



Postoperative Nutrition and Nutritional Complications in Patients with Bariatric Surgery: An Update

Bariatrik Cerrahi Geçiren Hastalarda Postoperatif Beslenme ve Beslenme ile İlgili Komplikasyonlar: Güncelleme

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Abstract

Bariatric surgery is the most effective therapeutic option for long-term weight loss among patients with morbid obesity. Nutrition after bariatric surgery is a very specialized condition. The most severe complications that can develop after bariatric surgery are nutritional deficiencies and the diseases related to them, such as anemia and osteoporosis. Screening associated with nutritional deficiencies should be performed preoperatively to optimize the postoperative outcomes and the nutritional status of patients. Bariatric surgeries such as Roux-en-Y gastric bypass (RYGB) and biliopancreatic diversion with duodenal switch (BPD-DS) reduce nutrient absorption. Moreover, bariatric surgery can exacerbate preexisting nutritional deficiencies. Patients who have undergone bariatric surgery should be followed up for common micronutrient deficiencies and protein-calorie malnutrition. There are gaps in the postoperative follow-up of these patients. This review aimed to focus on the postoperative nutritional strategies and nutritional complications in patients who have undergone bariatric surgery.

Keywords: Bariatric surgery; nutrition; nutrient deficiency

Özet

Bariatrik cerrahi ciddi obezitesi olan hastalar arasında uzun süreli kilo kaybında en etkili tedavi yöntemidir. Bariatrik cerrahi sonrası beslenme çok özel bir konudur. Bariatrik cerrahi sonrası gelişebilecek en ciddi komplikasyonlar beslenme yetersizlikleri ve bunlarla ilişkili anemi ve osteoporoz gibi hastalıklardır. Postoperatif sonuçları ve hastaların beslenme durumunu optimize etmek için beslenme yetersizlikleri ile ilişkili tarama preoperatif dönemde başlatılmalıdır. Roux-en-Y gastrik bypass (RYGB) ve biliopancreatik diversiyon-duodenal switch (BPD-DS) gibi ameliyatlarda besin emilimini azaltır. Ayrıca, bariatrik cerrahi daha önceden var olan beslenme yetersizliklerini şiddetlendirebilir. Bariatrik cerrahi geçiren hastalar yaygın mikro besin eksiklikleri ve protein-kalori yetersizliği açısından takip edilmelidir. Bu hastaların postoperatif takiplerinde boşluklar vardır. Bu derleme makale, bariatrik cerrahi geçirmiş hastalarda postoperatif beslenme stratejilerine ve beslenme ile ilgili komplikasyonlara odaklanmayı amaçladı.

Anahtar kelimeler: Bariatrik cerrahi; beslenme; besin eksikliği

Introduction

Therapeutic options for obesity have trended toward bariatric surgeries in recent decades. Bariatric surgery involves different procedures that can be restrictive, malabsorptive, or a combination of both. Malabsorptive procedures lead to weight loss by intestinal

segment bypass that reduces food absorption. Restrictive procedures lead to weight loss by restricting food intake (1). Restrictive procedures include laparoscopic sleeve gastrectomy (LSG), laparoscopic adjustable gastric banding (LAGB), and vertical band gastroplasty. Malabsorptive procedures in-

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Peer review under responsibility of Turkish Journal of Endocrinology and Metabolism.

Received: 13 May 2021 **Received in revised form:** 14 Aug 2021 **Accepted:** 01 Sep 2021 **Available online:** 05 Oct 2021

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clude jejunioileal bypass and biliopancreatic diversion (BPD). The combined procedures include Roux-en-Y gastric bypass (RYGB) and biliopancreatic diversion with duodenal switch (BPD-DS) (1).

Bariatric surgery aims to help patients achieve maximum sustainable weight loss and maintain a proper nutritional balance (2). Bariatric surgeries can exacerbate malnutrition and micronutrient losses, which are risk factors for obesity. Thus, nutrient deficiencies should be screened before the surgery, and the detected deficiencies should be replenished. This is essential because the patients that apply for weight loss surgery (WLS) have at least one mineral or vitamin deficiency (3). Compared with restrictive procedures, malabsorptive procedures cause nutritional deficiencies more frequently (4).

Postoperative Dietary Strategy

Nutritional intake following bariatric surgery consists of the following five stages: stage 1 (first 1–3 days) is clear fluid diet, stage 2 (1–2 weeks) is fluid diet, stage 3 (3–4 weeks) is pureed diet, stage 4 (5–8 weeks) is soft diet, and stage 5 (from week 9 on) is normal diet (5).

