understand and treat these patients.

**Keywords** Brazilian bariatric nutrition (MesSH) · Nutrition recommendations (MeSH) Gut microbiota (MeSH) · Inflammatory bowel disease (MeSH) · Bariatric weight regain (MesSH) · Bariatric surgery (MesSH)

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## Introduction

Obesity is a chronic, multifactorial, complex disease with an exponential increase in worldwide prevalence. This growth can be observed at all ages and in both sexes, regardless of geographic location, ethnicity, and socioeconomic status [1]. In Brazil, overweight affects almost 50% of the adult population, with 30 million patients with obesity and 95 million overweight [2]. Overweight and obesity are responsible for approximately 80% of cases of type 2 diabetes, 30% of ischemic heart disease, and 55% of hypertensive disease in the adult population [3–5].

In view of the increase in obesity and morbidity, bariatric surgery (BS) is an established treatment option, especially for promoting and maintaining long-term weight loss (WL), as well as controlling or reversing associated comorbidities, with a low occurrence of complications [3, 6, 7]

In 1991, the National Institutes of Health (NIH) established the criteria for performing BS—failure of clinical treatment in patients with body mass index (BMI) > 40 kg/m$^2$ or BMI > 35 kg/m$^2$ with reversible comorbidities induced by WL after the surgical treatment of obesity [8]. These criteria were ratified in Brazil by the Federal Council of Medicine (*Conselho Federal de Medicina*—CFM) in its ordinance 1942/2010 [9]. Recently, the American Association of Bariatric and Metabolic Surgery and the International Federation of Obesity Surgery have made new indications for the surgical treatment of obesity, among them, considering bariatric and metabolic surgery for patients with obesity class I and associated diseases. For obesity classes II and III, the indication of surgical treatment is already established [10].

In Brazil, according to data published by the Brazilian Society of Bariatric and Metabolic Surgery (Sociedade Brasileira de Cirurgia Bariátrica e Metabólica—SBCBM), in the last eight years, there was a growth of 84.73% in the number of surgeries performed [11]. It is worth highlighting four techniques recommended in our country: gastric bypass (gastroplasty with Roux-en-Y intestinal bypass – RYGB), vertical sleeve gastrectomy (SG), duodenal switch (DS), and adjustable gastric band (AGB) of which less than 1% are performed [11]

At the same time, with the increase in the number of bariatric surgeries, more nutritional conduct material has been published, much of which however, without scientific basis, exposing professionals to inappropriate practices, compromising the appropriate outcome for the patient with obesity.

In this way, the Brazilian nutrition recommendations for bariatric and metabolic surgery were developed with the objective of providing data based on scientific evidence on nutritional practices related to different surgical techniques, and nutritional treatment and the intragastric balloon (IGB).

## Method

The review was carried out with nine nutritionists, two endocrinologists, and a physician nutrition specialist, based on their content and methodological experience, record of publications, achievements, and commitment to the project.

Each group member performed a systematic literature search of the designated topic with the appropriate MeSH terms using Medline/Pubmed/LiLACS and the Cochrane database.

The established criteria were based on the inclusion of articles, according to the degree of recommendation, and strength of evidence. There was strong evidence for randomized controlled trials (grade A); intermediates, for non-randomized clinical studies, or well-conducted observational studies (grade B); and for those without clinical evidence, which are derived from expert opinion and consensus (grade C). Another important aspect is the analysis and qualification of the treatment effect size, subdivided into classes: class I: benefit superior to risk and evidence in favor of the indication; class II: there may be conflicting evidence or divergence of opinion about the effectiveness of a procedure (it is divided in this case into IIa: there is divergence, but the majority approves; and IIb: there is divergence and division of opinions: and in class III it is not recommended [12].

The articles were gathered to assist in the individualized clinical practice of Brazilian nutritionists in the nutritional management of bariatric patients, including nutritional management in the IGB; pre and postoperative nutritional treatment in bariatric and metabolic surgeries; pre and postoperative nutritional supplementation; hypoglycemia and reactive hyperinsulinemia; recurrence of obesity, microbiota; and finally, BS in inflammatory bowel diseases (IBD).

## Non-surgical procedure

### Nutritional treatment in the intragastric balloon

The use of the IGB for the treatment of obesity is based on the recommendations of the American Society for Metabolic and Bariatric Surgery (ASMBS) and the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) [13] (class I; grade C), as well as the guidelines recently published by the American Association of Clinical Endocrinologists/American College of Endocrinology together with the societies described above [14] (class I; grade C), and according to the latest Brazilian Consensus on IGB [15] (class I; grade C). The pathophysiological mechanisms by which IGB leads to WL have not yet been fully elucidated. It is believed that WL is caused by an increase in early satiety, causing individuals to consume smaller amounts of food, associated with delayed gastric emptying [13, 16].

The ASMBS indicates endoscopic balloon therapy as the first treatment for WL, for patients with a BMI > 35 kg/m$^2$

[14, 17, 18], or for patient with obesity whose BS has been contraindicated, or for the elderly population, or for patients with super obese (BMI ≥ 50 kg/m$^2$) who need to lose weight before surgical treatment [18] to reduce the operative risk. The Food and Drug Administration (FDA) recommends the use of IGB for patients with a BMI between 30 and 40 kg/m$^2$ [14] (class I; grade C). IGB is recommended for individuals between 18 and 70 years of age.

In Brazil, the use of the IGB technique is indicated as a therapy for weight reduction in patients with a BMI ≥ 25 kg/m$^2$, or overweight, or moderately obese (BMI ≥ 30 kg/m$^2$), or morbid (BMI ≥ 40 kg/m$^2$), with or without comorbidities such as arterial hypertension, type 2 diabetes, dyslipidemia, sleep apnea, among others. The IGB can also be used to reduce the surgical risk or for individuals who do not accept the surgical indication as a treatment for obesity [15] (class I; grade C).

### Pre- and post-IGB nutritional treatment

The candidate for IGB placement should be informed of how the nutritional guidance will be during the period of balloon insertion, whether it is 6 or 12 months, and must be aware that the treatment of obesity requires the follow-up from a multidisciplinary team [17, 19] (class IIb; grade B).

Successful WL with IGB requires following a food guide with dietary recommendations and restrictions (Table 1), in addition to physical exercise and behavioral changes. In the pre-placement consultation, the patient must receive nutritional information that involves understanding the energy balance, reading the labels of industrialized products (calories, distribution of macronutrients and micronutrients such as sodium), and estimating the size of the portions.

In the first 14 days after IGB implantation, rapid WL occurs, which can lead to deficiencies in vitamin D, iron, vitamin B9, vitamin B12 and thiamine. These micronutrients should be monitored and supplemented in case of serum depletion [20].

The IGB technique is considered safe and effective as a WL option for overweight and patient with obesity; however, it does not represent a definitive treatment for obesity (class I; grade C). It must be associated with permanent behavioral changes (Table 2).

## Surgical procedure

### Nutritional treatment in bariatric and metabolic surgery

The nutritionist is one of the professionals who make up the basic team of an interdisciplinary outpatient service. It is recommended that they have experience in obesity and BS, and that they are duly certified and qualified, as well as other team members to carry out pre and postoperative follow-up throughout the life of the patient with obesity [14, 21–23] (class: I; grade C).

Nutritional treatment, before and after bariatric and metabolic surgery, must be individualized, based on scientific evidence, and performed through the systematization of nutritional care (Fig. 1) [24, 25]. In addition to patient follow-up, the team should hold support group meeting [14].

