Chapter 2

Theoretical Bases and Dietary Approach of Bariatric Patients

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1. Introduction

Obesity ultimately results from an unbalance between the intake and oxidation of the energy obtained from foods, and its treatments are based on correcting this unbalance by basically restricting energy intake. Consequently, food intake is the center of attention when the subject is obesity, either as an etiological, protection, or even therapeutic factor.

The inability of severely obese individuals to reduce or maintain their body weight using traditional methods makes them candidates to bariatric surgery, which is admittedly an effective method to reduce body weight significantly and obesity-associated morbidities. Bariatric surgery involves anatomic and physiological changes in the gastrointestinal tract that promote energy restriction, essential for weight loss, but also the restriction of many essential dietary nutrients. In addition to the anatomic aspects, bariatric surgery decreases appetite and increases postprandial satiety, possibly because of its effect on the secretion of hormones that regulate these systems (Kohli, Stefater e Inge, 2011).

In addition to reducing body weight significantly, bariatric surgery also decreases some systemic inflammation markers (Chen et al., 2009; Miller et al., 2011), improves insulin sensitivity, promoting remission of type 2 diabetes (T2D), and lowers high blood pressure, among others.

Although bariatric surgery is associated with better quality of life, nutritional deficiencies may occur after surgery because of the dramatically reduced food intake and/or micronutrient absorption. Unmonitored postoperative patients may develop severe malnutrition (Dodell et al., 2012). The literature has often reported deficiencies of vitamin B complex, iron, folic acid, vitamin D, and calcium (Saltzman e Karl, 2013). These deficiencies may cause neurological symptoms, osteopenia, and anemia.

Hence, the nutritional approach of the bariatric patient, which began when the patient was in line for surgery and continued after surgery, is one of the most important themes of the interdisciplinary care of obese patients. The objective of this chapter is to review the theoretical bases for the nutritional approach of bariatric patients, the instruments for assessing food intake, and the nutritional recommendations, both preoperatively, when the patient is preparing for surgery, and postoperatively, during follow-up. The chapter also includes practical examples.

2. The nutrition process after bariatric surgery

The surgeries used for treating severe obesity include restrictive surgeries that limit food intake, such as vertical banded gastroplasty (VBG), adjustable gastric band (AGB), and sleeve gastrectomy (SG); and mixed surgeries that combine food intake restriction with nutrient malabsorption, such as Roux-en-Y gastric bypass (RYGB) and biliopancreatic diversion (BPD) with duodenal switch (BPD-DS) (Pories, 2008).

The implications of surgery on nutritional status stem specifically from the types of anatomic and physiological changes the surgery makes. The main macro-and micronutrient absorption sites reflect the dimension of the nutritional impairment, especially in the long run, and the possible nutritional complications promoted by bariatric surgery, a situation that should be prevented with appropriate monitoring and supplementation.

In restrictive surgeries, nutritional deficiencies are associated with inadequate food intake, while in malabsorptive interventions, deficiencies are more associated with the hindrance of nutrient digestion and absorption. In summary, the energy deficit caused by low macronutrient intake and/or absorption is accompanied by inadequate intake of essential nutrients.

The small intestine, target of the bypasses associated with malabsorptive techniques, is where most of food digestion and absorption occurs. The absorption of iron (Fe), calcium (Ca), zinc (Zn), selenium (Se), copper (Cu), and some water-soluble vitamins, such as vitamin C, thiamin (B_1), and riboflavin (B_2) occurs in the duodenum; the absorption of Fe, Zn, chromium, amino acids, peptides, carbohydrates, lipids, the fat-soluble vitamins A, D, E, and K, and most of the water-soluble vitamins occurs in the jejunum; and the absorption of amino acids, peptides, lipids, fat-soluble vitamins, magnesium, vitamin B_{12}, and folic acid occurs in the ileum. Generally, the most common micronutrient deficiencies after bariatric surgery are Fe, Ca, vitamin D, vitamin B_{12}, folic acid, and Zn (Bloomberg et al., 2005).

In BPD associated with gastrectomy, mostly a malabsorptive mixed surgery, nutrient malabsorption is even greater, causing massive nutrient loss. Nutrient malabsorption is one of the factors that explain weight loss promoted by malabsorptive techniques, but techniques that

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are mostly malabsorptive reduce the intestinal absorption capacity significantly. BPD, for instance, decreases protein absorption by 25% and fat absorption by 72%, impairing the absorption of fat-soluble vitamins (Aills et al., 2008). BPD-DS lowers the serum concentration of thiamin in the first few months after surgery and of vitamins A and D one year after surgery more than RYGB does (Aasheim et al., 2009).

Today the main type of bariatric surgery done globally is RYGB, which reduces gastric capacity and causes a small degree of malabsorption as it bypasses the duodenum and a small part of the jejunum, namely, 30 centimeters of the proximal jejunum. Nevertheless, the bypassed segments can influence the absorption of proteins and some water-soluble vitamins, namely vitamins C, B_1, B_2, B_6, and folic acid, absorbed in the proximal jejunum. Fat-soluble vitamins that require lipids to be absorbed may also be affected. Hence, mineral deficiencies in RYGB, such as Fe, Ca, and Zn stem from proximal small intestine bypass, specifically from duodenum bypass.

Vitamin and mineral deficiencies at first are asymptomatic or present unspecific symptoms. Laboratory tests are necessary to monitor and avoid the development of postoperative nutritional and clinical complications. Nutritional deficiencies found one year after surgery included Fe (51%), Ca and vitamin D (47%), folic acid (39%), and Zn (12%) (Gasteyger et al., 2008).