Within the first 24 h of the surgery, clear fluids containing low carbohydrates should be given to the patients. On the first postoperative day, 30–60 g of non-carbonated and caffeine-free fluids every hour, totaling up to 750–1000 mL/day (d), should be given. The volume of fluids should be increased up to 1500–2000 mL/d from the second day to maintain adequate hydration (2). Fluids should not be consumed with solid foods. It is advised to keep a 30 min interval between the solid foods and fluids consumption to prevent gastrointestinal symptoms (2).

During the first 3 weeks, patients should drink only liquids with enough protein (in the form of powder), and enough hydration should be provided. In stage 3, pureed foods can be given. Pureed foods can be described to the patients as foods that can be swallowed without chewing (2). In stage 4, the patients can be given soft foods that do not require excess chewing (2). In stage 5, most patients can start eating some solid foods. They can eat all types of solid foods as per tolerance (2). Daily calorie intake is 400

kcal/d in the first postoperative week, which progresses to 600–800 kcal/d by the third and fourth week. From the fifth week, patients are advised to consume 1200–1500 kcal/d. Most patients can consume approximately 1500–1800 kcal/d, 6 months after surgery (2).

Patients who have undergone bariatric surgery should not consume concentrated sweets to reduce caloric intake and dumping symptoms (2). Two main dishes and three snacks are recommended to these patients. Sufficient protein intake is very crucial. Protein can be provided by mixing protein powder with fluids during the first three weeks. Carbohydrates should constitute 50% of the total calories intake. Consumption of complex carbohydrates such as fruit, vegetables, and grains is recommended (50 g/d in the early postoperative day and up to 130 g/d as diet intake increases in the following days) (2).

Crushed or liquid form of medications should be used and long-acting drugs should be avoided to maximize absorption during the early postoperative period (2).

Patients should be advised to eat slowly by chewing thoroughly. They should stop eating once they feel satiated. If the food is ingested quickly or the quantity of food is more than the stomach pouch capacity, the patient can experience vomiting or gastric distress. Therefore, patients should decide their food intake. In the early postoperative phase, patients utilize calories (energy) mainly from their fat deposits. They require nutritional supplementation and good hydration from outside. After their weight is stabilized, patients get most of their calories from the nutrients in their diet. Their nutrient requirements are similar to those of people without bariatric surgery (2).

Before surgery, the patient's basal vitamin and mineral levels should be evaluated. In the follow-up, these levels need to be evaluated at regular time intervals. If any deficiencies are observed, then they should be replenished. Patients that undergo LSG, RYGB, and BPD-DS should be prescribed 2 adult multivitamin supplements containing minerals (iron, folic acid, and thiamine), 1200–1500 mg of elemental calcium supplements (calcium citrate), minimum of 3,000 IU of vitamin D supplements (titrated to 25-

hydroxyvitamin D levels >30 ng/mL), and vitamin B12 supplements (sublingual, oral, subcutaneous, or intramuscular formulations) to keep their nutrient and micronutrient levels within normal limits (2).

In patients that undergo LAGB, an adult multivitamin supplement containing minerals (folate, thiamine, and iron) should be taken every day. Also, elemental calcium supplement (calcium citrate) up to 1200-1500 mg and a minimum of 3,000 IU of vitamin D (titrated to 25-hydroxyvitamin D levels >30 ng/mL) are required (6-8). Multivitamin and mineral supplement therapies should be continued lifelong.

Nutritional support should be given to patients with WLS that are at high nutritional risk (Nutrition Risk Score ≥ 3) (Table 1 and Table 2) (9). Life-threatening complications that requiring admission to the intensive care unit may develop in patients following bariatric surgery. The complications that are likely to see early (<30 d) are anastomotic leaks, gastrogastic fistulas, gastrointestinal haemorrhages, and perforations, on the other hand bowel obstructions, anastomotic strictures, and band erosions occur after the first 30 d. Oral intake is avoided to manage of gastrointestinal complications until the complication has resolved (10-14). Parenteral nutrition (PN) should be given to the patients that cannot use their gastrointestinal tract for at least 3-7 days with critical illness or 5-7 days with noncritical illness (2). PN therapy is also recommended for patients with severe malnutrition and hypoalbuminemia who are not responsive to oral or enteral protein supplementation (15,16). There is no consensus for the nutritional requirements for obese patients requiring nutritional support following bariatric surgery. PN treatment should contain hypoenergetic high protein nutrients for patients with WLS (2).

Nutrient Deficiencies

Protein and micronutrients deficiencies are mainly seen in patients with bariatric surgery. Nutrient deficiencies are due to insufficient calorie intake, differences in the digestive anatomy, malabsorption, and bacterial overgrowth in the small intestines (17).

