

## Metabolic and nutritional complications of bariatric surgery : a review

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### Abstract

Bariatric surgery is considered as the only effective durable weight-loss therapy and may be curative for obesity-related comorbidities such as diabetes. Nevertheless this surgery is not devoid of potential long-term complications such as dumping syndrome, gastroesophageal reflux disease and nutrient deficiencies. For this reason, preoperative nutritional assessment and rigorous postoperative follow-up with administration of multi-vitamins supplements and assessment of serum levels is recommended for each patient who is undergoing a bariatric surgery.

The aim of this review is to identify and treat the metabolic and nutritional complications of bariatric surgery. (*Acta gastroenterol. belg.*, 2017, 80, 515-525).

**Key words** : Bariatric surgery, metabolic complications, nutritional complications, follow-up and nutritional recommendations.

### 1. Introduction

Obesity and associated comorbidities are a major health problem. The prevalence of obesity is increasing, in 2016, more than one-third of the worldwide population was overweight or obese (1,2).

All obese patients (BMI  $\geq 30\text{kg/m}^2$ ) should receive counseling on lifestyle, diet, exercises and goals for weight management. Patients with BMI  $\geq 40\text{kg/m}^2$  or those with BMI  $\geq 35\text{kg/m}^2$  with obese comorbidity who failed diet, exercises and drug therapy can be considered for bariatric surgery (3,4).

Bariatric surgical procedures are currently the most effective treatment modality to induce weight loss and reduce obesity-related complications such as type 2 diabetes, obstructive sleep apnea, hypertension, depression, nonalcoholic fatty liver disease, gastroesophageal reflux (GERD), etc. However, bariatric interventions also involve major changes in the anatomy and function of the gastrointestinal tract and these procedures are not devoid of potential long-term complications. Early post-operative complications are relatively well known while late complications, especially nutritional and metabolic, are not well documented, which is also due to a lack of long-term data (5,6).

Compliance with long-term follow-up is vital as nutritional and metabolic problems can be easily treated or avoided after bariatric surgery.

### 2. Types of bariatric surgeries

Patients with morbid obesity, with BMI  $\geq 40\text{kg/m}^2$  or BMI  $\geq 35\text{kg/m}^2$  with obesity-related complications can be treated by bariatric surgery. There are no evidence-based protocols for choosing the most appropriate type of bariatric surgery. It is determined by the patient and the surgeon's experience, taking into account the existing comorbidities and the type of eater : restrictive surgery is for "volume eaters" and malabsorptive surgery for "sweet eaters" (7,8). Bariatric procedures can be a restrictive surgery such as lap band, sleeve gastrectomy (SG), malabsorptive surgery or a combination of both of them such as roux-en-y bypass (RYGB). The three most frequent types of bariatric surgery are illustrated in Fig. 1 (9).

#### 2.1. Lap band

An adjustable silicone ring with a soft inflatable balloon is placed around the upper portion of the stomach and is connected to a port that is placed under the skin in the abdomen. The band is adjusted by injecting saline solution through the port. As a consequence, patients feel early satiety and eat smaller food portions.

The lap band is the least invasive type of bariatric surgery. The 30-day mortality is 0.05-0.4%, the overall complications are between 6-9% and major complications are about 0.2%, according to the Society of American Gastrointestinal and Endoscopic Surgeons (10).

Because the lap band is a restrictive bariatric surgery, nutrients deficiency is rare.

The most common complications are mechanical: band erosion or intolerance (7%), band slippage (2-4%), port infection or dolor, port leak (0.4-1.7%), etc. As after every bariatric surgery, indigestion, nausea and vomiting can appear (9).