- **Calcium and vitamin D**

Calcium and vitamin D deficiencies in obese patients in line for bariatric surgery are common, as well as high parathyroid hormone (PTH). Assessment of calcium metabolism should include measuring serum PTH, total calcium, phosphorus, 25-hydroxycholecalciferol, and the calcium present in 24 hours of urine. The normal levels of vitamin D, 25-hydroxycholecalciferol, or 25(OH)D range from 30 to 80 ng/mL. Vitamin D insufficiency occurs when these levels are below 30 but above 20ng/mL and deficiency when below 20ng/mL. The prevalences of vitamin D deficiency before and one year after RYGB were 86% and 70%, respectively (Signori et al., 2010). This deficiency may stem from inadequate intake and higher calcium and vitamin D requirements after surgery since the main calcium absorption sites are located in the bypassed intestinal section. Calcium, PTH, and vitamin D levels should be normalized before and after surgery to avoid bone loss.

In a sample of 30 female RYGB patients assessed eight years ago, Duran de Campos et al. (2008) found osteopenia (67%), osteoporosis (13%), low urine calcium (70%), vitamin D deficiency (90%), and high markers of bone metabolism, namely high PTH (54%) and high alkaline phosphatase (57%). Their mean calcium intake was roughly 50% of their daily requirement (1000mg), suggesting that bariatric patients should be encouraged to consume an adequate amount of calcium.

- **Iron**

Iron deficiency is the main cause of anemia in bariatric patients. However, other nutrients associated with anemia are also malabsorbed, such as proteins and micronutrients required for iron metabolism and erythropoiesis, such as zinc, copper, folic acid, vitamin B_{12}, and vitamin A. Specifically, iron deficiency may stem from three events: 1) less dietary iron, especially heme iron present in meats; 2) less hydrochloric acid because of the stomach bypass, which reduces the dissolution of iron salts; and 3) duodenum bypass, given that the duodenum is the main site of iron absorption (Ruz et al. 2009).

The prevalence of anemia in bariatric patients varies according to time elapsed since surgery, type of surgery, and sex, with women of childbearing age being more vulnerable. In a prospective study of 1125 RYGB patients of which 999 were females, Drygalski et al. (2011) found a prevalence of anemia of 12% six months after surgery, which increased to 21% eighteen months after surgery and 23% one to two years after surgery. Six months after surgery, the prevalence of anemia in menopausal women was 6% against 16% in premenopausal women.

- **Vitamin B12**

The absorption of vitamin B12 is also impaired by gastric restriction, a procedure performed in restrictive, mixed, and mostly malabsorptive surgeries. Although the absorption of vitamin B12 occurs in the terminal ileum, B12 can only be absorbed when bound to an intrinsic factor, a glycoprotein produced by parietal cells, in the presence of hydrochloric acid and pepsin. These molecular interactions usually occur in the distal stomach and duodenum, and RYGB bypasses both (Flancbaum et al., 2006).

Vitamin B12 deficiency is common: 33-40% of the patients develop it one year after RYGB (Brolin et al., 2002). A study found that RYGB patients taking conventional nutrient supplementation still developed B12 deficiency and required further supplementation. The most common deficiency was of vitamin B12: 62% and 80% of the patients had it one and two years after surgery, respectively. A combined deficiency of vitamin B_{12} and folic acid may cause megaloblastic anemia (Heber et al., 2010). Other studies have reported that conventional supplementation is enough to prevent folic acid deficiency. In addition to the dosages present in multivitamins, our patients take a quarterly injection of Citoneurin 5000UI, rich in B complex.

- **Generality**

Deficiencies present preoperatively, such as iron (44%), vitamin D (68%), and thiamin (29%) deficiencies (Flancbaum et al., 2006), may worsen after surgery, but few studies have investigated how preoperative deficiencies relate to postoperative nutritional complications, another theme requiring further investigation. Another particularity that deserves attention regards iron, since preoperative deficiency may not be exclusively nutritional: the inflammation associated with obesity hinders the regulation of iron metabolism, promoting the development of functional iron deficiency. Iron homeostasis is regulated by hepcidin, a circulating peptide hormone produced mainly by hepatocytes but also by adipocytes, which acts as a negative regulator of iron metabolism (Bekri et al., 2006). Studies grouping these two situations, preoperative functional deficiency and postoperative iron levels, may clarify current perspectives and establish new ones on iron supplementation.

The significant changes made by bariatric surgery reduce energy intake and intestinal absorptive capacity, factors that contribute to weight loss. In addition to the anatomic and

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physiological changes, bariatric surgery promotes hormonal changes, such as reducing ghrelin production in the fundus of the stomach (an important endogenous orexigenic) and increasing intestinal hormones, namely peptide YY, glucagon-like peptide-1 (GLP-1), and gastric inhibitory polypeptide (GIP). The presence of poorly digested food in the distal small intestine after RYGB and BPD seem to stimulate the production of gut hormones, increasing incretins, GLP-1, and GIP, which help to control postoperative weight and glycemia (Rodieux et al., 2008). GLP-1 has a significant postprandial incretin effect, affecting insulin secretion, modulating appetite and gastric emptying, and eventually impacting the capture of glucose by tissues. Although some studies emphasize the role of lower serum ghrelin and higher incretin on satiety and weight control, other studies have not ultimately confirmed that hunger, satiety, and weight loss are related to these hormonal changes, so more studies are needed (Heber et al., 2010).