The type of surgery determines the nutritional deficiencies. As the procedure be-

Table 1. Nutritional risk screening (9).

| Initial screening | | Yes | No |
|---|---|-----|----|
| 1 | Is the BMI below 20.5? | | |
| 2 | Has the patient lost weight in the last three months? | | |
| 3 | Did the patient have a reduced dietary intake in the last week? | | |
| 4 | Is the patient severely ill? | | |
| Yes: If the answer is "Yes" to any of the questions, the screening in Table 2 is performed. | | | |
| No: If the answer is "No" to all of the questions, the patient is rescreened at weekly intervals. | | | |

BMI: Body mass index.

comes more complicated, the chances of malnutrition increase. Nutrient deficiencies are common after malabsorptive surgeries like RYGB and BPD-DS. Malnutrition is observed after LSG to a lesser extent (18-22). In RYGB and BPD-DS, the duodenum and some parts of the small intestine are removed. These regions are responsible for the absorption of folate, vitamin B12, vitamin D, and minerals like iron and calcium (23). BPD-DS is the least performed bariatric surgery. Protein malnutrition, diarrhea, and fat-soluble vitamins deficiencies are observed after this procedure. Nutritional deficiencies after restrictive procedures are related to the diet and eating habits of the patients. The decrease in nutrient intake, poor food choices, food intolerance, excessive vomiting, and insufficient portion size may cause nutritional deficiencies. Excessive vomiting can lead to acute thiamine deficiency. Also, decreased food intake and especially meat can lead to nutritional deficiencies (24). Bacterial overgrowth in the small intestine can develop after bariatric surgery, which can increase the risk of micronutrient deficiencies (25).

Protein Deficiency

Protein digestion begins in the stomach with the release of hydrochloric acid. The inactive pepsinogen is converted to active pepsin in the acidic environment of the stomach (26). Dietary protein intake decreases after

Table 2. Nutritional risk score (9).

| Final screening | | Severity of disease | |
|--|-------------------------|-------------------------|--|
| Impaired nutritional status | Absent Score 0 | Absent Score 0 | Normal nutritional status |
| Normal nutritional status | Mild Score 1 | Mild Score 1 | Hip fracture, chronic patients (cirrhosis, COPD, chronic hemodialysis, diabetes, oncology) |
| Weight loss is >5% in the last three months or food intake is below 50–75% of the normal requirement in the previous week. | Moderate Score 2 | Moderate Score 2 | Major abdominal surgery, stroke, pneumonia, hematologic malignancy |
| Weight loss is >5% in the last two months, or BMI is between 18.5–20.5 + impaired general status or food intake is 25–60% of the normal requirement in the previous week. | Severe Score 3 | Severe Score 3 | Head injury, bone marrow transplantation, intensive care patients (APACHE > 10) |
| Weight loss is >5% in the last one month (>15% in 3 months) or BMI <18.5 + impaired general status or food intake is 0–25% of the normal requirement in the previous week. | Score | Score | =Total score |
| | + | | |
| Age if ≥70 years: add 1 to total score above | | | |
| Score ≥3: the patient is nutritionally at risk, and a nutritional care plan should be initiated | | | |
| Score <3: the patient requires weekly re-screening | | | |

BMI: Body mass index, COPD: Chronic obstructive pulmonary disease, APACHE: Acute physiology and chronic health evaluation.

bariatric surgery. Gastric acid and pepsinogen secretion are significantly reduced in the stomach. The secretion of pancreatic enzymes is reduced. All these reasons alter normal protein digestion in the duodenum. Postoperative alteration in the taste and olfactory perception can also decrease protein intake (26).

Adequate protein intake is very important to avoid malnutrition. Protein intake should be calculated based on the age, sex, and weight of the patient (2). Excess hair loss can be the first symptom of protein malnutrition. Moreover, poor wound healing, sarcopenia, edema, anemia, and hypoalbuminemia can also be observed. Protein replenishment should begin from the second postoperative day. Protein should constitute 10% of the total daily calories intake. The daily protein requirement will be at least 60 g/d (adequate intake is up to 1.5 g/kg of ideal body weight (IBW) per day) and should be calculated for each patient by the dietician (maximum protein intake can be up to 2.1 g/kg IBW per day) (27). As per the guidelines (2,5), a minimum of 120 g/d protein should be given to patients with BPD, and a minimum of 60 g/d protein should be given to patients with RYGB or LSG (2). The recommended daily intake of protein after bariatric surgery may be up to 0.8-1 g/kg IBW per day in patients with stage 3-5 chronic kidney disease without dialysis. For patients on dialysis, the minimum protein requirement is 1.2 g/kg IBW per day. For patients that underwent kidney transplantation, protein intake is less restricted (≥1.1 g/kg IBW per day) and dependent on kidney function (28).