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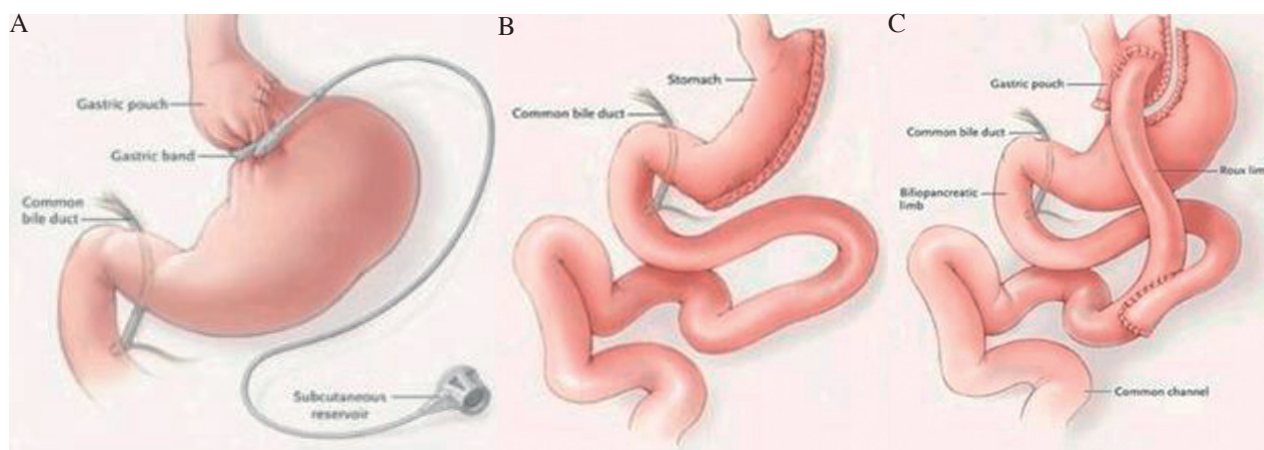


Fig. 1.

## 2.2. Sleeve gastrectomy

The aim of the sleeve gastrectomy is to restrict the size of the stomach with a vertically excision of the stomach alongside the lesser curvature. This surgery also allows to shut off the production of ghrelin through the removal of the gastric fundus (11). This surgery shapes the remaining part of the stomach into a tube or a “sleeve” like structure, resulting in a restrictive component for weight loss.

The SG is a restrictive bariatric surgery such as lap band surgery, nutrients deficiency is rare.

The most common complications are surgery complications such as fistula, bleeding but also GERD, gallbladder stones, etc (9). The mortality of SG is about 0.3% (9).

## 2.3. Roux-en-Y Bypass

This surgery consists in gastric restriction by cutting proximally the stomach and making a small pouch (20ml) which is directly connected to small intestine (Roux limb) ; the malabsorption is created by dividing the small intestine into an alimentary (most of the time 150 cm) and a biliopancreatic segment. This leads to a bypass of the duodenum and a part of the jejunum.

The length of the common channel, where digestive enzymes and bile combine with nutrients, as determined by the length of the limbs, influences the degree of altered digestion and absorption.

The length of the standard roux limb is correlated to the weight loss but also the risk of nutrients deficiency (5). This creates a restrictive and malabsorptive component for weight loss. The mortality of RYGB is less than 1% (9).

The RYGB is a malabsorptive and restrictive bariatric surgery. Due to malabsorption and altered post-surgical anatomy, functional and metabolic complications are frequent, such as dumping syndrome, hypoglycemia. Nutritional complications can also appear, such as deficiency of vitamins, proteins or micronutrients (6).

Table 1. — **Weight loss after bariatric surgery (data from (85))**

	Lap band	Sleeve gastrectomy	Roux-en-Y Bypass
After 1-2 years	20±10%	25±9%	32±8%
After 10 years	14±14%	16±11%	25±11%
After 15 years	13±14%	18±11%	27±12%

A prospective cohort compared mean weight loss for the three more frequent bariatric surgeries. Maximal weight loss at short and long terms was higher with the RYGB, compared to the SG and the lap band. (Table 1)

## 3. Complications of bariatric surgery

### 3.1. Functional and metabolic complications

#### 3.1.1. Dumping syndrome

Dumping syndrome (DS) is a series of symptoms that can develop after bariatric surgery, including dizziness, nausea, and fatigue occurring after food intake. It is attributed to the rapid emptying of gastric content into the small bowel. The etiology of DS is multifactorial. The DS develops after RYGB with a prevalence from 40 to 76% and up to 30% after a SG (12). There is an early and a late DS.

In severe situations, DS may cause protein-wasting malnutrition because of persisting symptoms and decrease in ingesta (13,14). Uncontrolled severe DS can lead to sitophobia (fear of food or eating), weight loss and under- or malnutrition (15).