3. The nutritional needs of obese and ex-obese individuals

Although obesity is caused by an intake of macronutrients in excess of the body's requirement, certain nutrient deficiencies are often present in obese individuals. High intake of processed, energy-dense foods of usually poor nutritional value contributes significantly to micronutrient deficiencies. Additionally, an increase in adiposity and consequent oxidative stress may reduce the levels of some fat-soluble vitamins and nonenzymatic antioxidants. As a matter of fact, population data have shown that micronutrient inadequacy is greater among overweight and obese adults (Kimmons et al., 2006).

Patients in the waiting line for bariatric surgery have a high to moderate prevalence of the following deficiencies: calcium (Jastrzębska-Mierzyńska et al., 2012), folic acid (Schweiger et al., 2010; Jastrzębska-Mierzyńska et al., 2012; de Luis et al., 2013), iron (Flancbaum et al., 2006; Schweiger et al., 2010; Jastrzębska-Mierzyńska et al., 2012), vitamin A (Nicoletti et al., 2013), vitamin C (Aasheim et al., 2008; Nicoletti et al., 2013), vitamin E (Aasheim et al., 2008), vitamin B_1 (Flancbaum et al., 2006), vitamin B_6 (Aasheim et al., 2008; Moizé et al., 2011;), vitamin B_{12} (Ernst et al., 2009; Nicoletti et al., 2013), magnesium (Moizé et al., 2011; Nicoletti et al., 2013), copper (de Luis et al., 2013), and zinc (Ernst et al., 2009; de Luis et al., 2013). The prevalence of anemia is also moderate to high (Flancbaum et al., 2006; Schweiger et al., 2010; Moizé et al., 2011). Finally, vitamin D deficiency has been the most often reported deficiency (Flancbaum et al., 2006; Carlin et al., 2006; Aasheim et al., 2008; Toh, Zarshenas, Jorgensen, 2009; Gammel et al., 2009; Fish et al., 2010; Casagrande et al., 2010; Ducloux et al., 2011; Moizé et al., 2011; Jastrzębska-Mierzyńska et al., 2012; de Luis et al., 2013; Censani et al., 2013).

Vitamin D is a fat-soluble vitamin with hormonal functions. It acts on many tissues especially through nuclear and membrane receptors. Evidence shows that vitamin D is essential for bone mineralization and acts on the pancreas, immune system, and nervous system, among others. Low vitamin D in obese individuals may be related to low dietary bioavailability, inadequate sunlight exposure, and even sequestration by adipose tissue (Brouwer et al., 1998). Some studies report a low to moderate inverse correlation between serum vitamin D and body mass index (Parikn et al., 2004; Carlin et al., 2005; McGil et al., 2008; Cimbek et al., 2012; Taheri et al., 2012).

The prevalences of micronutrient deficiencies vary between studies (Flancbaum et al., 2006; Carlin et al., 2006; Aasheim et al., 2008; Toh, Zarshenas, Jorgensen, 2009; Gammel et al., 2009; Fish et al., 2010; Casagrande et al., 2010; Ducloux et al., 2011; Moizé et al., 2011; Jastrzębska-Mierzyńska et al., 2012; de Luis et al., 2013; Censani et al., 2013). These differences may stem from different food habits, which vary between cities, states, and countries. Therefore, nutritional assessment by laboratory tests and food surveys is strongly recommended to detect nutritional insufficiencies early and make the necessary nutritional interventions. Symptoms caused by undetected preexisting deficiencies may become worse during the postoperative period. Since biochemical tests are expensive, Mechanick et al., (2013) suggest starting micronutrient supplementation in the preoperative period.

Gastric surgery is essential for promoting energy intake restriction and consequently, energy deficit and weight loss. Nonetheless, this procedure may induce strong aversion to certain foods, malnutrition, and specific micronutrient deficiencies. Recently, the American Association of Clinical Endocrinologists, The Obesity Society and the American Society for Metabolic & Bariatric Surgery (Mechanick et al., 2013) published the nutritional requirements of ex-obese bariatric patients. In summary, these individuals should take multivitamin and multimineral supplements that help them to meet their daily requirements of the main micronutrients (elemental calcium: 1200-1500 mg; vitamin D: 3000 IU; vitamin B_{12}: 1000 mcg; folic acid: 400 μg; iron: 45-60 mg) and protein (1.5 grams (60g/d) per kilogram of body weight).

4. Food intake assessment

Determining food intake is a constant challenge for the science and practice of nutrition and dietetics. Food surveys indirectly assess nutritional status. They are always under scrutiny because of their limited ability to measure energy and nutrient intakes. Quantitative and qualitative food intake can be determined by different methods, such as recalls, in which individuals remember the foods they ate. The most important of these retrospective methods are the food frequency questionnaire (FFQ) and the 24-hour recall (24HR). Food intake may also be investigated prospectively by asking individuals to write down the foods they eat in a food diary or record (FD) the moment they eat them (Gibson, 2005; Anjos et al., 2009).

The food intake survey of choice depends on the study objectives and population, but administering a single 24HR or FD to assess habitual food intake is not recommended, not even for obese individuals. Intraindividual variations, that is, daily variations in food intake, occur, so at least two surveys should be administered on alternate days. Some studies recommend three 24HR or FD administered on alternate days, including a weekend day (Johnson, 2002), which allows statistical adjustment of the variances of the study days' mean. Some factors may distort food intake data, such as the interviewer's skill, interviewee's memory, and interview's environment. Moreover, the assessment itself may affect an individual's intake pattern and consequently, information quality. Nutrient intake estimates may also err because of the use of standard recipes and data variation in food composition tables (Dodd et al., 2006).

The food intake assessment of obese patients consists of many challenges, such as obtaining reliable information, identifying underreporting, correctly estimating energy and nutrient requirements, and establishing the appropriate interventions (Anjos et al., 2009).