**Table 1** Nutritional treatment after IGB placement

| Phases | Consistency of the diet | Permitted foods |
|---|---|---|
| 1st) first three days after balloon implantation: | Clear liquid diet | Still water, tea without added sugar, coconut water; low-acid unsweetened juice, liquid protein, unsweetened gelatin, clear broth/soup, unsweetened fruit popsicles (not creamy)<br>Avoid caffeinated teas and coffee |
| 2nd) 3 to 14 days after balloon implantation: | Complete liquid diet | Keep the foods allowed in the first phase<br>Include low-fat milk and yogurt with no added sugar; diluted oatmeal; blended and sieved vegetable soup<br>The calorie recommendation for the second phase is between 1000 and 1200 cal/day. During this period, rapid WL occurs |
| 3rd) 15 to 21 days after balloon implantation: | Pureed diet | The nutritional recommendation at this stage is 1200 to 1500 cal/day, with 60 to 80 g of protein/day. The food should have a very soft texture and liquefied vegetable and legume cream can be included, as well as grated or mashed fruit<br>The patient must evaluate the introduction of the food as well as the acceptance of the texture of the preparation |
| 4th) after 22 days of balloon implantation: | Normal/solid diet | Phase comprising the solid texture of food. Patients should be instructed to maintain a balanced diet<br>WL continues, however<br>more slowly |

Adapted from Papademetriou M & Popov V [16]'

**Table 2** Nutritional guidelines after the introduction of a solid diet and guidance for successful weight maintenance

| Introduction of the solid diet | The ten steps to successful weight maintenance |
|---|---|
| 1. Solid foods should be introduced gradually | 1. Continue nutritional monitoring monthly or every two months to maintain WL for six months |
| 2. Chewing must be prioritized | 2 Insufficient WL is associated with non-adherence to nutritional consultations and non-compliance with dietary guidelines |
| 3. All foods must be cooked, and raw foods must be avoided | 3. Eat 3 meals and 2 small "smart snacks" throughout the day |
| 4. Limit the intake of bread, pasta, and other flours, as they stick to the balloon and can cause halitosis | 4. Eat slowly and chew your food well |
| 5. It is recommended to drink ½ glass of water 30 min before and 30 min after feeding, to rinse the balloon | 5. Avoid foods high in sugar and simple carbohydrates and limit alcohol intake to 1–2 drinks/week |
| 6. Avoid lying down after meals. Wait at least two hours | 6. Fluid intake should be 8 to 10 glasses of water/day |
| 7. Exercises and walking should be guided for 15–30 min or more daily | 7. Ingest protein of high biological value at breakfast and at other meals of the day (lunch and dinner) |
| | 8. Monitor your weight once a week |
| | 9. Practice physical exercise regularly, at least 3 times a week and try to walk with the aim of reaching 10,000 steps/day |
| | 10. Avoid snacking between meals and eating close to bedtime. Avoid processed foods like potato chips, fries, cereal bars, crackers, and cookies. Most of these foods contain ingredients that stimulate appetite and are high in sodium, fat and carbohydrates |

Adapted from Papademetriou M & Popov V [16]

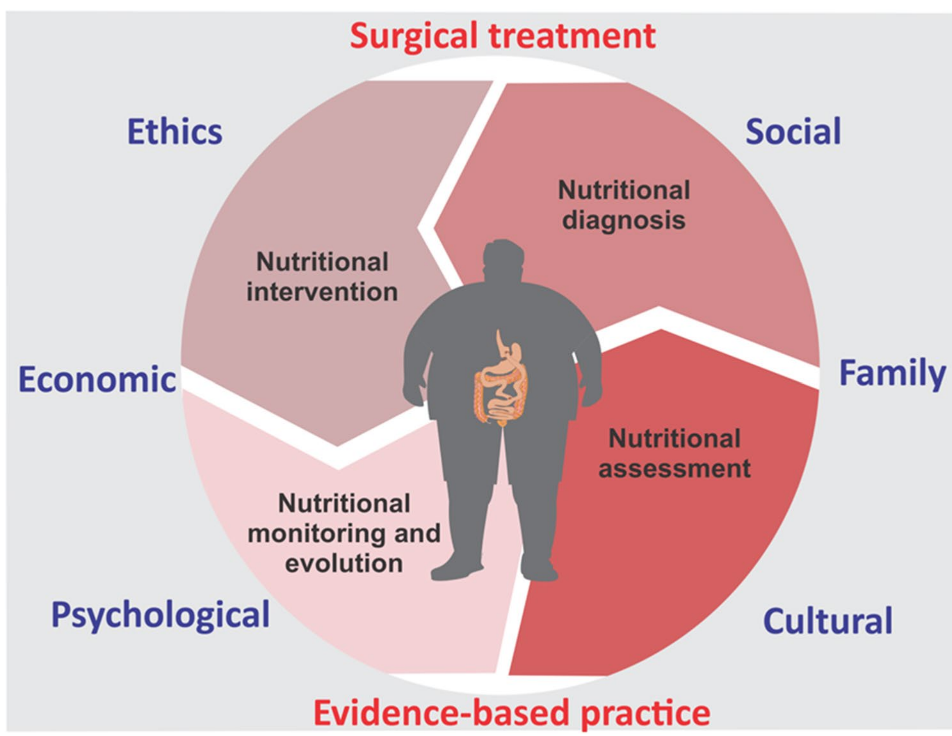


**Fig. 1** Systematization of nutritional care in the surgical treatment of obesity

## Nutritional assessment

This should be performed systematically to identify the etiology and extent of nutritional abnormalities. Nutritional assessment methods cover anthropometric and biochemical parameters, food consumption, body composition, and physical examination (Table 3), which will allow comparative analysis, definition of diagnosis, intervention, monitoring and nutritional evolution at all stages of treatment [24, 25] (class: I grade A). It is necessary initially, to know the patient, their life habits, history of obesity disease, previous treatments performed (clinical, pharmacological, endoscopic, and alternative), presence of associated comorbidities and eating disorders, food allergies and intolerances, as well as the adoption of dietary patterns, such as vegetarianism. The family history of obesity and other chronic conditions should also be investigated [14]. In adolescents, aspects related to the period of birth (preterm or term), birth weight, maternal complications during pregnancy such as gestational diabetes, pre-eclampsia, whether they were breastfed, and how food was introduced, should be evaluated [26], in addition to performing a complete nutritional anamnesis.

**Table 4** Determination of adequate weight according to WHO (2000) [27]

| Adequate weight (kg) | Excess body weight (kg) |
|---|---|
| BMI 25 kg/m$^2$ × Height$^2$<br>BMI 30 kg/m$^2$ × Height$^2$ | Current weight – adequate weight |

The calculation of excess body weight is defined considering the classification of eutrophic/normal BMI (BMI 25 kg/m$^2$), class I obesity (BMI 30 kg/m$^2$), and for the patients with super obese (BMI ≥ 50 kg/m$^2$). Initially, the appropriate weight is defined through the calculations presented in Table 4.