The reduction of protein intake leads to loss of muscle mass in the first month after bariatric surgery. It has been reported that during the first year after LSG and RYGB, the majority of patients could not intake the advised protein intake of a minimum of 60 g daily (29). Additionally, Verger et al. reported that nearly one-third of

the patients suffered from mild protein deficiency (29). Protein deficiency was also observed in the patients at the first and third months of postoperative LAGB (30). A study by Giusti et al. reported inadequate protein intake until three years of RYGB (31). Protein supplements are generally prescribed to replenish protein levels. Schollenberg et al. observed that daily protein supplements (30-35 g of protein powder) positively influence both body weight loss and body composition within the six months follow-up (32). 0.5 g whey protein supplement/kg IBW helps to achieve desired body weight and fat loss after RYGB (33). Oral protein supplements should be consumed for six months after LSG or RYGB (32).

Micronutrients and Their Deficiencies

Calcium-Vitamin D

Calcium is absorbed maximum in the duodenum and proximal jejunum, but it is absorbed passively throughout the gastrointestinal tract. Surgeries that decreased gastric acidity like RYGB, LSG, BPD-DS have also increased the risk of calcium malabsorption. Calcium is absorbed in the presence of vitamin D. Vitamin D is absorbed maximum in the jejunum, and ileum and these regions are bypassed in RYGB and BPD-DS (34). In patients with obesity, vitamin D deficiency and secondary hyperparathyroidism are seen even before bariatric surgery. Patients that undergo BPD-DS are especially at increased risk of vitamin D deficiency due to fat malabsorption (35). Secondary hyperparathyroidism due to vitamin D deficiency is seen after surgery as well (36,37).

Calcium citrate, vitamin D (ergocalciferol [vitamin D2] or cholecalciferol supplements [vitamin D3]) should be prescribed to patients that underwent RYGB, BPD, or BPD-DS, at a concentration that does not cause hypercalciuria. Calcium citrate is absorbed better when the gastric pouch has less acidity. Calcium carbonate, which is more easily available as supplements, does not get absorbed well in the less acidic environment. Thus, after LSG, when acid-producing cells are present to some extent, calcium carbonate can be prescribed. In addition, 40-50% of calcium citrate is absorbed, while less than 10% of calcium carbonate is absorbed. Hence, the

deposition of excess calcium carbonate can lead to the formation of kidney stones. In case of severe vitamin D malabsorption, 50,000 IU oral doses of vitamin D2 or D3 1-3 times a week should be prescribed. Calcitriol may be added in resistant cases at doses of 0.25-4 µg daily. Hypophosphatemia can also be observed due to vitamin D deficiency. In the case of hypophosphatemia (1.5-2.5 mg/dL), phosphate supplements should be given orally (2).

Iron

Patients with obesity generally develop iron deficiency. Insufficient iron intake, higher requirement, and low-grade chronic inflammation inhibit the absorption of iron and can lead to the development of iron deficiency in patients with obesity (38). After consumption, dietary iron (heme and non-heme forms) is oxidized to ferric (3+) state by the acid environment for solubility. In the duodenum, iron is reduced to a ferrous (2+) state by duodenal ferro-reductase for absorption (39). Iron is absorbed in the duodenum and proximal jejunum. After bariatric surgery, decreased secretion of hydrochloric acid, use of proton-pump inhibitor (PPI), faster gastric emptying, and reduced surface area may lower iron absorption. Low iron levels in the diet, decreased oral intake, and intolerance to iron-rich foods (red meat) can also contribute to iron deficiency (24). The iron level should be evaluated after all bariatric surgeries. It has been observed that the prevalence of iron deficiency ranges is between 1 to 54% after LSG (24). Routine evaluation of iron levels for all patients is advised, especially after LSG, RYGB, or BPD-DS (40) within 3 months of post-operation, then every 3-6 months until 12 months, and then once a year (2). Additionally, before bariatric surgery, 15% of patients with obesity have anemia, of which 47% had anemia due to iron deficiency (41). Therefore, the iron level should be evaluated during the preoperative period as well.

The most common symptom of iron deficiency after bariatric surgery is hair loss (42). Fatigue, decreased work performance, impaired learning ability, glossitis, vertical ridges on nails, and palpitation can also be observed (43). Iron supplements should be prescribed as oral ferrous sulfate, fumarate,

or gluconate. To replenish serum iron levels, 45-60 mg is recommended daily via multivitamins in patients with post-RYGB, LSG, or BPD-DS (2). Oral iron supplements cause significant gastrointestinal side effects, which can have an additive role in iron deficiency. In patients with WLS with iron deficiency, oral supplements should be increased to obtain 150–200 mg elemental iron daily (43). Vitamin C should be also be prescribed to increase the absorption of iron. Patients that are unable to tolerate oral iron supplements and patients with severe malabsorption can be administered intravenous iron infusions along with ferric gluconate or sucrose (44,45). The resolution of the coexisting inflammatory state may decrease ferritin level in patients who underwent bariatric surgery (46).