A common finding in studies that assess the food intake of obese individuals is low energy intake, which may stem from food intake underreporting and/or physical activity overreporting (Macdiarmid; Blundell, 1998; Lichtman et al., 1992). Individual characteristics associated with underreporting include being older, female, and physically inactive; having low social and educational levels; restricting foods; experiencing emotional changes (Abbot et al., 2008; Macdiarmid; Blundell, 1998); and especially, having a high body mass index, that is, being overweight or obese (Rennie, Coward, Jebb, 2007; Scagliusi et al, 2009).

The classification of individuals as underreporters is based on the premise that individuals in energy balance, that is, whose weights are constant, have equivalent energy intake and expenditure (Goldberg et al., 1991; Trabulsi; Schoeller, 2001). Energy intake determined by quantitative survey can be confirmed by doubly labeled water (DLW), which accurately measures total energy expenditure (TEE) (Schoeller, 1999). The energy intake reported in food intake assessments is usually much lower than the actual energy intake (Black, Cole, 2001).

A review of DLW and calorimetry studies treated the intra-and interindividual energy intake variations statistically to establish the cutoff points that identify the lowest, plausible energy intake levels and expressed them as multiples of the resting energy expenditure (REE) (Goldberg et al., 1991). The TEE:REE ratio is known as the physical activity level (PAL). In energy balance, reported energy intake (EIrep) divided by REE should be equal to the TEE divided by REE, that is, EIrep:REE=TEE:REE or EIrep:REE=PAL. Many adjustments have been proposed to maximize the sensitivity and specificity of the cutoff point. Different studies have replaced variables of the Goldberg's equation, one at a time, by constants (Black, 2000), especially PAL, sample size, and number of food intake assessments (Black et al., 1991; Black, 2000; Goldberg et al., 1991; Abbot et al., 2008). Our research group Quesada (2011) used the Goldberg's equation in six different ways to classify the underreporting of 100 morbidly obese women. The prevalence of underreporting varied significantly, from 43% to 92%. This difference stemmed mainly from the intraindividual variations of the study sample, namely PAL and sample size, which minimized the underreporting interpretation error when used in the equation.

Nowadays studies tend to investigate food pattern, as opposed to individual nutrients, to establish relationships between diet and the health statuses of intragroup individuals (Hu, 2002). Dietary pattern analysis characterizes the eating behavior of population groups, elucidating the association between diet and health and/or other factors (Moeller et al., 2007). Dietary patterns characterized by the intake of fruits, vegetables, whole grains, fish, and poultry have been associated with a high intake of micronutrients and with selected biomarkers of dietary exposure and disease risk in the expected direction (Kant, 2004).

The association of one or a few nutrients with a given disease has conceptual and methodological limitations (Hu, 2002). These limitations are evidenced by the fact that they do not take into account the complex synergy between dietary nutrients, the cumulative effects and multiple nutrients that compose dietary patterns, the statistical significance that a wide range of chemical elements or foods can produce, and the relationship of association between the intake of certain nutrients and dietary patterns (Moeller et al., 2007). Hence, dietary pattern analysis has emerged as an alternative and complementary approach in nutritional epidemiological studies that evidence the relationship between the overall diet and the risk of chronic diseases (Hu, 2002).

Multivariate statistical analyses have been used for defining dietary patterns. Factor analysis, which includes both principal component analysis (PCA) and factorial analysis, is a multivariate statistical technique that uses food intake data to identify common subjacent dietary factors or patterns (Hu, 2002; Moeller et al., 2007). Cluster analysis, another multivariate method, aggregates individuals into relatively homogeneous subgroups with similar dietary characteristics. These techniques allow the classification of individuals into distinct groups or in groups according to food intake frequency; classification of foods or food groups according to their percentage energy contribution or mean amount consumed in grams; establishment of nutrient intake patterns; and combination of dietary and biochemical measurements (Hu, 2002; Moeller et al., 2007).

The association between dietary pattern and the prevalence of obesity and/or cardiovascular diseases has indicated a positive correlation between certain dietary patterns and indicators of these diseases (Berg et al., 2009; Howarth et al., 2007; Ma et al., 2003; Meyer et al., 2011; Newby et al., 2003; Neumann et al., 2007; Sherafat-kazemzadeh et al., 2010; Sichieri, 2002). Nevertheless, reviews on dietary patterns and their relationship with certain diseases have found data inconsistencies, signaling the need of more thorough studies on this theme (Bhupathiraju; Tucker, 2011; Kant, 2004; Togo et al., 2001).

Based on the high frequency of food intake underreporting among the obese, some food groups and/or nutrients in the dietary patterns of obese women classified as energy intake underreporters may vary, so more studies are needed to identify the intake particularities of this population. In our group, Ravelli (2013) found that women often underreported their energy intake and that underreporting was associated with a healthier dietary pattern than the pattern of women who reported their intake correctly. This suggests that underreporting involves foods that obese individuals should restrict.

5. Dietary approach of preoperative patients

The objective of bariatric surgery is to reduce energy intake and consequently promote weight loss, better quality of life, and the improvement of associated comorbidities. Long-term weight loss maintenance depends on the development of a multidisciplinary education program focusing on the surgery, making patients and family members aware of its risks and benefits,

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the importance of adhering to the dietary recommendations because of the anatomical and hormonal changes, and the resultant biopsychosocial and physical activity changes.

Once the type of surgery is selected, patients should undergo a nutritional assessment as soon as possible to identify possible nutritional deficiencies, establish a plan to promote dietary adequacy, and make sure they understand the dietary changes they will experience to prevent postoperative complications. Factors such as the patient's readiness for change, realistic expectations, general food and nutrition knowledge, and financial aspects must be investigated and clarified during the preoperative nutritional treatment.