Waist circumference is considered one of the main parameters for assessing the risk of developing cardiometabolic disease [27]. Despite the limitations due to the degree of adiposity in this region, which makes it difficult to define the midpoint between the iliac crest and the last rib, it is recommended to measure the waist circumference considering the greatest protuberance, when possible, at the height of the umbilicus. It should be noted that there is no standard methodology for measurement and reference

**Table 3** Nutritional assessment of adolescents, adults, elderly, and pregnant women before and after bariatric and metabolic surgery [27, 28, 31, 87, 91, 124–134]

| Population/Methods | Anthropometric | Biochemistry | Food Consumption | Body Composition | Physical Exam |
|---|---|---|---|---|---|
| Evaluation Period | Monthly: up to 6th month<br>Quarterly: until the end of the 1st year<br>Semester: until the end of the 2nd year<br>Annual: from the 3rd year | Quarterly: until the end of the 1st year<br>Annual: from the 2nd year | Monthly: up to 6th month<br>Quarterly: until the end of the 1st year<br>Semester: until the end of the 2nd year<br>Annual: from the 3rd year | Semester: until the end of the 2nd year<br>Annual: from the 3rd year | Hair: shine, texture, fall<br>Skin: dry, eyes (conjunctiva)<br>Mouth: sores in the corners, glossitis<br>Fragile and brittle nails, |
| Adolescent | (Class: I Level: B)<br>Weight<br>Height<br>BMI | Complete blood count<br>Ferritin, Transferrin Saturation Index<br>Transferrin, Total transferrin binding capacity<br>Folic Acid B9, Vitamin B12<br>Acetyl Malonic Acid (AAM)<br>Vitamin B1, Vitamin C<br>Vitamin A (beta carotene) Vitamin D | Food Record 3 days (RA3) | Electrical Bioimpedance, Tetrapolar, segmented<br>(Class: IIa Level: C) | Edema in lower limbs<br>Signs of nutritional deficiencies: cramping, tingling, foot pain |
| Adult | % Weight reduction<br>Circumferences: waist, neck and calf | Vitamin E, Vitamin K, calcium, phosphorus, magnesium, parathyroid hormone, serum copper and celluroplasmin, zinc, selenium, total proteins and fractions | Semi-Quantitative Food Consumption Frequency Questionnaire (QFCA) | DEXA<br>(when possible) | sensory changes (taste and smell) and memory[4]. |
| Elderly | | C peptide<br>Liver and kidney functions | | | |
| Pregnant | Weight (concurrent assessment of fetal growth)<br>Height<br>Pregnant BMI | PS: For DM screening, do not use TTOG due to the risk of hypoglycemia and DS. Monitor glycated hemoglobin every 3 months and investigate for risk factors. Continuous glucose monitoring or 7-point fasting glucose monitoring is indicated between the 24th and 28th week of gestation. | | DEXA<br>(1 year after pregnancy) | |

DEXA: bone densitometry or dual energy X-ray absorptiometry; TTOG: oral glucose tolerance test

**Table 5** Waist circumference limits (cm) stratified according to BMI, for white individuals [27, 127]

| **BMI** kg/m$^2$ | **Waist circ** (cm) | **Waist circ** (cm) |
|---|---|---|
| Normal weight (18,5–24,9) | ≥80 | ≥ 90 |
| Overweight (25-29,9) | ≥ 90 | ≥ 100 |
| Obese I (30-34,9) | ≥105 | ≥110 |
| Obese II and III (35) | ≥115 | ≥125 |

parameters for adolescents. Table 5 shows the limits of waist circumference according to BMI.

Calf circumference is one of the recommended methods for estimating muscle mass [28],, which contributes to the diagnosis of aging sarcopenia and sarcopenic obesity [29, 30] (class: I grade B). However, it is affected by excess subcutaneous fat or fluid accumulation, so it should be used in the absence of edema [29, 31–33]. Studies to validate the adjustment for BMI with reduced calf circumference and muscle mass and potentially sarcopenic obesity in obese people are recommended [34].

## Nutritional diagnosis

Nutritional diagnosis is critically determined from nutritional assessment, which covers the domains related to food intake, clinical, biochemical and body weight conditions, in addition

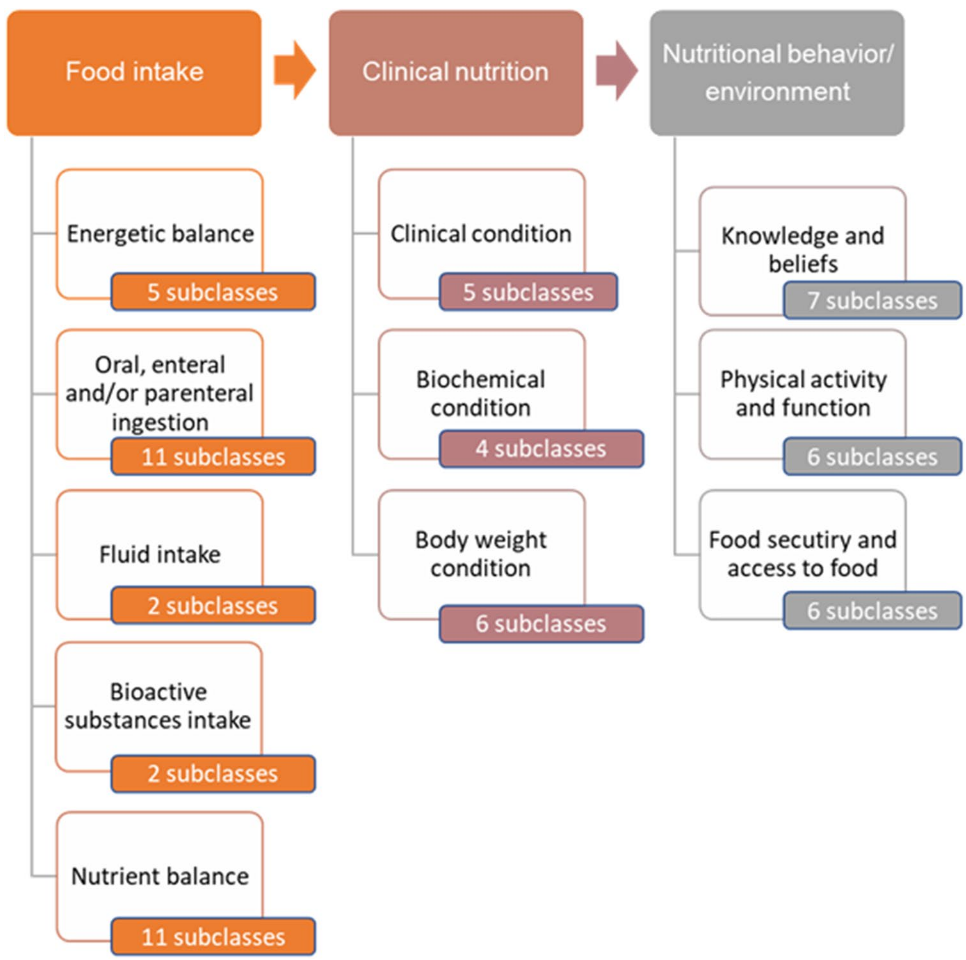


**Fig. 2** Domains of nutritional diagnosis, adapted from ASBRAN

to the nutritional behavior and environment (Fig. 2) [24, 25] (class I; grade C), i.e., they are already existing problems. This diagnosis is not definitive, it changes according to the response to nutritional intervention [24, 25].

## Nutritional intervention

### Preoperative

Preoperative nutritional intervention aims to optimize the nutritional status, to reduce the surgical risk, through the reduction of body weight, glycemic control, oral nutritional therapy, and shortening of preoperative fasting.

Body weight reduction aims to reduce liver volume, contributing to surgical access to the left subphrenic space, improving exposure, reducing complications and possible conversions [29, 35]. Despite studies published in the literature, there is still no uniformity regarding the appropriate conduct for preoperative weight reduction, i.e., a) whether pharmacological, endoscopic, low-calorie diet, low-carb diet; or the association of one or more aspects; b) reference parameters for body weight reduction, whether 10% or 20%; and c) whether this practice should be extended to all patients and/or only to those with a higher degree of surgical risk, such as the patients with super obese (BMI ≥ 50 kg/m$^2$) [35–38]. (class IIa; grade B).