Vitamin B12 (Cobalamin)

Vitamin B12 deficiency is due to the depletion of parietal cells that secrete gastric acid and due to the deficiency of intrinsic factor (47). Vitamin B12 deficiency can also be associated with a reduced intake of vitamin B12-rich foods because of intolerance (48). PPI intake can contribute to vitamin B12 deficiency (49). The symptoms of vitamin B12 deficiency include paleness with slightly icteric eyes and skin, glossitis, fatigue, paresthesia, numbness in extremities, vertigo, and palpitation (43). Deficiency of vitamin B12 can be observed after RYGB or LSG. It is observed in one-third or more patients in the postoperative period (50,51). A meta-analysis study reported that LSG leads to a less postoperative risk of vitamin B12 deficiency compared with RYGB (52).

Vitamin B12 deficiency is a permanent situation that requires lifelong medication (23). Vitamin B12 deposits in the body are present for 18 months; thus, symptoms of vitamin B12 deficiency are seen late in the postoperative period. Vitamin B12 levels should be evaluated before and yearly after LSG and RYGB. To maintain a normal serum level of vitamin B12, can be prescribed 350-500 µg daily, sublingually or orally, provided that the absorption is adequate (2). Doses up to 1000 µg may need to be taken daily. Intranasal vitamin B12 500 µg/week can also be prescribed. If the patient is unable to maintain normal vitamin B12 levels by

oral supplements, vitamin B12 can also be given intramuscularly or subcutaneously, 1000 µg/month or 1000–3000 µg every 6 to 12 months (2,5).

Vitamin B9 (Folate)

Because folic acid can be absorbed throughout the small intestine, particularly in the jejunum, vitamin B9 deficiency is rare compared with vitamin B12. As folate is a hydrophilic vitamin, it is not stored in the body; therefore, deficiencies may occur in cases of inadequate oral ingestion (17). The most important dietary source of folic acid is green leafy vegetables. Folic acid deficiency can be observed along with vitamin B12 deficiency because vitamin B12 plays a role in converting folate to its active form (methyltetrahydrofolic acid→tetrahydrofolic acid). The most common causes of megaloblastic anemia are vitamin B9 and vitamin B12 deficiencies. Common symptoms of folate deficiency include fatigue, muscle weakness, pale skin, the feeling of pins, tingling or burning in the extremities, and memory problems (43). Folic acid deficiency is rare after restrictive surgery but common after malabsorptive surgery (2). Evaluation of Vitamin B9 level is recommended for all patients (2). Different supplement dosages are mentioned in the literature. Cappocia et al. observed adequate folate levels in patients that were prescribed standard oral folate supplements after LSG (53). This data suggests that folic acid absorption from the distal intestine is protected after LSG (54). However, Hakeam et al. reported that patients might need more than the daily recommended dose to keep folic acid levels within the normal range (55). Folic acid may be provided as 400-800 µg/d folate in multivitamins or as 800-1000 µg/d folate in prenatal supplements to decrease the risk of fetal neural tube defects (56).

Vitamin B1 (Thiamine)

Thiamine is a cofactor for several metabolic pathways in glycolysis to neurotransmitter synthesis. It is mainly absorbed in the duodenum and proximal jejunum. The deficiency of thiamine impairs oxidative metabolism that leads to oxidative stress, inflammation, and neurodegeneration (57,58). Thiamine deficiency is increased,

especially after RYBG and BPD-DS. It may be observed in patients with progressive emesis and/or severely restricted oral intake of food after three weeks of bariatric surgery (59). After only 20 days of insufficient oral intake, thiamine reserves in the body are depleted. Thiamine deficiency occurs faster than other vitamin deficiencies. Thiamine deficiency was reported along with intestinal flora changes after RYBG (60). Since thiamine is transported by albumin, its levels will be reduced with concomitant hypoalbuminemia. Wernicke's encephalopathy occurs because of thiamine deficiency, which is characterized by oculomotor dysfunction, confusion, and walking ataxia (58,59). Patients with rapid weight loss, progressive weight loss, parenteral feeding, excessive alcohol consumption, neuropathy, encephalopathy, or cardiac failure should be screened for thiamine deficiency. Routine screening after bariatric surgery is not recommended (2).