5.1. Initial interventions and strategies for preoperative weight loss

Planning the nutritional intervention requires defining treatment objectives. Goals are individual and based on associated diseases, personal preferences, and habits mentioned in the nutritional anamnesis. Weight loss maintenance demands the adoption of proper food choice-related habits and practices, eating behaviors, and energy expenditure.

The preoperative nutritional approach may be collective or individual. We conduct a complete nutritional anamnesis in our first meeting with the patients and seize the opportunity to help them to improve their dietary habits, bond with them, destroy misconceptions and myths, and inform them about the surgery and the necessary postoperative dietary changes required by the surgery of choice.

5.1.1. Nutritional anamnesis

Nutritional anamnesis has a critical role in nutrition and health research. Its objective is to characterize the general nutritional status of an individual to determine the appropriate intervention.

Anamnesis consists of:

- Anthropometric assessment: preoperative weight, height, body mass index (BMI=kg/m^2), percentage of excess weight (%), and body composition determined by bioelectrical impedance analysis;
- History of weight and previous treatments: patients are asked about the details of their obesity history, unsuccessful weight loss treatments, life events that may have promoted weight changes, weight loss expectations, and previous clinical treatments;
- Biochemical parameters: includes the tests routinely requested by the surgeon and endocrinologist during the preoperative period as recommended by the Brazilian Society of Bariatric and Metabolic Surgery and American Society for Metabolic & Bariatric Surgery;
- Clinical history: assesses the patients' comorbidities and the drugs and supplements they are taking and verifies the presence of orthodontic and sight problems and of food allergies. Bowel movements, voiding habits, and menstrual frequency are also investigated;
- Smoking: the patients are asked about their smoking habits, including the number of cigarettes consumed per day;

- Alcohol intake: the patients are asked about their drinking habits, including amount and frequency;
- Food-related emotional aspect: the patients are asked about how their emotions affect their eating habits;
- Physical activity: the patients are asked about their physical endurance, the types of activity they performed in the past, and what they expect to achieve physically after surgery. At this time the patients are informed about the importance of starting a physical activity program supervised by a certified professional as soon as the surgeon releases them;
- Dietary history: collects information on snacking habits, mastication, fluid intake during meals, and daily water intake;
- Food preferences: investigates patients' food and preparation preferences, aversions, and intolerances;
- Food intake: the patients are asked about their habitual food intake during weekdays and weekend days; intake frequency of the main foods of each food group; meal number and location; food preferences and aversions; possible religious and/or cultural food restrictions; and food preparation techniques and purchasing habits to identify preparation problems or facilities. We also routinely ask the patients to make a food diary on three nonconsecutive days, including a weekend day, to better determine their food intake profiles.

We also take into account the reality of the patients, their jobs, routines, schedules, financial resources, literacy levels, and regional habits to personalize the intervention, otherwise it would be difficult to obtain good adherence to treatment.

The patients receive nutrition education based on the information collected by the nutritional anamneses, with emphasis on healthy food choices, the importance of consuming foods from all food groups, and the relationship between hunger and satiety. A personalized eating plan with lower energy content is created for the patients for them to start losing weight before surgery, reducing surgery risks and allowing us to assess their discipline.

The number and frequency of visits may vary according to the particularities of the patient and determination of the bariatric surgery team. The objective of the follow-ups is to assess adherence to the recommendations, weight loss, and changes in dietary habits, and to clarify surgery-related doubts. In the last visit prior to surgery, the patient and his/her companion receive verbal and written advice about the pre-and postoperative fluid diet.

Many issues are discussed with the patients in more detail during the visits, such as their need to lose 5% to 10% of their body weight before surgery, the preoperative eating plan, mastication, surgical techniques and resulting nutritional changes, healthy food choices, and specifics about the fluid diet that should be followed before and after surgery, always emphasizing healthy food choices and habits. The nutritional intervention also has the following cognitive objectives:

- The surgery helps the patient to limit food intake by reducing gastric volume and absorption area, depending on surgical technique, thereby promoting weight loss;

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- The importance of the patient assuming a compromise with his/her health, since postoperative eating discipline is critical to avoid nutritional inadequacies and/or weight regain;
- The intake of energy-dense fluids and alcoholic beverages and early or excessive inclusion of simple sugars and fats may cause treatment failure or dumping syndrome;
- Dumping syndrome – definition, symptoms, how to avoid;
- Mastication – the patient must eat slowly to avoid the sensation of having food stuck on the way down, malaise, or even vomiting. This is valid for fluid and solid preparations;
- Advice and required dietary changes for the preoperative (fluid) and postoperative (fluid, soft, and general) periods, and foods that should be avoided after the surgery.

The advice regarding patients' new eating behavior should be provided by a dietician together with a psychologist to encourage patients to identify inappropriate eating behaviors and teach them new eating habits even before surgery. These recommendations increase postoperative adherence to the nutritional therapy and reduce the incidence of postoperative complications.

6. Dietary approach of postoperative patients

Nutritional counseling after surgery is essential because of all the changes patients must make to their eating habits. Follow-ups must be periodical to assess weight loss, encourage the adoption of healthy eating habits, clarify doubts, and identify possible nutritional inadequacies. Counseling is critical to ensure surgery success and avoid future complications.

Nutritional recommendations may vary by type of surgery, but all of them have similar diet therapy objectives: to reduce the work of the stomach and intestinal overload in the immediate postoperative period and to promote healthy food choices and habits using a diet plan associated with specific, personalized nutritional supplementation to meet the nutritional requirements of the patient.