Glycemic control should be optimized to reduce perioperative complications (class IIa; grade A) and increase long-term remission rates of diabetes (class IIa; grade B), through a diabetes treatment plan including nutritional adequacy, medication adjustment, and glycemic monitoring with preoperative glycemic targets of 70–180 (mg/dL). Postprandial blood glucose plays an important role in the contribution of glycated hemoglobin (HbA1c), with blood glucose measured two hours after the start of a meal (ideally between 140 and 180 mg/dL) (class I; grade C). Postprandial glycemia is influenced by several factors related to the composition of the diet (rich in carbohydrates: peak glycemia in one and two hours; high in fat and protein: peak in glycemia in three to five hours after-meal) [39]. There is no consensus among specialists regarding the best macronutrient composition and/or calorie recommendation in the preoperative period. However, most institutions recommend a calorie-restricted diet and adequacy in the distribution of macronutrients, according to the patient's intake, adjusting with postprandial blood glucose values, aiming to improve glycemic control (class IIa; grade C). Although there is no robust evidence demonstrating the benefits of glycemic control in the preoperative period of metabolic surgery, many studies show that in other surgeries, preoperative glycemic control reduces hospital stay and postoperative complications [39–41].

Thus, it is necessary to evaluate the function of beta cells (pancreas) to later adjust the prognosis in relation to diabetes remission, avoid diabetic ketoacidosis (for patients with undiagnosed autoimmune diabetes), plan glycemic monitoring, avoid diabetic complications, and assess the need for postoperative supplemental medication [42, 43] (class I; grade B).

C-peptide is used as a measure of insulin secretion and is the most useful and most widely used method to assess beta cell function. It is produced together with insulin in equal amounts, and is degraded more slowly than insulin, i.e., it is more stable, and there is no risk of cross-reaction when the patient uses exogenous insulin. C-peptide levels are associated with the type of diabetes and the duration of the disease, hence the need for its evaluation. Random C-peptide levels less than 0.6 ng/mL correlate well with stimulus tests, but levels greater than this value require confirmation with another method. The tests with the greatest sensitivity and specificity are the glucagon stimulation test and the mixed meal tolerance test. In insulin-using patients, a C-peptide of less than 0.6 ng/mL fasting or after mixed meal testing or less than 0.96 ng/mL after glucagon challenge correlates with high sensitivity and specificity for low insulin production [44] (class I; grade B).

Oral nutritional therapy (ONT) contributes to preoperative nutritional optimization in major abdominal surgeries, as well as in bariatric and metabolic surgery, with a reduction in postoperative complications. Evidence shows that immunomodulatory ONT should be administered five to seven days before the procedure and, if this is not possible, replace it with protein supplementation. To promote the same benefits of the immunomodulatory diet, the protein supply should be 18 g/meal, three to four times a day [35, 42] (class I; grade A).

The preoperative fasting is a continuation of the nutritional optimization process, as it reduces postoperative complications, through the reduction of insulin resistance, protein catabolism and the restoration of intestinal functionality. The first recommendations for rapid postoperative recovery, of the ERAS/BS Protocol, were published in 2016, containing 22 items, three related to nutritional aspects [38]. Currently, the bariatric and metabolic surgery centers that have implemented this protocol on the five continents have done so based on the knowledge of the literature, although they do not present uniformity about the shortening of preoperative fasting, early introduction of diet and protein supplementation in the postoperative period [39] (class I; grade A).

The ERAS/BS (2021) [39] recommendations for the abbreviation of preoperative fasting are:

| | |
|---|---|
| Solid meal | 6h |
| Clear liquids | 2h – 200ml |

**Except:** major gastroesophageal reflux, intestinal obstruction, gastroparesis, pyloric stenosis.

## Postoperative

Postoperative nutritional intervention aims to minimize the nutritional impacts resulting from the procedure, in the short and long term, as well as to continue the process of nutritional optimization which began in the preoperative period through the early introduction of the diet; food adequacy and individualized nutritional supplementation; and according to the surgical technique.

The early introduction of the postoperative diet (Table 6) should be started within the first 24 h after the surgical procedure, around 50 ml every 15 min, and gradually evolving to 100 to 200 ml/, according to the patient's tolerance. The diet should be of a liquid consistency, light in color and its nutritional composition with low sugar content prescribed by the clinical nutritionist and/or bariatric surgeon [39, 45] (class I; grade B).

Protein supplementation should also be started within 24 h postoperatively in small volumes and fractionated. The progression of diets will be carried out by the nutritionist in the consultations after the postoperative period, according to the surgical procedure. Normally, it evolves from a diet of clear liquid consistency to complete liquid, pureed, bland and normal. There is no uniformity regarding the period, however the literature presents the phases of progression, considering the individual tolerance and the characteristics of the surgical technique [14, 45] (class I; grade C). For greater protein intake, the inclusion of protein milk drinks, and/or a liquid or powdered protein nutritional supplement is recommended [14, 46] (class I; grade B).

**Table 6** Evolution and characteristics of postoperative diets for adolescents, adults (non-vegetarians and vegetarians), elderly [14, 23, 39, 45]

| Phase | Diet Consistency | Energy (kcal) | Proteins (g) | Lipids (%) | Carbohydrates (g) | Sugar (%) | Water (L) | Restrictions |
|---|---|---|---|---|---|---|---|---|
| 1 | Clear liquid administered at short intervals<br>Period: 1st to 24 h P.O<br>Volume: starting with 50 ml/h, progressing to 100 m/200 ml/h, according to the patient's tolerance<br>PS: Associated with protein supplementation = ERAS/BS protocol | — | — | — | — | | | Alcohol<br>Caffeine<br>Tough meats |
| 2 | Complete liquid<br>Period:<br>Start 2nd or 3rd day, until the 14th day P.O<br>Volume: 50. ml/h, evolving to 100 ml/h, according to the patient's tolerance | > 300 to 500 kcal/day | 25 to 30 g per portion | — | | ↓ | 1,5 | Carbonated drinks<br>Liquids with the main meals |
| 3 | Pasty<br>Period: 15th to 30th day P.O | 500 kcal/day | 25 to 30 g per portion<br>Prioritize protein source foods 3 to 5 times a day | Prioritize unsaturated fatty acids | | | | Concentrated sweets<br>Fried food |
| 4 | Soft/Normal<br>Period: from the 30th day P.O<br>PS: Solid foods | 500 to 750 kcal/day | 60 to 120 g day or<br>1.5 g/kg day | 25 to 30% of total caloric intake | 130 g<br>Prioritize prebiotic foods and whole grains | < 10% of total caloric intake | | Popcorn<br>Juices and processed products |

During the liquid diet phase, the diabetic patient should be encouraged to perform capillary glucose monitoring in a fasting state and at bedtime for glycemic assessment. To avoid major glycemic changes, we advise that during the liquid phase, the patient alternates liquids with and without carbohydrates throughout the day. It is possible that in this phase, in addition to nutritional adaptations, medication adaptation is necessary to avoid episodes of hypoglycemia. (class IIa; grade C). Treatment of hypoglycemia requires the ingestion of foods that contain glucose or carbohydrates [47]. Once mild hypoglycemia is detected (< 70 mg/dL), it can be easily treated with 15 g of fast-absorbing carbohydrate—150 mL of grape juice appears to be the best tolerated option by patients in the postoperative period of metabolic surgery (class IIb; grade C).

Food and nutrition adequacy must be complete and contain all essential nutrients according to the models proposed by *My PLATE* and the long-term *DASH Diet* [14, 48, 49]. These models propose smaller meals, rich in protein, whole grains, vegetables, fruits, and foods that are sources of omega 3, except sweets. Regarding hydration, a consumption of more than 1.5 l/day is recommended (class I; grade B). The minimum protein intake should be between 60 and 120 g/day, or 1.5 g/kg/day of ideal weight for adults (class I; grade A). Higher amounts of protein intake, up to 2.1 g/kg/day of ideal weight, need to be evaluated individually, within the socioeconomic and cultural conditions of the patient and constitute the fundamental axis of nutritional care. The goal of protein adequacy is minimal maintenance of lean mass loss during rapid WL. When protein intake does not reach adequate amounts through food alone, the use of protein nutritional supplements is recommended [14, 45] (class I; grade A). The supply of carbohydrates in the early postoperative period should be 50 g, and as food intake increases, 130 g are adequate. Pregnant women should avoid the use of simple carbohydrates and liquids during meals. It is recommended to consume low glycemic index carbohydrates, carbohydrates associated with proteins, and frequent ingestion of small meals a day (class I; grade C). Pregnant women with gestational diabetes should follow a diet plan with at least 175 g of carbohydrates, 71 g of protein, 28 g of fiber, prioritizing mono and polyunsaturated fats, limiting saturated fats, and avoiding trans fats (class I; grade C) [46, 50].