Thiamine can be provided along with multivitamins. To normalize serum thiamine levels, at least 12 mg should be administered to the patients. Preferably a 50-100 mg of thiamine with multivitamins may be given to some patients daily to obtain adequate thiamine (2). In patients with severe thiamine deficiency, 500 mg/d thiamine should be given intravenously for 3-5 days. Thereafter, 250 mg/d thiamine should be given intravenously for 3-5 days or until the symptoms subside, and then 100 mg/d thiamine should be given orally to maintain thiamine levels. Mild deficiency could be treated with intravenous administration of thiamine, 100 mg/d, for 7-14 days. In case of recurrent thiamine deficiency or deficiency that cannot be fixed, antibiotics for bacterial overgrowth can be given. Antibiotics such as metronidazole, amoxicillin, or rifaximin can be given orally for 7-10 days every two months (60). Probiotic therapy can be planned for patients with antibiotic resistance (1).

Selenium

Selenium is absorbed in the duodenum and proximal jejunum (61). The occurrence of selenium deficiency after RYBG and BPD-DS is observed to be 14% and 22%, respec-

tively (62). Striated muscle dysfunction, cardiomyopathy, mood changes, disorders of the immune system, progressive persistent diarrhea, decreased pigmentation, metabolic bone disease, and unexplained anemia may be observed in patients with selenium deficiency. The interval between the therapeutic supplementation of selenium is very less; toxic doses are very close to the therapeutic doses. Selenium supplementation is recommended at a dose of 2 µg/kg of IBW/d.

Zinc

Zinc plays an important role in DNA synthesis, wound healing, and protein synthesis. Zinc is absorbed in the duodenum and proximal jejunum. It is also involved in fat absorption. Zinc deficiency can be observed after malabsorptive procedures (63). It was observed in 11% patients in the postoperative 2-3 years period after BPD and BPD-DS (62) and 6-40% patients after RYBG (63). It was also reported after LSG (3). The risk factors that can contribute to zinc deficiency include reduction in gastric HCl that limits zinc absorption and insufficient intake of dietary zinc (64). Zinc deficiency should be screened for patients with hair loss, distorted taste perception, pica, delayed wound healing, skin lesions, immune deficiency, and in males with hypogonadism and erectile dysfunction. Screening should be done at least once a year for post-RYGB and post-BPD-DS patients regardless of the symptoms (2). Multivitamins containing 8-22 mg/d zinc will be enough to prevent zinc deficiency (2).

Copper

Copper is essential for the synthesis of erythrocyte and leucocyte and the normal functioning of the central nervous system (essential for neurotransmitter synthesis) (61). It is absorbed in the stomach and proximal jejunum (65). Copper deficiency has been reported after RYBG and BPD-DS (66). In a retrospective screening of 136 patients that underwent RYBG, the prevalence of copper deficiency was 10% (67). A lower rate of copper deficiency is observed after LSG (3). Copper deficiency is more evident with iron supplementation (2). Routine screening for copper is not recommended

but is considered in the cases of anemia, neutropenia, ataxia, myeloneuropathy, and difficulties in wound healing. Supplementation with 1-2 mg/d of elemental copper may be started for all patients post-WLS (2). In case of serious copper deficiency, intravenous copper (3-4 mg/d) may be given for six days, followed by oral administration of copper sulfate or gluconate (3-8 mg/d) until the copper level is normal and symptoms disappear. Although hematological conditions improve after two months of copper supplementation, neurological problems require supplementation for a longer period. In the small intestine, zinc competes with copper for absorption. Because zinc supplementation can lead to copper deficiency, 1 mg of copper should be given for every 8-15 mg of elemental zinc supplementation (2).

Fat-Soluble Vitamins

Fat-soluble vitamins are primarily absorbed in the jejunum and ileum (35). Deficiencies are observed, especially in patients with RYGB (23) and BDS-DS (68,69). Routine screening is not recommended for vitamin E and K deficiencies. Vitamin A deficiency may be screened in patients with malabsorptive procedures. Bariatric patients with vitamin A deficiency should be screened for concurrent iron and/or copper deficiencies because these deficiencies can prevent the recovery of vitamin A deficiency (6). Screening is advised for these patients within the first postoperative year regardless of the symptoms (70,71). To prevent deficiencies, 5,000-10,000 IU vitamin A, 15 mg vitamin E, and 90-120 µg vitamin K (300 µ for post-BPD-DS) are recommended daily (2).

A summary of micronutrient deficiencies, nutrient supplementation, and replenishment after WLS is given in Table 3.

Screening for Micronutrient Deficiencies

Guidelines (2,5) recommend the micronutrient screenings should be conducted at 1, 3, to 6 and 12 months postoperatively (2). Thereafter, screening depends on the type of surgical procedures and known micronutrient deficiencies (2).

Screenings should include complete blood count, electrolytes, glucose, iron, iron-binding capacity, transferrin saturation, ferritin,

vitamin B12, aminotransferases, alkaline phosphatase, bilirubin, albumin, lipid profile, 25-OH vitamin D, parathyroid hormone, thiamine, folate, zinc, and copper. If any other deficiency is observed, follow-up for the same should be performed (21).

