

Nutrient deficiencies secondary to bariatric surgery

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Purpose of review

The number of adolescent and adult patients submitting to bariatric surgery is increasing rapidly around the world. This review describes the literature published in the last few years concerning nutritional deficiencies after bariatric surgery as well as their etiology, incidence, treatment and prevention.

Recent findings

Although bariatric surgery was first introduced in the 1950s, safe and successful surgical management has progressed over the last two decades and longer post-surgical follow-up data are now available. Most of the patients undergoing malabsorptive procedures will develop some nutritional deficiency, justifying mineral and multivitamin supplementation to all postoperatively. Nutrient deficiency is proportional to the length of absorptive area and to the percentage of weight loss. Low levels of iron, vitamin B₁₂, vitamin D and calcium are predominant after Roux-en-Y gastric bypass. Protein and fat-soluble vitamin deficiencies are mainly detected after biliopancreatic diversion. Thiamine deficiency is common in patients with frequent vomiting. As the incidence of these deficiencies progresses with time, the patients should be monitored frequently and regularly to prevent malnutrition.

Summary

Nutritional deficiencies can be prevented if a multidisciplinary team regularly assists the patient. Malnutrition is generally reverted with nutrient supplementation, once it is promptly diagnosed. Especial attention should be given to adolescents, mainly girls at reproductive age who have a substantial risk of developing iron deficiency. Future studies are necessary to detect nutrient abnormalities after new procedures and to evaluate the safety of bariatric surgery in younger obese patients.

Keywords

bariatric surgery, nutrient deficiency, obesity

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Abbreviation

RYGB Roux-en-Y gastric bypass

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Introduction

Obesity is a multifactorial disease where the excess of body fat is related to genetic predisposition and, mainly, environmental factors. Patients with severe obesity often suffer serious illness as well as physical and psychological disabilities that markedly increase mortality and morbidity. Certainly, the first-choice therapy for severe obesity is a nonsurgical program that integrates behavior modifications, adequate physical activity and psychological support. However, in many cases of severe obesity, nonsurgical treatment fails in providing sustained weight loss and surgical treatment can be indicated in some specific cases (body mass index >40 or >35 with comorbidities).

Although bariatric surgery was first introduced in the 1950s, safe and successful surgical management has progressed over the last two decades [1•]. However, due to undernutrition imposed on the patient and inherent complications after all bariatric procedures, patients should be regularly accompanied, in both the pre and post-operative periods, by a multidisciplinary team with medical, surgical, psychiatric, and nutritional expertise [2•].

There are several recent studies showing fast improvement of major obesity complications after bariatric surgery [3•,4–7]. However, the most important outcomes of any weight-loss program should also include long-term data of changes in health-related quality of life [8,9] as well as a close follow up of psychological and nutritional status. The improvement of health quality in obese patients after bariatric surgery has been confirmed by different studies [10•–13•,14,15].

Bariatric surgeries are divided into restrictive, restrictive/malabsorptive and malabsorptive procedures. Several recent reviews about open and laparoscopic procedures have been published [5,16•,17•,18•,19•,20•,21•,22•,23–26].

Purely restrictive procedures, including vertical banded gastroplasties and silastic ring vertical gastroplasties, are based on the reduction of gastric capacity, reducing food intake. The weight loss in these techniques is modest, in general less than that established as the criterion of success (excess-weight loss >50% sustained for at least 5 years after surgery) [18••].

The classical restrictive/malabsorptive surgery is the Roux-en-Y gastric bypass (RYGB). In this procedure,

gastric capacity is reduced by 90–95%. The biliopancreatic limb includes stomach, duodenum, and part of jejunum and drains bile, digestive enzymes, and gastric secretions. The distal end of the jejunum is anastomosed to the gastric pouch (Roux or alimentary limb) and carries ingested food. The biliopancreatic limb is anastomosed generally 50–100 cm above the ileocecal valve, creating the common limb. As food and enzymes are only mixed in the small area of the common limb, the digestion and absorption of most nutrients are compromised. The mean excess-weight loss (60–75%) depends on the length of the common limb [18••,23,26].

The first malabsorptive operation was the jejunoileal bypass. Due to severe nutritional complications, this procedure is now discredited. Biliopancreatic diversion with or without duodenal switch replaced jejunoileal bypass. Biliopancreatic diversion consists of a modest gastric restriction associated with a long biliopancreatic limb with the common limb of 50 cm. In biliopancreatic diversion with duodenal switch, there is a smaller gastric pouch with preservation of the pylorus and a small portion of duodenum. As a consequence of these malabsorptive procedures, an excess-weight loss of 75–80% can be reached [18••,27].