Individualized energy requirements should be guided, based on pre-gestational nutritional status, with a minimum initial caloric supply of 1800 kcal/day, and an addition of 300 kcal in the third trimester of pregnancy [50] (class I grade C). Caloric intake from lipids ranges from 20 to 35%, with the majority through consumption of unsaturated fat (class I; grade C). Regarding fiber, patients should be advised and encouraged to include in their diet at least five serving/day of fresh fruits and vegetables (total of 400 g), in addition to foods that are sources of fiber with prebiotic action. Associated with these aspects, postoperative eating behavior should be developed, such as: conscious eating, chewing, satiety, excluding the consumption of liquids at meals, limitations on the consumption of simple sugars, carbonated drinks, and alcohol consumption [14, 23] (class I; grade C). Vegetarians are advised to be offered foods that are a source of animal and vegetable proteins, fiber, phytochemicals, and essential fatty acids, which should be prioritized as they minimize the nutritional deficits promoted by the procedure, promote intestinal health, and maintain body weight in the long term [22, 51] (class I; grade B).

## Nutritional monitoring and evolution

Monitoring and nutritional evolution aim to minimize the nutritional impacts resulting from the procedure in the short, medium, and long term, as well as to continue the process of food re-education which began in the preoperative period. Long-term nutritional deficiencies and micronutrient deficiencies related to complications occur with variable frequency depending on the type of procedure and require lifelong vitamin supplementation [14, 23]. Long-term follow-up should be performed by the multidisciplinary team. Long-term concerns include vitamin and mineral deficiencies, anemia, osteoporosis, dumping syndrome and hyperinsulinemic hypoglycemia (class I; grade A).

## Nutritional supplementation in bariatric and metabolic surgery

Nutritional deficiencies are commonly observed both preoperatively and after BS. According to recently published consensus, in the period before surgery, in addition to clinical, dietary, and anthropometric assessment, biochemical analysis should be included, including complete blood count, iron, B12, folic acid, vitamin D (25 OH), parathyroid hormone (PTH) and thiamine. In patients who will undergo malabsorptive procedures—biliopancreatic diversion (BPD) and DS—a more extensive evaluation of micronutrients should be considered, according to the symptoms and risk presented [52, 53].

The main deficiencies observed in the period before surgery are iron and low levels of hemoglobin (0–47%); folic acid (0–63%); vitamin B12 (0–23%) and the most prevalent, vitamin D (up to 99%) [14, 52].

In the postoperative period, the anatomical changes resulting from the surgery imply a restriction of gastric volume and malabsorption secondary to the decrease in the absorption area in the small intestine, where nutrients are preferentially absorbed—the deficient conditions tend to increase considerably [14, 23, 41, 53–56].

Additionally, there may be dumping syndrome and food intolerances that limit the intake of foods that are sources of vitamins/minerals, in addition to the lack or inappropriate use of multivitamin supplements, which are recommended and fundamental for the maintenance and/or treatment of nutritional disorders.

The nutrient deficiencies after the different surgical techniques, in the postoperative period, are variable: thiamine 1 to 49%; folic acid up to 65%; vitamin B12 in RYGB < 20% and in SG between 4 and 20%; vitamin D up to 100%. Iron deficiency varies as a function of postoperative time (3 months to 10 years) and surgical technique: AGB 14%; SG < 18%; RYGB 20 to 55%; BPD 13 to 62%; and in DS 8 to 50%. Zinc deficiency is higher in BPD, and DS malabsorptive surgeries up to 70%, up to 40% in RYGB, up to 19% in SG, and up to 34% in AGB. Copper depletion reaches 90% in BPD and DS and is less frequent in RYGB, 10 to 20% and not reported in SG [52, 53]

The occurrence of multiple deficiencies in vitamins and minerals makes it imperative to recommend multivitamins after bariatric surgeries, as well as biochemical monitoring after surgery [14, 53].

Table 7 shows the postoperative supplementations (micronutrient and protein) in adults, pregnant women, adolescents, vegetarians, and the elderly.

The main recommendations regarding nutritional management of vitamins and minerals after surgical treatment of obesity are as follows.

Should the vitamin and mineral profile be carefully evaluated preoperatively? Yes, mainly complete blood count, iron, B12, folic acid, vitamin D (25 OH) and PTH (class I; grade B), calcium (class IIa; grade C) and thiamine in some cases (class IIa; grade C). In patients who will undergo malabsorptive procedures – BPD and DS, a more extensive evaluation of micronutrients should be considered, according to the symptoms and risk presented.

Is preoperative treatment of nutritional deficiencies recommended? Yes, (class I; grade C). Is the use of multivitamins in the postoperative period recommended? Yes, (class I; grade C). Is (additional) vitamin and mineral supplementation recommended postoperatively? Yes. Iron (class IIa; grade C); folic acid (class I; grade C); vitamin B12 (class IIa; grade B); vitamins A, D, E and K, zinc, and selenium (class IIa; grade C); copper (class IIb grade C) and thiamine (class I; grade C).

Is protein supplementation recommended after BS? Yes, (class IIa; grade C). Is biochemical monitoring recommended after BS? Yes, assess at regular intervals (3, 6, and 12 months in the first year and annually thereafter) (class I; grade C).

## Hypoglycemia and reactive hyperinsulinemia after bariatric surgery

Dumping syndrome and hyperinsulinemic (or reactive) hypoglycemia are complications that can occur after BS, especially after RYGB, however they can also occur after SG and DS.

Dumping syndrome results from changes in gastric and/or intestinal anatomy which allow a considerable amount of glucose to be absorbed by the small intestine very quickly[57]. Early symptoms usually occur within the first hour after a meal and include gastrointestinal symptoms such as abdominal pain and distension, borborygmus, nausea, diarrhea; and vasomotor symptoms: flushing, palpitations, sweating, tachycardia, hypotension, fatigue, drowsiness, and syncope although rarely. The underlying mechanisms may involve osmotic effects through the release of peptide hormones and autonomic neural responses [57, 58].

Reactive hyperinsulinemic hypoglycemia, in contrast, usually occurs between one and three hours after meals (postprandial period) and is characterized by manifestations of hypoglycemia, resulting from an exaggerated hyperinsulinemic response after carbohydrate ingestion [59]. Neuroglycopenic symptoms related to hypoglycemia may be reported as: feeling of fatigue, weakness, confusion, hunger, syncope, sweating, palpitations, tremor, and irritability [60, 61] (class I, grade B). Post-BS hypoglycemia can be severe and disabling for some patients, leading to falls, motor vehicle accidents, and often loss of employment and income [59] (class I grade B).

One of the hypotheses for the occurrence of hypoglycemia may be related to the increase in insulin sensitivity generated by WL mediated by the exacerbated response of glucagon-like peptide-1 (GLP-1) [59] (class IIa, grade B).

Another hypothesis would be that some patients undergoing BS tend to have a delay in decreasing the production of insulin by pancreatic beta cells, in response to the reduction in blood glucose, generating hyperinsulinemic hypoglycemia, or even to present a decrease in insulin clearance, which can contribute to sustained elevations of its plasma levels [59] (class IIb, grade B).

Usually after RYGB surgery, a decrease in postprandial glucagon is noted. This reduction in counterregulatory hormone responses may perpetuate recurrent hypoglycemia in the affected individual [59]

Generally, the presentation of reactive hyperinsulinemic hypoglycemia occurs after the first year of surgery and almost exclusively in the postprandial period [62] (class II; grade B).