Other Complications Related to Nutrition After Bariatric Surgery

Anemia

The etiology of anemia should be determined even in the absence of blood loss during the surgery. The main causes of anemia are iron, folic acid, and vitamin B12 deficiencies. In the absence of these deficiencies, protein, copper, selenium, and zinc deficiencies should be screened (72).

Osteoporosis

Vitamin D deficiency is commonly seen in patients with obesity. A large amount of adipose tissue in patients with obesity serves as a reservoir for vitamin D, which can lead to vitamin D deficiency (73). Hepatic synthesis of 25-OH vitamin D also decreases in patients with obesity (73). Secretions of the visceral fat increase the level of proinflammatory cytokines, which then increases vitamin D resorption in the bones (74). Obesity may increase the risk of fall-related injuries and extremity fractures because of the impairment in mobility and loss of muscle strength (75).

There is a strong association between the extent of weight loss and the amount of bone loss after bariatric surgery (76). The detrimental effects of bariatric surgery on bones are mainly due to calcium and vitamin D deficiencies, which can cause secondary hyperparathyroidism. The bone fragility increases after bariatric surgery due to skeletal changes. Loss of bone mineral density has been reported in patients that undergo RYGB and LSG (77). A significant increase in the carboxy-terminal telopeptide of collagen type I (CTX) levels has been reported after five years of LSG (78). However, bone turnover markers increased to a lesser extent after LSG compared with RYGB (78). In a study where 94% of the patients underwent bypass surgery, the risk for any type of fracture increased 2.3-fold. After 10+ years post-surgery, the reported risk

Table 3. Micronutrient deficiencies, nutrient supplementation, and replenishment after weight loss surgery (2,5).

| Micronutrient | Monitoring | Supplementation to prevent deficiency | Replenishment for patients with deficiency |
|-------------------------------------|--|--|--|
| Vitamin B1 (thiamine) | -High-risk groups | -At least 12 mg once orally -Preferably 50-100 mg 1-2 times orally in the form of multivitamin supplements for at-risk patients | -100 mg 2-3 times orally daily until symptoms resolve -IV 500 mg/d 3-5 days, followed by 250 mg/d 3-5 days or until symptoms resolve, then 100 mg/d orally to maintain normal levels |
| Vitamin B ₁₂ (cobalamin) | -Post-LSG, post-RYGB, or post-BPD-DS | -350-500 µg oral/sublingual daily -1,000 µg IM monthly | -1,000 µg daily to achieve normal levels and then resume recommended dosages to maintain normal levels |
| Folate | -All patients | -400-800 µg oral daily -800-1,000 µg oral daily in women of childbearing age | -1,000 µg oral daily to achieve normal levels and then resume dosages recommended to maintain normal levels |
| Iron | -All patients | -18 mg oral daily for males that underwent LAGB, LSG, or RYBG -45-60 mg oral daily for menstruating females that underwent LAGB, LSG, or RYBG | -150-200 mg orally daily -Dose should be increased as high as 300 mg orally 2-3 times daily |
| Vitamin D and calcium | -All patients | -1,200-1,500 mg/d calcium citrate for patients that underwent LAGB, LSG, or RYBG; 1,800-2,400 mg/d calcium citrate for patients that underwent BPD-DS -3,000 vitamin D3 IU daily, titrate 25-OH vitamin D level to 30 ng/mL | -1,200-1,500 mg/d calcium citrate for patients that underwent LAGB, LSG, or RYBG, 1,800-2,400 mg/d calcium citrate for patients that underwent BPD-DS -3,000-6,000 vitamin D3 IU/d -50,000 IU vitamin D2 IU/weekly |
| Vitamin A | -Post-BPD-DS, regardless of symptoms -Post-RYGB with protein-calorie malnutrition | -5,000 IU/d for patients that underwent LAGB -5,000-10,000 IU/d for patients that underwent RYGB or LSG -10,000 IU/d for patients that underwent BPD-DS | -For patients without corneal changes, 10,000-25,000 IU/d orally until clinical symptoms improvement -For patients with corneal changes 50,000-100,000 IU/d IM for 3 d, followed by 50,000 IU/d IM for two weeks |
| Vitamin E | -Symptomatic patients | -15 mg/d | -Optimal dose for patients that underwent bariatric surgery is not defined -Antioxidant benefits can be achieved with supplements of 100-400 IU/d |

Continue...→

Table 3. Micronutrient deficiencies, nutrient supplementation, and replenishment after weight loss surgery (2,5) (Continue).