#### Clinical manifestation - Symptomatology (early and late DS)

##### (i) Early dumping syndrome

Early dumping is due to bowel distention, gastrointestinal hormones hypersecretion and autonomic dysregulation; it begins within 30 minutes following a meal. This syndrome causes vasomotor and systemic

Table 2. — Dumping syndrome

Early dumping syndrome	Late dumping syndrome
30-60 minutes after meal	1-3 hours after meal
Hyperosmolar nutrients in small bowel → Fluid shift	Hyperglycemia → Insulin peak → hypoglycemia
<p><i>Symptoms</i></p> <ul style="list-style-type: none"> <li>• Gastrointestinal symptoms: Abdominal pain, diarrhea, borborygmi, bloating, nausea, vomiting, etc.</li> <li>• Vasomotor symptoms : Flushing, palpitations, perspiration, tachycardia, pallor, hypotension, syncope, etc.</li> </ul>	<p><i>Symptoms</i></p> <ul style="list-style-type: none"> <li>• Hypoglycemia symptoms : Perspiration, palpitations, hunger, weakness, confusion tremor, syncope, etc</li> </ul>

Table 3. — Sigstad’s scoring (data from (19)). Points are given for each symptom that the patient experiences postprandially. A score > 7 suggests dumping syndrome; a score < 4 suggests another diagnosis

Shock	+5
Fainting, syncope, unconsciousness	+4
Desire to lie or sit down	+4
Dyspnea	+3
Weakness	+3
Sleepiness, apathy	+3
Palpitations	+3
Restlessness	+2
Dizziness	+2
Headaches	+1
Warm, clammy skin or pallor	+1
Nausea	+1
Abdominal fullness	+1
Borborygmi	+1
Eructation	-1
Vomiting	-4

symptoms, such as palpitations, tachycardia, fatigue, a need to lie down following meals, flushing or pallor, hypotension, headache and possibly syncope. It may also lead to abdominal symptoms such as early satiety, epigastric fullness or pain, diarrhea, nausea, cramps, bloating and borborygmi, as illustrated in Table 2 (16,17).

(ii) Late dumping syndrome

Late dumping syndrome is due to a reactive hypoglycemia that occurs one to three hours postprandially. The late DS is due to an hypersecretion of gastrointestinal hormones such as glucose-dependent insulinotropic

peptide (GIP) and glucagon-like peptide-1 (GLP1) that leads to hypoglycemia and vasomotor symptoms such as perspiration, pallor, hypotension and syncope (18), as illustrated in Table 2 (15,17,25). Furthermore, improvements in lifestyle have been reported with long-term therapy (23,24). Nevertheless, not all patients will respond to somatostatin analogues in daily practice.

A promising therapy is the use of GLP1 analogs. This molecule is well documented for stabilizing glucose levels without causing hypoglycemia for patients with type 2 diabetes (26). This treatment may be a good option for patients with late DS because of the hypersecretion of GLP1 which induces postprandial hypoglycemia such as shown in the recent study of N. Abrahamsson *et al.* (18). The postprandial hypoglycemia after a RYGB has a complex pathogenesis; the counter-regulation against low blood glucose is not working very well because of a lack of inhibition to insulin secretion or a subnormal response from anti-insulinary hormones, or a combination of both. But there is an increased GLP1 peaks because of the rapid transit and appearance of nutrients in the

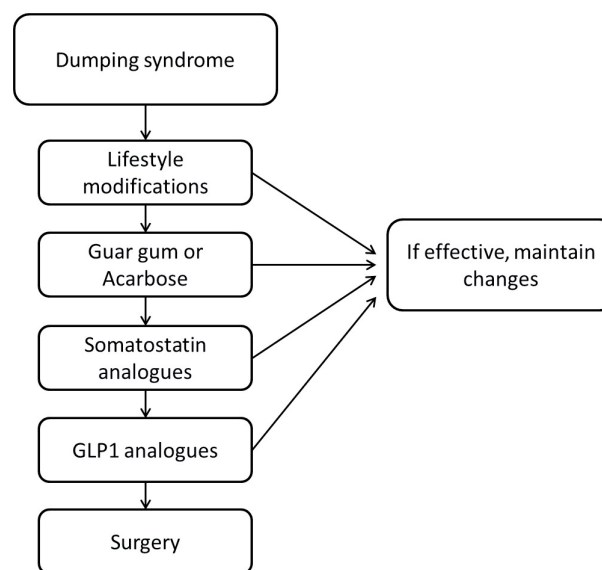


Fig. 2.

intestine. In their study the authors observed a protective effect of GLP1 analogs on the symptoms of postprandial hypoglycemia in the five patients who had a RYGB 1-4 years before. Furthermore, there is less side effects with the use of GLP1 analogs than the currently used treatment. Further research is currently in progress to establish the use of GLP1 analogues in this setting (17).