Criteria for defining the diagnosis of reactive hypoglycemia are not universally defined, but generally must meet the criteria of Whipple's triad, i.e., symptoms of hypoglycemia, low glucose concentrations (< 50 mg/dl), and symptom relief after carbohydrate ingestion [58, 63]

Regarding the therapeutic approach, diet is recognized as the main strategy in the management of hypoglycemia after BS and aims to reduce the stimuli for glycemic and insulin peaks.

The principles of nutritional management of hypoglycemia are [62, 64] (class I; grade A): 1) use of low glycemic

**Table 7** Nutritional supplementations (micronutrient and protein) in adults, pregnant women, adolescents, vegetarians, and the elderly after bariatric surgery [14, 22, 50, 53, 135]

| NUTRIENT | ADULTS | PREGNANT WOMEN | ADOLESCENTS | VEGETARIANS |
|---|---|---|---|---|
| IRON | Men and patients without a history of anemia: 18 mg of iron per day contained in multivitamins. Menstrual women and patients undergoing RYGB and SG or malabsorptive surgery: 45–60 mg of elemental iron daily (including iron contained in the multivitamin) | Gradually increase the oral dose to a maximum of 240 mg, in several doses per day, if necessary, in combination with vitamin C to increase absorption. Can start with 60 mg/day | 45 to 60 mg (elemental iron) day | 28 to 30 mg/day – Oral |
| VITAMIN B12 | 350–1000 mcg daily (sublingual or liquid or oral absorption tablet or nasal spray). Parenterally (subcutaneously or intra-muscularly) 1000 mcg monthly. The use of 5000 mcg intramuscularly quarterly is also recommended | Increase frequency of oral doses (e.g., 1000 µg/day for 8 days and then twice/week) or intramuscular injection to 1000 µg/month, or weekly | 5000 mcg/d – sublingual, 350 mcg/day – orally, 500 to 1000 mcg intramuscular every 2/3 months, 500 mcg/week nasal spray | 500 to 1000 mcg/biweekly – Intramuscular<br>1000 to 1200 mcg/day – Sublingual or intranasal |
| FOLIC ACID | 400–800 mcg contained in multivitamins<br>800–1000 mcg in women of childbearing age | Initially 0.8 mg/day to adjust blood folic acid levels<br>A dose greater than 0.8 mg/day may be necessary to correct<br>folic acid deficiency | 400 – 1000 mcg/day | 400 mcg/day – Oral |
| VITAMIN D | 3000 UI orally daily until serum 25OH levels are sufficient (30 ng/mL) | Initial dose of 3,000 UI/day (i.e., 100,000 UI/month), adjusted to serum 25 OH vitamin D level | 600 to 2000 UI/day for maintenance, if deficiency: 1000 to 5000 UI/day | 30,000 to 60,000 UI (cholecalciferol)/weekly or fortnightly) |
| CALCIUM | RYGB, SG and AGB: 1200–1500 mg daily orally. Malabsorptive surgeries: 1800–2400 mg orally daily | Increase to 1500 mg/day away from iron intake<br>Increase calcium intake in the diet<br>The interpretation of results should consider the physiological decrease in parathyroid hormone (PTH) during pregnancy and the correction of calcium by serum albumin | 1300 mg/day (calcium citrate) | 1000 to 1200 mg/day – Oral<br>Do not administer more than 500 mg at a time |
| VITAMIN A | AGB – 5000 UI orally daily. SG and RYGB – 5000–10,000 UI orally daily. DS – 10,000 UI orally/day | Initial dose of 10,000 UI/day. A dose greater than 10,000 UI/day may be required to correct deficiency, depending on the clinical situation | DRIs 700 mcg/day for girls and 900 mcg for boys (in Multivitamin) | 50.000 UI / every 2 weeks |
| VITAMIN E | 15 mg daily orally. Higher doses may be necessary to maintain nutritional status in patients with a previous history of deficiency | | | |
| VITAMIN K | AGB, RYGB and SG: 90–120 mcg orally/day. DS: 300 mcg/day | | | |
| ZINC | Malabsorptive surgeries: 16–22 mg orally/day. RYGB: 8-22 mg orally/day. SG: 8-11 mg orally/day | 15 to 60 mg of oral zinc gluconate/day, fasting in the morning or at bedtime | DRIs 9 mg/day for girls and 11 mg/day for boys | Routine daily multivitamin should contain 8 to 22 mg of zinc per day |

**Table 7** (continued)

| NUTRIENT | ADULTS | PREGNANT WOMEN | ADOLESCENTS | VEGETARIANS |
|---|---|---|---|---|
| COPPER | RYGB and malabsorptive surgeries: 2 mg a day orally. SG and AGB: 1 mg daily orally. The recommended form for supplementation is copper gluconate or sulfate | | DRIs 890 mcg/day for girls and boys | |
| THIAMIN | Oral therapy: 100 mg 2–3 times daily until symptoms improve. Intravenous therapy: 200 mg 3×daily or 500 mg once or twice daily for 3 to 5 days, followed by 250 mg daily for 3 to 5 days or until symptoms improve. Intramuscular therapy: 250 mg 1×daily for 3 to 5 days or 100–250 mg per month | 100 to 500 mg/day intravenously or intramuscularly (in case of uncontrollable vomiting)<br>- In the absence of vomiting, 250 to 500 mg orally/day | 50 mg/day (in complex B) | |
| SELENIUM | Multivitamin containing RDA of selenium is recommended[7] | | | |
| PROTEIN | Between 60 to 120 g/day minimum, or 1.5 g/kg/day of ideal weight | 60–80 g or 1.1–1.5 g/Kg of ideal weight/day<br>In cases of multiple pregnancies, an increase of 15 to 20 g of extra protein for each baby | 60 – 90 g/day (1 – 1.5 g/Kg/d) | 1.0 to 1.5 g/kg of ideal weight/day – Bariatric surgery<br>1.5 to 2.0 g/kg of ideal weight/day – Duodenal Switch or Biliopancreatic Diversion |

**ELDERLY:** Micronutrient dosages should be requested according to an existing consensus for adults[26,28] (with special attention to vitamins B1 and B12, folate, iron, copper, and zinc) and supplemented according to individual deficiency, observing clinical and biochemical signs of this deficiency

Special attention should also be given to calcium supplementation (in the form of calcium citrate) and vitamin D, to prevent or minimize secondary hyperparathyroidism and osteoporosis (common in the elderly and which can be exacerbated by the surgical procedure)

RYGB: Roux Y Gastric Bypass; SG: sleeve gastrectomy; AGB: adjustable gastric band; DS: duodenal switch

RDA: Recommended Dietary Allowance; DRIs: Dietary Reference Intakes index carbohydrates; 2) controlled portion intake of low glycemic carbohydrates: 20–30 g per meal and 10–15 g per snack; 3) inclusion of healthy fats—15 g per meal and 5 g per snack; 4) adequate amounts of protein 1.5–2.1 g/kg of ideal weight or 0.91 g/kg of current weight; 5) periodic nutritional consultations; 6) intervals of 3–4 h between meals; 7) avoid liquids during meals and 30 min after; 8) avoid caffeine and alcohol; 9) optimize vitamins and minerals; and 10) avoid high glycemic carbohydrates such as sweets, sugars, fruit juice, and white flour.

In some cases, when diet does not effectively control symptoms, drug therapy may be necessary [59] (Acarbose – class I, grade B; Diazoxide – class III, grade B; Somatostatin Analog – class I, grade B; and blockers of calcium channels and GLP-1 agonists – class IIb, grade C).