Especial attention should be given to adolescent and pregnant women submitted to bariatric surgery. Pregnancy in women submitted to bariatric surgery could be associated with nutritional deficiencies in both mother and child, due to the higher nutritional requirements. However, Marceau *et al.* [28•] found a reduction of fetal macrosomia and normalization of the infant's birth weight in pregnant women previously submitted to biliopancreatic diversion. Despite favorable pregnancy outcomes after bariatric surgery, careful studies are required to evaluate nutritional status in both mother and child after bariatric surgery in mothers.

A significant number of severely obese adolescents have now been submitted to bariatric surgery. In recent years, information about efficiency, risks, and follow up of post-surgical adolescents has been published [29••,30•–32•,33,34•,35•,36]. Gastroplasty used to be the first-choice technique, but it has been replaced by gastric bypass. Different groups suggested that RYGB is safe and effective, reducing complications and improving quality of life [29••,30•,31•]. However, long-term safety should be evaluated carefully, since nutritional status has not been analyzed carefully in many of these studies. Type and frequency of nutritional complications are similar to those seen in adults, namely anemia, deficiencies of vitamins D and B, and folate, and protein-calorie malnutrition [36]. However, as pointed out by Garcia *et al.* [32•], application of the principles of adolescent growth,

development, and compliance is essential to avoid adverse physical, cognitive, and psychosocial outcomes following bariatric surgery.

Predicting and preventing nutritional deficiencies after bariatric surgery

Many obese subjects already have clinical or subclinical nutritional deficiencies before surgery, such as of vitamin D, folate, and vitamin B₁₂. For this reason, nutritional assessment, including serum levels of vitamins and minerals, should be evaluated before surgery to avoid, retard, or minimize the installation of nutritional complications in the post-surgical period.

Conceptually, specific nutritional deficiencies are less common in restrictive than in malabsorptive procedures [37••,38•]. However, poor eating behavior, food intolerance, and food restriction are frequently seen in patients submitted to restrictive surgeries [39,40]. Consequently, long-term follow up is also necessary to prevent or detect potential nutritional deficiencies in these patients.

Malabsorptive procedures are more related to nutritional disorders. Generally, more aggressive procedures lead to a higher incidence of nutritional deficiencies [41,42•]. Patients submitted to RYGB are at risk from developing iron, vitamin B₁₂, folate, and calcium deficiencies [42•]. In biliopancreatic diversion with duodenal switch, protein and fat-soluble vitamin deficiencies are also seen [43••]. The incidences of abnormal levels of serum albumin, hemoglobin, and calcium 3 years after duodenal switch are about 2, 48, and 29% respectively [44••].

Although nutritional problems are more prevalent in biliopancreatic diversion than in RYGB [41], retrospective analysis comparing both procedures showed no differences in the occurrence of nutritional deficiencies, except ferritin [45]. However, there was a high and progressive incidence of nutritional disorders in both procedures when the pre- and post-surgical periods were compared. Low levels of hemoglobin, iron, and ferritin were found in more than 44% of patients and vitamin B₁₂ deficiency was found in about one-third of patients after 4 years of RYGB or biliopancreatic diversion. It has been estimated that after 1 year of biliopancreatic diversion, one-third of the patients develop anemia and/or fat-soluble vitamin deficiencies and less than 5% are hospitalized for treatment of protein-calorie malnutrition [23].

Specific deficiencies

The main nutrients affected by bariatric surgery are protein, vitamin B₁₂ and folate, iron and calcium. For this reason, a careful and regular check of these nutrients should be also introduced once their deficiencies limit quality of life.

Protein-calorie deficiencies

The restriction of exogenous energy availability is the goal of bariatric surgery. Energy deficits occur as a consequence of low food intake, food intolerance (mainly meat and dairy products), or nutrient malabsorption (mainly fat and protein). The ratio of fat-mass to fat-free-mass loss is about 4:1 in restrictive techniques [37•,46•,47•].

Protein deficiency is seen after RYGB [48•] and, mainly, after biliopancreatic diversion [24,49]. The latter appears to cause severe protein-calorie deficiencies in some studies [50,51] although low incidences have been described by others [52,53].

Vitamin B₁₂ and folate

Vitamin B₁₂ deficiency is common after gastric surgery, mainly when restrictive procedures are involved. The deficiency is due to a failure of separation of vitamin B₁₂ from protein foodstuffs and to a failure of absorption of crystalline vitamin B₁₂, since intrinsic factor is not present. Although the body storage of vitamin B₁₂ is substantial (about 2000 µg) compared to the small daily needs (2 µg/day), the deficiency is relatively common in patients after 1–9 years of gastric bypass.