Exceptionally (<1%), in cases where DS is severe and difficult to manage, a re-surgery can be considered to reconstruct the gastric reservoir, to add a restrictive intervention, to undo the surgery if possible or to insert a short anti-peristaltic loop (23). Long-term studies to assess the effectiveness of these procedures are limited. Furthermore, no controlled trials exist to examine the efficacy of one procedure compared with the others. (Fig. 2).

### 3.1.2. Gastroesophageal reflux disease

GERD is a condition that develops when there is retrograde flow of stomach. The typical manifestations of GERD are heartburn, regurgitation and dysphagia, other symptoms include a globus (lump in the throat) sensation, odynophagia, and nausea. This most often occurs 30 minutes to 60 minutes after meals and upon reclining (27).

Obesity is one of the major risk factor for GERD (28). Weight loss alone may decrease GERD (29). The effect of bariatric surgery on GERD differs according to the type of surgery. Most of the available studies show improvement of GERD after RYGB and an increase in GERD symptoms after a SG or a lap band (30,31,32,33). The improvement of GERD after RYGB is explained by decreased lower esophageal sphincter pressure, an esophageal body contractile amplitude, and the disappearance of the acid pocket at the gastroesophageal junction (34). The increase of GERD after SG is explained by decreased gastric compliance which may increase the accumulation of gastric acid in the pouch, increase the intragastric pressure and thus involve reflux (35).

#### Management/ treatment – recommendations

When patients present typical symptoms, the diagnosis can be established with a high degree of confidence and initial diagnostic tests are not necessary. Radiographic studies are of limited use in the management of GERD due to poor sensitivity. The studies most commonly used are the barium swallow (27).

The goal of treating GERD is to resolve symptoms. Treatment options include lifestyle modifications, medical management with antacids and antisecretory agents, and mechanical therapies. Lifestyle modifications are essential in the treatment of GERD (e.g., head elevation, tobacco and alcohol cessation, avoidance of late meals, and cessation of foods that can potentially aggravate symptoms). When lifestyle modifications are not enough, the symptoms oral medication such as

Proton Pump Inhibitor (PPI) can be used and sometimes a re-surgery can be reconsidered, especially after SG (27,36).

It is very important to know the existing of GERD before of the surgery. Indeed, GERD is a contraindication for the SG.

### 3.1.3. Band slippage

Band slippage can occur after lap band and is defined as prolapse of the gastric wall proximally through the band, with dilatation of the upper gastric pouch (37). The band slippage develops after lap band with a prevalence of 10% after one year following the surgery and 2-5% after 5 years (38). There is a relation between band slippage and compliance of the patient and a regular follow-up. This complication appears to be more common in patients who discontinue follow-up assessment, many of whom return to their eating habits (39).

There are different types of slippage: anterior, posterior (two types of eccentric slippage) and concentric slippage (40). Approximately 20% of the band slippage are asymptomatic. Acute symptoms of slippage are sudden dysphagia, progressive epigastric pain and signs of peritonitis. Chronic symptoms are epigastric pain, vomiting and progressively worsening reflux (39).

Concentric slippage can be treated by deflation while eccentric slippage is treated by surgery (38).

### 3.1.4. Billiary stones

In the general population in Europe, prevalence of biliary stones is 19% for women and 9% for men, whereas only 1-5% of these patients require cholecystectomy (CHE) due to symptomatic disease. There is a significantly higher incidence (28% to 71%) of biliary stone formation and/or sludge in bariatric surgery patients (41). CHE due to symptomatic gallstones is performed in approximately 7% of patients after bariatric procedures (41).

All bariatric procedures have been associated with formation of gallstones, less frequent with restrictive (lap band and SG) than with malabsorptive procedures (RYGB), respectively 6-7% and 38-52% (42).

The risk factors for gallstones formation are female gender, age above 40 years, obesity and rapid weight loss. Female gender and rapid weight loss are the major risk factors for CHE in patients having undergone bariatric surgery (41,42).

#### Management/ treatment – recommendations

Ultrasound measurements for detecting gallstone formation are recommended within 2 to 5 years during the period of pronounced and rapid weight loss, for every patient and regardless of the bariatric procedure (41).

Several studies recommend preventive measures for patients undergoing RYGB including a systematic

cholecystectomy or, more frequently, a preventive treatment with ursodeoxycholic acid (43).

### 3.1.5. Diabetes mellitus – lipids

A Swedish study in 2004 showed that metabolic surgery can induce type 2 diabetes remission for up to 72% of subjects after 2 years ; however, this number was reduced to 36% after 10 years (44). In a more recent study, patients who underwent bariatric surgery and specifically gastric bypass sustained diabetes remission rates of 62% after 6 years (45,46).