Patient noncompliance with postoperative control programs is usually high, especially one year after surgery, which means lower adherence to the recommended healthy behaviors, and consequently, risk of bariatric surgery failure. Therefore, it is essential for the patient to learn and recognize the importance of adherence to treatment before the surgery.

6.1. Dietary changes

Ingestion is forbidden in the 24 hours that follow surgery, regardless of type. After this period the patient may start ingesting fluids. The objective of the fluid diet is to allow gastric rest and adaptation to small volumes, promote systemic hydration, ease the digestive process and gastric emptying, and prevent the ingestion of residues (Aills et al., 2008).

Our patients are placed on a fluid diet three days before surgery and recommended to stay on the diet until the twentieth day after surgery. This diet must consist exclusively of fluids. Patients receive verbal advice and a written document containing instructions regarding volume, fractioning, the foods they may and may not consume, a menu example, recipes, and supplementation. The preoperative fluid diet differs from the postoperative fluid diet only in volume. During the hospitalization period, which varies from two to four days, the patients are given a residue-free fluid diet consisting only of water, light-colored tea, sugar-free gelatin dessert, isotonic drinks, coconut water, and stock.

All diets are adapted to the type of surgery and the particularities of each patient. When our patients return for a follow-up visit fifteen days after the surgery, we verify the volume they are ingesting, meal fractioning, the use of protein and micronutrient supplements, daily water intake, voiding habits, bowel movements, possible eating difficulties, and physical signs of nutritional deficiencies. Our patients also receive verbal and written advice about the soft diet that should be started twenty days after the surgery.

The second follow-up visit occurs 25 to 35 days after surgery. During this visit, we advise patients about the general diet, examine them for physical signs of nutritional deficiencies, and collect information about food intake during the soft-diet period, such as amounts consumed, number of meals consumed per day, ingestion of the recommended nutrient supplements, water intake, voiding habits, bowel movements, and eating difficulties. We also advise the patients to start the general diet slowly, according to their recovery and food acceptance. The general diet (solid) should begin 35 days after surgery.

Bariatric surgery patients should be nutritionally monitored. Visiting the dietician regularly is extremely important because the small volume of the stomach greatly restricts nutrient intake. In the first months after surgery, nausea and vomiting are common; nevertheless, they must be investigated and the patients, counseled (Mechanick et al. 2009). The follow-up schedule may vary according to individual needs and possible surgery complications. Some patients even require special follow-up (Mechanick et al., 2009). We ask our patients to visit us once a month for five months after they start the general diet, then quarterly for six months, then semiannually or as needed.

Nutritional care after bariatric surgery has two objectives: the first is to adjust the energy and nutrient intakes necessary for tissue repair after surgery and for preserving lean body mass during extreme weight loss, and the second is to minimize the symptoms caused by surgery-induced changes, such as reflux, early satiety, and dumping syndrome (Aills et al., 2008).

The manner in which postoperative weight loss factors interact determines how surgery affects body weight in the short and long terms, hence the importance of knowing the weight loss pattern and related factors. Long-term follow-up is also advised to monitor the outcome and make sure that the surgery-related benefits are long-lived.

7. Dietary approaches to prevent and treat postoperative complications

The main comorbidities associated with obesity, such as diabetes and high blood pressure, improve significantly shortly after bariatric surgery, but other complications may arise given the surgery-induced anatomic and physiological changes. The most common postoperative complications include nutritional deficiencies, anemia, dumping syndrome, vomiting, and alopecia.

Nutritional deficiencies (iron and anemia, calcium, vitamins D, B_{12}, B_6, and B_1, zinc, and protein-energy malnutrition) and their consequences may occur after surgery, especially in the long-term. The severity of these complications depends on the extension of the anatomic and physiological changes made to the gastrointestinal tract, as mentioned earlier. Nutritional deficiencies may cause severe morbidity and irreversible damage, and conventional supplementation is often not enough. Specific inadequacies must be corrected to restore normal serum levels and avoid greater consequences. It is essential to perform periodical tests as recommended by the guidelines to measure the serum levels of certain nutrients (Heber et al., 2010).

Patients who undergo mixed surgeries (RYGB) and mostly malabsorptive mixed surgeries (BPD) require specific monitoring and supplementation, especially in the first year after surgery. Additional supplements of iron and calcium, water-soluble vitamins, and vitamins A and D are prescribed more often to BPD-DS (55%) patients than to RYGB (26%) patients (Aasheim et al., 2009).

Bariatric patients require a minimum daily mineral and vitamin supplementation of one (AGB) to two (RYGB, BPD, and SG) multivitamin and multimineral tablets, 1200-1500 mg of elemental calcium in the form of citrate divided throughout the day, 3000 IU of vitamin D (to keep serum 25(OH)D above 30ng/mL), and enough vitamin B_{12} to maintain normal serum values. Vitamin B_{12} can be taken orally, sublingually, intranasally, or intramuscularly as follows: 350 mcg orally per day; or 500 mcg intranasally per week; or 1000 mcg intramuscularly per month; or 3000 mcg intramuscularly semiannually. Finally, the amount of folic acid present in multivitamins is adequate (400 mcg) (Mechanick et al., 2009; Mechanick, et al., 2013).

The vitamin B_{12} status of all patients undergoing bariatric surgery, regardless of type, should be assessed before surgery, and of patients who lost the lower part of their stomach (SG, RYGB and BPD), should also be assessed annually after surgery. Supplementation with 1000 ug or more of crystalline vitamin B_{12} daily may be necessary to maintain adequate serum levels of this vitamin (Kehagias et al., 2011).