In patients after RYGB, the prevalence of B₁₂ deficiency is estimated in 12–33% [41]. However, clinical symptoms are less common [45,54]. Currently the majority of patients undergoing RYGB are monitored and treated with B₁₂ once they have demonstrated low blood levels of this vitamin. The use of 350 µg/day generally corrects a low level of this vitamin [55,56,57••]. Only a small percentage of individuals will require parenteral administration of B₁₂ (2000 µg/month) [57••]. However, due to the frequent lack of symptoms, the need to follow or treat low levels of B₁₂ vitamin and folate (unless the patient has symptoms) has been questioned. This decision should be carefully analyzed, since there is the risk of irreversible neurological damage if B₁₂ deficiency is maintained for a long period. There is also a case reported of an exclusively breastfed infant with B₁₂ deficiency, born of an asymptomatic mother that had undergone gastric bypass [58].

Folate deficiency is less common than B₁₂ deficiency and occurs secondary to decreased dietary intake. Although folate absorption occurs preferentially in the proximal portion of the intestine, it can take place along the entire small bowel with adaptation after surgery. Folate deficiency is preventable and promptly corrected with multivitamin supplementation (1 mg/day).

Iron

Iron deficiency is one of the most frequent deficiencies after bariatric surgery. The incidences of anemia or iron

deficiency after vertical banded gastroplasty are about 46 and 32% respectively [59]. The incidence of iron deficiency or anemia estimated by the American Society of Bariatric Surgery surgeons is about 14–16% in RYGB and 21–26% after biliopancreatic diversion [41], lower than the levels estimated in the literature. In superobese patients submitted to RYGB, iron deficiency occurred in 49–52% and anemia in 35–74% after 3 years, depending on the Roux limb length [24]. Comparing patients undergoing RYGB or biliopancreatic diversion, in a 5-year follow up, incidence of iron deficiency was similar after both operations [45].

The etiology of iron deficiency is multifactorial. In order to be absorbed, dietary iron (as ferric ion) must be reduced to the ferrous state by the acid secretion of the stomach. Since there is a reduced production of hydrochloric acid after restrictive procedures, iron is less available to be absorbed. Moreover, with the exclusion of duodenum and proximal jejunum, the main areas of its absorption are bypassed.

Iron deficiency and microcytic anemia are also very common in adolescents and women with active menstruation [29••,36]. Most multivitamin and mineral supplements contain sufficient amounts of iron to prevent deficiency. However, iron deficiency and anemia sometimes persist even in patients taking multivitamins. In these cases an additional iron supplementation (300 mg of ferrous sulfate three times a day associated with ascorbic acid) should be prescribed to correct it.

Thiamine

Thiamine is absorbed in the entire duodenum, mainly in the acid milieu of the proximal duodenum. The deficiency occurs through the combination of a reduction in acid production by the gastric pouch, restriction of food intake, and frequent episodes of vomiting [60•–62•,63–67,68•,69,70]. Cases of clinical deficiency were published in the last decade, the majority associated with persistent vomiting or hyperemesis [60•,61•,63–67,68•,69,71,72]. Due to the participation of thiamine in carbohydrate metabolism, high dietary intake of carbohydrate or administration of glucose could precipitate clinical symptoms in patients with low reserves of thiamine [61•,63].

Chang *et al.* [73•] found 40 cases of vitamin B and/or thiamine deficiency in a total of 168 010 bariatric cases related by members of the American Society of Bariatric Surgery. Compliance to multivitamin intake could prevent thiamine deficiency in most of the cases. In suspected deficiency, administration of 50–100 mg of thiamine should correct the deficiency. In patients with hyperemesis, parenteral administration of thiamine 6 weeks after surgery should prevent the deficiency.

Calcium, vitamin D, and bone metabolism

Patients who have been submitted to restrictive or malabsorptive bariatric surgery are prone to bone mass abnormalities [46•,74••,75•–77•,78,79,80•,81•]. It is caused by restriction of calcium intake associated with malabsorption of both calcium and vitamin D. Reduced calcium absorption is secondary to the exclusion of duodenum and proximal jejunum, where calcium is maximally absorbed. Vitamin D is absorbed preferentially in the jejunum and ileum. The defective absorption of fat and fat-soluble vitamins, including vitamin D, aggravates calcium malabsorption. The relative lack of calcium stimulates the production of parathyroid hormone that, in turn, causes increased production of 1,25-dihydroxyvitamin D and increased release of calcium from bone. The result of this process is the long-term risk of osteoporosis.