The overall long-term effect of bariatric surgery on type 2 diabetes remission rates is currently not well documented and the mechanism of this remission has not been completely elucidated but appears to include an incretin effect in addition to caloric restriction and weight loss (3).

#### Management/ treatment – recommendations

During the early postoperative period, frequent monitoring of blood glucose is necessary and the use of insulin secretagogues should be discontinued and insulin doses should be adjusted to minimize the risk of hypoglycemia. The use of antidiabetic medications that improve insulin sensitivity such as Metformine may be continued postoperatively until prolonged clinical resolution of diabetes is demonstrated by normalized glycemic targets (47).

Postoperative glycemic control should consist in reducing glycated hemoglobin (HbA1c) to 8.6mmol/l (7%) or less (48), (49,50).

Lipid levels and need for lipid-lowering medications should be evaluated after bariatric surgery. The effect of weight loss on dyslipidemia is variable and incomplete; therefore, lipid-lowering medications should not be stopped unless clearly indicated (51).

### 3.1.6. Osteopenia – osteoporosis

There are contradictory data regarding the risk of bone mineral density impairment after bariatric surgery (52). Some studies indicated that the risk of osteopenia or osteoporosis after one year is similar after RYGB and SG, respectively 24% vs 18% for osteopenia and 3% for both surgery for osteoporosis (53).

The data and limitations of dual energy x-ray absorptiometry (DXA) are not conclusive regarding the association between bariatric surgery and an increased incidence of osteoporosis, as well as fracture risk. Patients who underwent bariatric surgery are more likely to have fracture than obese or non-obese patients but this risk was already presents before the surgery (54). Bone mineral density (BMD) determinations remain an option for preoperative screening and postoperative surveillance (55).

The evaluation of patients includes serum parathyroid hormone, total calcium, phosphorous, 25-OH-vitamin

D and 24 hours urine calcium levels. Patients with osteoporosis should receive bisphosphonate after appropriate therapy with calcium and vitamin D (47,56).

For the prevention of osteoporosis, a systematic supplementation in calcium (2g) and vitamin D (1000-2000UI) is required for all patients after bariatric surgery.

### 3.2. Nutritional complications

According to the European Society for Clinical Nutrition and Metabolism (ESPEN), malnutrition, a synonym of undernutrition, is defined as “a state resulting from lack of intake or uptake of nutrition that leads to altered body composition (decreased fat free mass) and body cell mass leading to diminished physical and mental function and impaired clinical outcome from disease”. Malnutrition increases morbidity and can eventually lead to death (57).

Bariatric surgical procedures have been associated with nutritional deficiencies and their prevalence and nature depend on the type of surgery. Malabsorptive procedures are at higher risk than restrictive procedures (58). The RYGB decreases fat and protein absorption but not carbohydrate.

Proteins malnutrition is mainly caused by increased catabolism (characterized by inflammatory response, including anorexia and tissue breakdown) produced by surgery or by sepsis or organ failure (59). Severe malnutrition may thus occur as a result of surgical complications (wound infection, fistulae, mesenteric ischemia, thrombosis, mechanical stenosis,...) (59), requiring prolonged hospitalization with nutrition support including parenteral or enteral nutrition (60). Furthermore, after all types of digestive surgery, there is a risk of deficiency because of the reduction of overall nutrient intake in the post-operative phase and thus poor intake of specific micro-nutrients (61).

The presence of nutritional deficiencies before the surgery must be evaluated. The causes of this deficiencies are multifactorial for obese patients: limited bioavailability of some nutrients (vitamins B, vitamin D, etc.), high intake of calorically food with low nutritional quality (62) and chronic inflammation status in obese patients. These causes can affect iron metabolism and small intestinal bacterial overgrowth, which can lead to deficiencies in some vitamins (vitamins B1, B12, and fat-soluble vitamins ADEK). The most common preoperative deficiencies are vitamins B1, B9, B12, D and iron (63,64). It is important to identify the preoperative deficiencies and correct it, because the preoperative status is related to postoperative nutritional deficiencies and is also associated with metabolic complications (65).

#### 3.2.1. Vitamins

Vitamins A, D, E and K are liposolubles vitamins; deficiencies are thus more frequent after RYGB due to the malabsorption after this surgery.