Conventional or additional supplementation should provide 45 to 60 mg of iron per day. Iron serum levels should be monitored in all bariatric surgery patients and individuals with iron-deficiency anemia. Anemia treatment includes the prescription of 150 to 200 mg of elemental iron orally per day in the form of iron sulfate, fumarate, or gluconate. Vitamin C may be taken simultaneously to increase iron absorption. Intravenous iron infusion is indicated for patients with severe deficiency, oral intolerance, or refractory anemia due to severe iron malabsorption. Nutritional anemia stemming from malabsorptive bariatric surgeries also include deficiency of vitamin B_{12}, folic acid, protein-energy, copper, selenium, and zinc, so these deficiencies must be assessed and corrected in patients with persistent anemia (Aills et al., 2008).

Protein-energy malnutrition is usually accompanied by hypoalbuminemia, alopecia, asthenia, and anemia. Some studies have found that two years after surgery, 5% to 13% of RYGB patients and 3% to 18% of BPD patients have hypoalbuminemia. Bariatric patients should ingest at least

60 grams of protein a day, or 1.5g/kg of the ideal body weight a day, or if necessary 2.1g/kg of the ideal body weight a day (Mechanick, et al., 2013).

Bone loss may occur in the long run, especially in women, so complete assessment of calcium metabolism is essential to make sure that the ingested and absorbed amounts are enough to prevent metabolic bone disease. RYGB, BPD, or BPD-DS patients must take calcium citrate and vitamin D [ergocalciferol (D_2) or cholecalciferol (D_3)] orally to prevent or minimize secondary hyperparathyroidism without inducing hypercalciuria. In severe cases of vitamin D malabsorption, oral doses may be increased to 50,000 IU one to three times a week or even daily. Hypophosphatemia is usually due to vitamin D deficiency. An oral phosphate supplement should be taken when the serum level is in the 1.5 to 2.5 mg/dL bracket (Mechanick, et al., 2013).

Vitamin A deficiency may cause vision problems. Supplementation, isolated or combined with other fat-soluble vitamins, is recommended for patients who undergo purely malabsorptive procedures, such as BPD or BPD-DS. There is no evidence to suggest that bariatric surgery patients should be routinely screened for low levels of essential fatty acids, vitamin E, or vitamin K. However, health care providers should consider vitamin K assessment when they find an established deficiency of fat-soluble vitamins (hepatopathy, coagulopathy, or osteoporosis) (Aasheim et al., 2009).

There is also no evidence to suggest that routine selenium screening or supplementation is necessary after bariatric surgery. Nevertheless, health care providers should measure the serum selenium levels of patients who undergo malabsorptive surgeries or of patients with anemia, fatigue, persistent diarrhea, cardiomyopathy, or metabolic bone disease. Zinc deficiency should be assessed routinely in BPD or BPD-DS patients or patients with alopecia, ageusia, and dysgeusia (Aills et al., 2008).

Copper supplementation (2 mg/day) should be included as part of the supplementation routine. Consider measuring the serum copper level of patients with persistent anemia, neutropenia, myeloneuropathy, and poor wound healing. Patients being treated for zinc deficiency and alopecia should take 1 mg of copper for each 8 to 15 mg of zinc since zinc supplementation may cause copper deficiency (Mechanick, et al., 2013).

Vomiting may occur in the postoperative period, especially in the first months after surgery, and is generally precipitated by eating more than the stomach can hold or not chewing well. It may also indicate other problems, such as stenosis or intolerance to solid foods (Fujioka, 2005).

Intolerance to solid foods is the main characteristic of patients who are not chewing foods well enough, especially foods that are harder to chew, such as meats, non-starchy vegetables, and all foods with a more fibrous consistency. These patients prefer softer foods, such as soups (with a high proportion of carbohydrates), pasta, puree, soufflé, ice cream, cookies, certain savory snacks and pastries, and other foods that do not require much effort to chew and swallow.

After surgery bariatric patients may also experience trauma or fear for not knowing how much food to put in their mouths at a time or how much to chew before swallowing, and end up feeling nauseated, vomiting, or feeling that the bolus got stuck somewhere between the throat and the stomach.

Patients with persistent vomiting who chew well but are intolerant to solids should be specifically examined for stenosis by the surgeon to rule out functional disorders, even if the intolerance developed postoperatively (Fujioka, 2005).

Frequent vomiting may cause thiamine deficiency. Thiamine should be part of the conventional supplementation, as the other water-soluble vitamins. Susceptible patients include those with rapid weight loss, prolonged vomiting, excessive alcohol intake, neuropathy, encephalopathy, and heart failure. Patients with suspected or established severe thiamine deficiency should receive 500mg of intravenous thiamine daily for three to five days, followed by 250 mg daily for three to five days until the symptoms subside. Health care providers should consider further supplementation with 100mg orally per day for an indeterminate period or until the risk factors are eliminated (Mechanick, et al., 2009).

Dumping syndrome is a common bariatric surgery complication experienced by roughly 70% of RYGB patients. Foods with high osmolarity, such as those with high sugar content, cause osmotic overload in the small intestine (Fujioka, 2005; Mechanick et al., 2009). The symptoms include hypoglycemia, abdominal pain, nausea, diarrhea, rubor, and tachycardia (Elliot, 2003; Merchanick et al., 2009). Late dumping syndrome symptoms may be caused by reactive hypoglycemia, normally controlled through diet or treated prophylactically with half a cup of orange juice roughly one hour after a meal (Mechanick et al., 2009).

Bariatric patients must learn about dumping syndrome, its symptoms, and which foods to avoid before surgery. During the nutrition education process, we strongly encourage our patients to restrict the intake of simple sugars and reduce the intake of high-fat foods before and after surgery. Patients are also encouraged to eat small amounts at a time, avoid ingesting fluids thirty minutes before and after a solid meal, prefer complex carbohydrates to simple ones, and increase protein intake.