| Micronutrient | Monitoring | Supplementation to prevent deficiency | Replenishment for patients with deficiency |
|---------------|---|---|--|
| Vitamin K | -Symptomatic patients | -90-120 µg/d for patients that underwent LAGB, LSG, o RYGB -300 µg/d for patients that underwent BPD-DS | -10 mg parenterally for patients with acute -Either 1-2 mg/d orally or 1-2 mg/week parenterally for patients with chronic malabsorption |
| Zinc | -Post-RYGB, post-BPD-DS annually -Anemia without iron deficiency | -8-11 mg/d for patients that underwent LAGB or LSG -8-22 mg/d for patients that underwent RYGB -BPD-DS: 16-22 mg/d for patients that underwent BPD-DS | -Sufficient data is unavailable -Screened routinely and avoid copper deficiency |
| Copper | -Post-RYGB, post-BPD-DS annually | -1 mg/d for patients that underwent LAGB and LSG -2 mg/d for patients that underwent RYGB or BPD-DS | -3-8 mg/d orally for mild to moderate deficiency, 2-4 mg/d IV for severe deficiency until serum levels return to normal |

Laparoscopic adjustable gastric banding (LAGB); Laparoscopic sleeve gastrectomy (LSG); Roux-en-Y gastric bypass (RYGB); Biliopancreatic diversion with duodenal switch (BPD-DS); Day (d); Intravenous (IV); Intramuscular (IM), International Unit (IU)

was 5-10 times greater (79). An increased risk of fracture after LSG remains inconclusive. Old age is also an important factor that can increase the risk of fractures (80).

Dual-energy X-ray absorptiometry can be inaccurate in patients with obesity, especially during the process of weight loss. In patients who have undergone malabsorptive surgery, bone mineral density measurements may be recommended at baseline after two years (2). Antiresorptive agents may be prescribed to patients with osteoporosis after bariatric surgery after the patient has received adequate treatment for calcium and vitamin D deficiencies. Antiresorptive agents (bisphosphonates or denosumab) should be administered intravenously or subcutaneously to avoid the risks of anastomotic ulceration and reflux that can occur if bisphosphonates are given orally (2).

Foul-Smelling Diarrhea

Foul-smelling diarrhea arises due to the malabsorption of protein, fat, calcium, iron, and vitamin B₁₂.

Kwashiorkor

Kwashiorkor is a potentially lethal form of protein malnutrition.

Unwillingness to Eat

Unwillingness to eat is observed during the transition of diets from fluid food to soft food and then to normal food. Patients can be angry and disappointed because their food volume is reduced after bariatric surgery compared with the preoperative period. Therefore, patients should be persuaded to eat. Most patients can tolerate normal food by the 6th month of the postoperative period. If emesis continues, the presence of ulcers or any gastric obstruction should be detected (2).

Food Intolerance

Food intolerance is seen especially toward red meat. Patients may prefer a vegetarian diet (2).

Dumping Syndrome

Dumping syndrome is most commonly reported after procedures that do not keep the pylorus intact. Early dumping occurs commonly within one hour of RYBG, after eating mainly refined carbohydrate or fatty food. It is due to the passage of hyperosmolar gastric

content in the jejunum, with shifts in intravascular fluid in the intestinal lumen. Abdominal pain, nausea, fatigue, diarrhea, and tachycardia may also be observed (81). Late dumping occurs 1-4 h after eating high glycemic index foods. Postprandial reactive hypoglycemia occurs in response to hyperinsulinemia. Symptoms such as nausea, sweating, tremor, palpitation, altered consciousness, and syncope can be observed (81).

Hypervitaminosis

Previous studies have reported hypervitaminosis in patients due to excess intake of vitamins. The excessive levels of vitamin B1, B6, B12, and folate were identified (82,83). Vitamin B6 toxicity was associated with the development of sensory neuropathy (84).

Conclusion

Nutrition after bariatric surgery is divided into five stages that start after the surgery and continue until the patient resumes a normal diet. Vitamins and minerals that the patient is unable to receive from the regular diet are provided as supplements. The amount of supplements prescribed differs based on the procedure. The most important complication that can occur after bariatric surgery is nutritional deficiencies. The quantity of vitamins and minerals needed by the patient should be determined preoperatively. Deficient vitamins and minerals should be prescribed preoperatively. Routine screening for vitamins and minerals should be performed postoperatively. If any deficiency is detected, the appropriate vitamins and minerals should be prescribed accordingly.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or mem-

bers of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: Havva Sezer, Dilek Yazıcı; Design: Havva Sezer, Dilek Yazıcı; Control/Supervision: Havva Sezer, Dilek Yazıcı; Data Collection and/or Processing: Havva Sezer, Dilek Yazıcı; Analysis and/or Interpretation: Havva Sezer, Dilek Yazıcı; Literature Review: Havva Sezer, Dilek Yazıcı; Writing the Article: Havva Sezer, Dilek Yazıcı; Critical Review: Dilek Yazıcı.

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