Coates *et al.* [74••] studied bone metabolism in patients after laparoscopic RYGB. Bone-turnover markers were significantly elevated, despite increased dietary calcium and vitamin D intake and unchanged levels of serum 25-hydroxyvitamin D and parathyroid hormone. After 9 months of surgery, patients showed bone mineral density reduced in the hip, trochanter, and total body. Slater *et al.* [43••] studied serum fat-soluble vitamin and calcium metabolism in patients supplemented with calcium and vitamin D after biliopancreatic diversion. They found abnormal levels of calcium and vitamin D in 57 and 63% of patients 1 and 4 years after surgery respectively. Hypocalcaemia was also present in 15 and 48% of patients 1 and 4 years after biliopancreatic diversion. Secondary hyperparathyroidism was present in 69% of patients after 4 years. Clinically significant hyperparathyroidism and raised alkaline phosphatase were seen in 27 and 6% of these cases, respectively.

On the other hand, Marceau *et al.* [82] reported only modest changes in bone mass in patients undergoing biliopancreatic diversion 4–10 years after surgery. However, these patients were under close surveillance to avoid metabolic complications and appropriated vitamin/mineral supplementation.

For these reasons calcium, phosphorus, alkaline phosphatase, parathyroid hormone, and 25-hydroxyvitamin D should be regularly monitored in patients submitted to bariatric surgery. Besides high intake of calcium (2 g/day) and vitamin D (400 i.u./day), calcium supplementation (1.2–1.5 g/day) is also recommended [53,83]. Calcium citrate rather than calcium carbonate is the required form to be supplemented, since calcium from carbonate is not bioavailable in the absence of stomach acid.

Other fat-soluble vitamins and antioxidant status

Fat malabsorption is common following RYGB and, mainly, biliopancreatic diversion where only about 32% of the dietary fat is absorbed [84]. This occurs due to short common channels that lead to a delayed mixing of fat with pancreatic enzymes and bile salts. The consequence is fat and fat-soluble vitamin malabsorption. Moreover, food intolerance may reduce fat consumption and aggravate malabsorption.

Vitamin E deficiency is not common in patients supplemented with multivitamin, although it was already reported after gastroplasty [85] and biliopancreatic diversion [86•]. An increase of serum α -tocopherol associated to low levels of lipid peroxidation was described after vertical banded gastroplasty, suggesting an improvement in antioxidant balance [87].

Clinical manifestation of vitamin A deficiency (night blindness) has already been reported [88,89•,90], including a report describing a newborn infant who developed vitamin A deficiency as a result of maternal malabsorption after biliopancreatic diversion [91].

Up to now, clinical manifestations of vitamin K deficiency have not been published despite a report of high incidence of hypovitaminemia K after biliopancreatic diversion [43••].

Slater *et al.* [43••] examined the incidence of fat-soluble vitamin deficiency following biliopancreatic diversion. The incidence of vitamin A deficiency was 69%, vitamin K deficiency 68%, vitamin D deficiency 63%, and vitamin E deficiency 4% by the fourth year after surgery. Based on these results, it is recommended to check serum fat-soluble vitamins before and regularly after biliopancreatic diversion.

Zinc

As a nutrient that depends on fat absorption, low serum concentrations were observed in patients after biliopancreatic diversion or duodenal switch [43••]. Low serum levels of zinc were also described after gastroplasty as a consequence of reduced dietary intake [85]. However, clinical manifestations of zinc deficiency are not common after bariatric surgery. There is one report of resolution of alopecia after supplementation of high doses of zinc sulfate in patients submitted to vertical gastroplasty [92].

Conclusion

Most publications about bariatric surgery state that the analysis of excess-weight loss and improvement of metabolic complications are the major goals of this type of surgery. However, as pointed out by Oria [93•], the success of surgical treatment of morbid obesity needs to include not only weight loss and the improvement in

obesity-related comorbidities, but also changes in quality of life experienced by the patients after the operation. In addition, a careful and regular check of nutrients should be also introduced once their deficiencies limit quality of life. As both success of surgery and incidence of nutritional deficiencies are related to the magnitude of weight loss, especial attention should be given to patients undergoing more aggressive malabsorptive procedures. Adolescents and women in reproductive age are the most vulnerable groups at risk of nutritional deficiencies. To avoid severe nutritional deficiencies as seen in the first years after bariatric surgery it is important to predict, prevent, and promptly treat nutritional abnormalities in vulnerable patients.

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Good comment about bariatric surgery.