Additionally, in more severe cases that are refractory to traditional treatments (diet and medication), the surgical approach such as: partial pancreatectomy, RYGB reversal, placement of a band or ring or endoscopic plication, transformation of the RYGB into a SG, and gastrostomy (probe placement in excluded stomach) [59, 64] can be considered. Due to high morbidity, incomplete resolution, or recurrence of symptoms, these surgical procedures must be performed carefully and individually.

## Weight recurrence

Weight recurrence (WR) after bariatric surgery is a result of hormonal and metabolic alterations, surgical failure (with inadequate weight loss), nutritional non-adherence, mental health issues and physical inactivity[65, 66] Among the criteria for identifying surgical failure and recurrence of weight: excess weight loss ≤ 50% or BMI > 35 kg/m$^2$ for patients with morbid obesity and excess weight loss ≤ 50% or BMI > 40 kg/m$^2$ for those who preoperatively presented super obesity[67] or then as a minimal 15.0% increase after the lowest weight achieved following surgery[68] respectively.

The causes of weight recurrence are multifactorial, with the main contributing factor being the lack of lifestyle changes. Management of weight recurrence include medical, endoscopic, and surgical interventions. Medical management usually involves the care by the multidisciplinary team including nutritionist, clinical physician, endocrinologist, psychologist, psychiatrist, and physical educator [69]. Endoscopic management has several treatment options such as argon plasma coagulation (APC), with or without full-thickness endoscopic suture. Revisional surgery is usually performed in patients that did not respond to medical and endoscopic management [69].

The greatest WL occurs in the first postoperative year [70]. Gastric bypass, SG and AGB showed a total WL of 38 ± 7%, 26 ± 10%, and 21 ± 10% respectively. In this study, after 10 years, patients undergoing RYGB, and gastric banding recovered 34% and 38% of maximum WL [60].

The amount of WL differs between surgical interventions. RYGB and the BPD produce larger and faster average WL than SG and AGB [61]. Recurrence of obesity can occur in 20 to 35% of patients, depending on the procedure and postoperative time [71–73].

Probable causes of WR were classified into five categories: anatomical, genetic, dietary, psychiatric, and temporal [74–76].

Anatomical factors: In patients undergoing RYGB there is no consensus that the diameter of the gastrojejunal stoma is a factor that may contribute to WR. Only in patients undergoing SG, it was observed that the gastric volume was greater among patients with WR and that the size of the stomach was related to the WL [76]. Dietary factors: There is a correlation of WR with high consumption of sweets, emotional eating habits, food portion sizes, food craving and binge eating episodes, in addition to loss of control/disinhibition of food intake. A prospective study evaluated over 10 years the food consumption of more than 1600 patients undergoing BS. Those who had a lower intake of fats and carbohydrates and a higher protein intake in the first 6 months were those who had better WL 10 years after the operation[77]. Consumption of caloric liquids, such as juices, soft drinks (soda), and alcoholic beverages, have been identified as factors that contribute to WR [78–81]. In addition, continuous snacking or eating habits during the day are related to WR [75, 82, 83].All dietary factors associated with WR can lead to intestinal dysbiosis. Faria et al. [84] showed that the gut microbiota of individuals who presented weight recurrence after RYGB was significantly different in comparison to individuals with a successful WL, a finding that points towards a significant role of gut microbiota on WL and maintenance after surgery. Regarding genetic factors, a study found an association between the genetic profile and WR in 96 patients. Psychiatric factors: Of nine studies, five found a strong positive association between depression and psychological stress and WR. Furthermore, a study by Livhits et al.[85] found an association between the use of antidepressant drug and low self-esteem with WR [69].. Temporal factors: Recent studies that investigated the relationship between duration of surgery with WR found an increase in the incidence and prevalence of WR with postoperative times. Hormonal factors: Hormonal mechanisms with decreased ghrelin and increased GLP-1 and peptide YY (PYY) may contribute to increased satiety and decreased hunger, leading to WL, although the exact mechanism is not completely understood. Baseline levels of GLP-1 are also not different between groups with and without WR. However, in the group with recurrence the increase in postprandial GLP-1 was lower [76, 86].

Treatment for WR depends on the amount of weight recurrence. Diet and lifestyle changes can help patients lose between 5 and 10% of their weight. The increase in protein intake can facilitate satiety and the maintenance of lean mass with consequent maintenance of the basal metabolic rate (BMR) favoring WL in situations of caloric deficit [87]. A lower energy expenditure is related to WR [88, 89].. It is important to monitor the WL and body composition during the first year after the operation, to avoid a marked loss of lean mass. It is accepted that up to 20% of the total weight is lean mass[90].

Physical activity is essential for long-term weight maintenance. The recommendation is to indicate 250 min/week of moderate exercise to prevent WR 150–250 min/week of moderate intensity aerobic exercise for WL. For WR prevention, the ideal is to perform more than 250 min/week with resistance exercise 2–3 times a week. For the treatment of WR, the recommendation is to increase the time of physical activity to more than 500 min/week in patients who respond to increased physical activity [91, 92].

Strategies for the treatment of weight recurrence are: 1) medical and nutritional treatment as early as possible, since the time factor increases the risk and amount of weight recurrence (class I; grade B); 2) adjunctive treatments to control anxiety, emotional eating, and control of binge eating (class I; grade C); 3) knowledge of portion sizes of foods and meals (class I; grade C); 4) adequate consumption of proteins, fruits, and healthy foods (real food) (class I; grade C); 5) reduction in the consumption of caloric beverages (including alcoholic beverages), diets rich in fat and low in protein and fiber should be avoided (class I, grade B); 6) regular physical activity (class I; grade B); 7) adequate consumption of proteins aiming at the maintenance of lean mass and resting metabolic rate; in addition, the consumption of proteins helps with satiety (class I, grade B); 8) consultations with physicians from the multidisciplinary team are recommended to evaluate the use of medications to control WR.

## Gut microbiota and bariatric surgery

Obesity is associated with a change in the structure of the gut microbiota, which leads to an interruption in its functional normality, leading to an increase in the energy capture capacity of the diet [93–95]. Currently, the preponderant role of the gut microbiota in the development of obesity is accepted on current knowledge of the disease[95]. Two phyla of bacteria are dominant in the human gut, the *Bacteroidetes* (gram-positive) and *Firmicutes* (gram-negative) [96].

Several studies have shown that both in humans and in animal models, BS is associated with important changes in both the composition and function of the gut microbiota that appear to be installed soon after the interventions, from the first week onwards [93, 97–99]and persist for up to nine years in humans [100].

This implies that the fundamental mechanisms underlying BS, including potentially the microbiota [95], bile acids (BA) homeostasis, endocrine regulation, and neural signals, are responsible for regulating metabolic homeostasis and providing important information for the adjustment of body weight [98].

We currently know that intestinal microbial diversity increases rapidly after BS and remains increased after one year [95]. At the high taxonomic level, *Firmicutes* are dominant in normal-weight and obese individuals, but significantly decrease in post-surgical individuals, as are *Bifidobacteria* [94, 97, 101] with increased members of the phylum *Bacteroidetes* and *Proteobacteria* [[93, 95, 102, 103]. In a mouse model submitted to RYGB, Liou et al. showed a rapid change in the gut microbiota, i.e., a decrease in the *Firmicutes*/*Bacteroidestes* ratio [104] and loss of body weight. Furthermore, an increase in the relative abundance of the phylum *Verrucomicrobia* (i.e., *Akkermansia muciniphila*) after RYGB has been reported in several studies [93, 103].

*Akkermansia muciniphila* contains mucin-degrading microbes, and animal studies have shown that this species protects against obesity and type 2 diabetes by increasing the intestinal epithelial barrier, potentially decreasing endotoxemia and low-grade inflammation. It has also been associated with improvements in markers of insulin sensitivity in humans [103].