Alopecia, classified as a nutritional complication of bariatric surgery, occurs mainly in the first year after surgery, a time of intense weight loss and patients' adaptation to diet and their new gastrointestinal system. Nutritional deficiency-related alopecia is mainly associated with the deficiency of zinc, iron, proteins, and essential fatty acids, so requires proper supplementation.

Most bariatric patients may experience one or more nutritional deficiencies, justifying the need of lifelong vitamin and mineral supplementation after surgery, and macronutrient supplementation when necessary. Thus, the dietician assumes the critical role of preventing and correcting nutritional changes after bariatric surgery.

8. Dietary approach for preventing weight regain

Bariatric surgery promotes the control of obesity, not the cure, and complications may occur at any time (Novais et al., 2010). Weight loss after bariatric surgery is clearly visible, with consequent improvement of the comorbidities and quality of life. Therefore, weight loss is considered one of the main parameters for defining bariatric surgery success (Brolin, 2002; Brolin, 2007; Silver et al., 2006; Novais et al., 2010). Researchers unanimously agree that a successful outcome requires an excess weight loss (%EWL) of at least 50% and the long-term maintenance of the weight loss (Capella, Capella, 1996; Brolin et al., 1994; Brolin, 2002; Fobi, 2004; Brolin 2007; Silver et al., 2006; Novais, 2010).

Weight regain after surgery may be promoted by physiological adaptations of the gastrointestinal tract. Adoption of a healthy lifestyle protects bariatric patients from old habits directly related to obesity. This new behavior is important to maintain the new body weight in the long run, so the support of a certified multidisciplinary team is critical (Bond et al., 2004; Novais et al., 2010).

Weight loss and control after surgery are checked routinely. Many indicators are used for this purpose, such as BMI, percentage of the initial weight loss, and percentage of excess weight loss. We use the latter in our practice.

Most of the weight loss occurs in the six months after surgery, when food intake restriction is greater (Novais et al., 2010). Patients submitted to malabsorptive procedures may lose 0.2 – 0.5 kg per day, achieving a loss of 18 – 40.5 kg in the first three months after surgery. The weight lost peaks between 12 and 18 months after surgery (Mechanick et al., 2009, Novais et al., 2010).

Small weight loss after surgery should be investigated by the multidisciplinary team. The dietician must check the patient's food habits, especially the intake of energy-dense foods. Some studies found that even bariatric patients may regain weight (Kaplan, 2005; Livingston, 2005), especially three to five years after surgery (Brolin *et al.*, 1994; Buchwald et al., 2004; Mechanick et al., 2009). Obesity may recur because it is a chronic disease. Patients must understand that weight fluctuations are normal and perfectly acceptable. Weight-loss plateau or even a small weight regain are part of the normal weight loss process. Professionals must emphasize on the better quality of life, healthy behaviors, and better health status instead of percentage of excess weight loss as a measure of success.

Our group (Novais, 2009) investigated the food intake, weight history, and quality of life of 141 females two years after bariatric surgery and found that 84.4% lost more than 50% of their excess perioperative weight. Significant weight loss occurred in the first six months after surgery and stabilized two years after surgery. About 15% of the patients regained part of their excess weight. In another study our group (Fogaça, 2009) assessed the factors associated with weight regain in women two years after bariatric surgery and found that the resting energy expenditure adjusted for total and lean body mass, and the serum lipids, glucose, insulin, and leptin of women who regained more than 10% of their weight did not differ significantly from those of the controls-women who did not regain weight.

Food habits impact weight loss speed and long-term maintenance. Hence, dieticians and psychologists work side by side with bariatric patients with eating disorders that may promote weight regain. Psychologists help patients to find skills that satisfy their emotional needs and dieticians help them to effectively learn to nourish their minds and bodies, enabling them to deal with their emotions, desires, and biological needs.

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The relationship between psychologist and dietician is essential to treat each patient individually. Many patients do not assimilate so many changes, justifying their weight regain or replacement of a symptom by another eating disorder or compulsive behavior. Others manage to carry out the necessary changes, improving their emotional status and reducing their levels of anxiety and depression. The importance of psychological and sometimes psychiatric follow-up is clear as it helps to improve patients' quality of life and interpersonal relationships.

Weight regain after bariatric surgery is a reality, hence the need of prospective studies with patients in line for bariatric surgery and the critical work of a multidisciplinary team to provide the best treatment possible and ensure a successful outcome, not only in terms of weight loss but also in terms of body nourishment and quality of life.

9. Final considerations

As a result of the knowledge we have accumulated in our clinical and research practice and consonant with the literature, we can state that bariatric surgery changes the nourishment process substantially, implying the need of permanently monitoring the patients' nutritional status. This practice should begin already in the waiting line for bariatric surgery because nutritional deficiencies may occur in obese individuals despite their excessive food intake; they may either have a poor diet.

In addition to anthropometric assessment, patients should undergo a thorough assessment of the signs and symptoms associated with nutritional deficiencies, measurement of serum nutrient levels, and food intake assessment. Food intake assessment has technical and operational limitations, but it is an essential tool for dietary diagnosis and prescription, and for food and nutrition education. Food and nutrition education must be based on science and supported by the other professionals in the team. In addition to a dietician, a psychologist is needed to help patients to develop the skills they need to practice self-care. Furthermore, although surgery improves the metabolic disorders associated with adipose tissue, nutritional deficiencies should always be a target of concern, prophylactic intervention, and monitoring. Therefore, a multidisciplinary health care team is critically needed for providing the lifelong care required by bariatric patients.

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