After RYGB, the main features related to the microbiota were: a decrease in Firmicutes (e.g., *Lactobacillus spp*. and *Coprococcus comes*) and *Bifidobacterium spp* and *Bacteroidetes* and an increase in *Proteobacteria*, more specifically *Escherichia coli* and *Klebsiella pneumoniae*. Furthermore, improvements in host lipids and blood glucose levels are associated with gastric bypass [100, 101].. In SG the microbial capacity to ferment butyrate decreased while the *Bacteroidetes* and *Firmicutes* ratio showed that the energy absorption potential of the gut microbiota also decreased [101].

It is important to report that the super-obese have a large decrease in intestinal diversity when compared to the morbidly obese, and it appears that this decrease is a marker of disease severity, low-grade inflammation, abdominal fat deposition, and cardiometabolic risks [105].

The relationship between the gut microbiota and the BAs is intriguing and, in both directions, they can modulate the profile of the gut microbiota and vice versa, i.e., the BA pool is shaped by bacterial metabolism. This interaction is mainly focused on the 5% of BA that are not reabsorbed by intestinal cells and reach the colon where into contact with the gut microbiota and produce secondary BA [106].

At the same time, BA are potent signaling molecules of host homeostasis as well as the microbiota population itself. These binding molecules are signaling molecules that activate the farnesoid nuclear X receptor (FXR) and the membrane G protein-coupled BA receptor-1 (Gpbar-1, also known as TGR5) to maintain metabolic homeostasis and protect the liver and other tissues and cells from BA toxicity [98].. This axis has been recognized as a mediator for metabolic improvements after BS. Changes in BA physiology, increased circulating levels (in humans and rodents) and FXR activities after RYGB and SG probably support WL and promote long-term sustained metabolic improvements [101, 106], although greater changes have been observed in RYGB, due to shunting of bile flow to the jejunum/ileum [106].

From this perspective, regarding the ability of BS to remodel the gut microbiota as one of the mechanisms implicit to its therapeutic success, several findings have been reported, such as: a greater richness of microbial genes and bacterial diversity associated with a healthy microbiota, although the findings vary widely about changes in the gut microbiota and types of surgery [107, 108].

Probiotics, prebiotics, and symbiotics are promising strategies for modulating the gut microbiota in the context of obesity and metabolic disorders. Some clinical trials support the hypothesis that the use of a prebiotic Fructooligosaccharide (FOS) after RYGB significantly reduces body weight; however, both prebiotics and symbiotic supplementation were not sufficient to improve inflammatory markers (class IIb; grade A) [109–111].. However, the inconsistencies of data found in the literature highlight the need for a better understanding of the implications of supplementation for a rational basis in preventive and therapeutic clinical prescription, since the variation in the composition of the gut microbiota, which is influenced by many factors such as genetics, age, dietary patterns, health conditions, as well as geographic location, can result in inter-individual differences in treatment response.

BS produces specific changes in the gut microbiota that are inherent to surgical techniques. However, eating habits can change part of the microbiota, influencing WL or weight recovery. Greater WL after BS is associated with increased bacterial diversity. The nutritional recommendations to maintain the benefits of the microbiota, after BS, is a diversified diet including vegetables, fruits, legumes, cereals, lean meats, and unsaturated fats.

## Inflammatory bowel diseases

Both the prevalence of morbid obesity and inflammatory bowel diseases (IBD) (Crohn's disease and ulcerative colitis) are increasing in association with the western lifestyle[112–114]. Both conditions are characterized by chronic inflammation [115, 116]. Evidence is still scarce on the results of BS in patients with IBD (class I; grade C). However, studies have reported safety and feasibility of BS and improvement in the inflammatory state of IBD, manifested by disease remission and reduced use of pharmacotherapy, with excellent results in WL when compared to morbidly obese patients without IBD [115].

The surgical approach indicated for morbidly obese patients with IBD is SG (recommended by 87% of experts at the Fifth International Consensus Conference on SG), to avoid potential disadvantages of RYGB, such as malabsorption, intestinal manipulation, and increased technical difficulties for future IBD surgeries [115, 117, 118]. Changes in the gut microbiota should also be evaluated to understand whether they promote the development of IBD [113].

Regarding the nutritional management of patients with IBD, who underwent surgical treatment for obesity, the protocol should be the same adopted for morbidly obese patients without IBD. When introducing a solid diet, the importance of fiber in the diet should be emphasized.

Patients with IBD eat less fiber than the general population and less than the recommended dietary guidelines for the prevention of cardiovascular disease and bowel cancer. Recent evidence suggests that adequate consumption of fiber, or types of fiber (soluble and insoluble), may be important in promoting the maintenance of IBD remission and the balance of the gut microbiota [119, 120].

A high-fiber, low-fat diet was recently compared with an improved standard American diet (more fiber than the usual American diet) in a randomized intervention study, in 17 patients with mild or remitting ulcerative colitis. The high-fiber diet was well tolerated by patients, it reduced markers of inflammation (C-reactive protein—CRP), and promoted a favorable composition of the gut microbiota, including increased abundance of the butyrate-producing bacterium *Faecalibacterium Prausnitzii* [121].

Fermentable fibers such as resistant starch and inulin are metabolized into short-chain fatty acids (butyrate, acetate, and propionate) that have anti-inflammatory action. Butyrate plays an important role as it is the main fuel for colonocytes that are impaired by intestinal mucosal damage and inflammation in IBD [122].

Current evidence suggests that a fiber-containing diet (25 to 30 g/day) can positively alter the gut microbiome, reduce markers of inflammation, and promote maintenance of remission, so it should be recommended for most IBD patients as well as for the general population [122].

The high-fat diet has been linked to an increased risk of ulcerative colitis. In contrast, patients with ulcerative colitis in remission had decreased inflammatory markers and reduced intestinal dysbiosis by consuming a low-fat, high-fiber diet [120, 121].

Saturated fatty acids are pro-inflammatory mediators that increase the production of inflammatory cytokines, exacerbating endotoxemia, increasing serum lipopolysaccharide (LPS) levels and the systemic inflammatory response. Thus, products of animal origin, a source of saturated fat (milk fat; meats, lard (pig fat) and charcuterie), as well as coconut oil (vegetable fat), should be avoided or consumed in restricted amounts (< 10% of the total amount of recommended fat intake) [123].

Food additives present in industrialized foods, such as acidulants, emulsifiers, thickeners, dyes and sweeteners, are directly related to changes in the gut microbiota and IBD and should be avoided in the postoperative period, as they act as fuel for intestinal inflammation [114].

## Conclusion

Nutritional treatment in BS begins when the patient seeks within the multidisciplinary team a specialist in bariatric and metabolic surgery, and whose follow-up must be systematic and individualized, based on scientific evidence, on which this guide was developed.

The procedures described here will guide nutritionists in the nutritional management with the IGB, as well as in the pre and postoperative period of surgeries. It is essential to identify and correct possible nutritional deficits, in addition to monitoring the nutritional status of the bariatric population, during all stages of surgical treatment, regardless of the life cycle (adolescents, adults, pregnant women and the elderly), as well as the domain of knowledge in special situations, such as IBD and vegans.

We also considered the changes that occur in the gut microbiota of individuals undergoing surgical treatment for obesity, which vary according to the surgical techniques.

Medium and long-term nutritional monitoring is essential since, in addition to nutritional deficiencies, reactive hyperinsulinemic hypoglycemia and weight recurrence can occur, especially for individuals without follow-up by the multidisciplinary team.

We believe that these recommendations will play a decisive role in the clinical practice of nutritionists who work in bariatric and metabolic surgery, with their implementation in health services, thus promoting quality and safety in the treatment of patients with obesity.

The concept of precision nutrition is expected to change the way we understand and treat these patients.

This guide will be updated as new evidence in nutrition and bariatric and metabolic surgery emerges.

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## Declarations

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