### Vitamin A

Vitamin A deficiency has been reported for up to 11% of the patients after RYGB (58). Clinical manifestations of vitamin A deficiency are dry eyes and reduced night vision. In case of deficiency, dose of 10000-25000 IU intramuscularly of vitamin A is administered up to 3 weeks.

Currently, the American Society of Metabolic and Bariatric Surgery (ASMBS) guidelines do not recommend an additional prophylactic vitamin A post-bariatric surgery (66). Most of multivitamins complements contain approximately 3500 IU of vitamin A, which accounts for about 70 % of the recommended daily intake (67).

### Vitamin D

Vitamin D deficiency before the surgery is identified for approximately 84% (68) and 25-75% of the patients after bariatric surgery (58,69). Patients who had a malabsorptive surgery have a higher risk of vitamin D deficiency after the surgery comparatively to a restrictive surgery. Vitamin D is essential for the bone metabolism: in case of deficiency, the risk of osteopenia and osteoporosis increases. Vitamin D is also important for the immunity, especially to fight viral infection. In case of malabsorptive bariatric surgery, a daily supplement of 800-2000 IU of cholecalciferol (vitamin D<sub>3</sub>) is recommended to decrease bone loss during rapid weight reduction (67). According to ASMBS guidelines, in case of deficiency, patients need administration of 50000 IU of vitamin D weekly during 8 weeks (70).

### Vitamin E

1 to 4 years after RYGB, 4-10% of the subjects have low serum vitamin E but, most of the time, without clinical manifestations. However, this deficiency can lead to cardiovascular, neurological manifestations or reproductive disorder. An additional supplement of 10mg daily may be recommended (63).

### Vitamin K

4 years after RYGB, 50% of subjects have low plasma levels of vitamin K but no clinical manifestation. An additional supplement of 25µg daily may be recommended (63).

### Vitamin B1 (Thiamine)

The prevalence of preoperative thiamine deficiency has been reported for 0% to 29% of the cases and is generally asymptomatic (58).

Thiamin deficiency has been reported for up to 30% of patients after bariatric surgery and appears more frequently within six months after the procedure, especially for patients with prolonged vomiting regardless of the type of surgery (restrictive or malabsorptive) (67), (58). There is no recommendation for a follow-up of

serum thiamine levels after bariatric surgery because dosage in laboratories is difficult. However, it could be considered for patients with rapid weight loss, vomiting, and excessive alcohol use. Acute deficiency in thiamine can lead to Gayet-Wernicke's encephalopathy which involves ocular paralysis, confusion and cerebellar ataxia. In case of chronic deficiency of vitamin B1, Korsakoff syndrome with confabulation may appear. Most of the time, the treatment starts when there is neurological signs, without laboratory confirmation; it is recommended to administered 100-500 mg daily intravenously of thiamine, during 7-14 days (47,71).

The ASMBS guidelines after bariatric surgery recommend taking a daily multivitamin that contains 3mg of thiamine. (66)

### Vitamin B9 (Folate)

Folate deficiency affects about 9-38 % of patients and especially women who become pregnant after the surgery (72). Deficiency of vitamin B9 can lead to megaloblastic anemia (58).

In case of deficiency, dose of 5 mg of folate daily are used, the prophylactic management of folate daily is important and especially for women of childbearing age (67).

### Vitamin B12 (Cobalamine)

Cobalamine deficiency has been reported for 0-18% of the patient before surgery (58). Post-operative prevalence of vitamin B12 deficiency is about 4-62%, especially after malabsorptive surgery (58). After RYGB, the stomach is bypassed and vitamin B12 cannot be cleaved to intrinsic factor and thus cannot be absorbed in the ileum. The risk of vitamin B12 deficiency is high, even after the first five postoperative years (50), (73).

Deficiency of cobalamine can lead to megaloblastic anemia, myelopathy and neuropathy. In case of vitamin B12 deficiency, a weekly administration of Cobalamin 10 mg intramuscular is recommended for 8 weeks followed by 1-2 mg PO for the maintenance therapy (74).

For the prophylaxis, a daily intake of 350-500 µg is recommended (47,71,75). Vitamin B12 can be administered either orally or sublingually. A study by Sharabi *et al.* showed that oral administration of 500 µg daily was equally effective to the sublingual route (67,74). Vitamin B12 may also be administered intramuscularly as 1000µg monthly or 3000µg every six months (63).

### 3.2.2. Proteins

Most of the patients after bariatric surgery have protein malnutrition which is defined by hypoalbuminemia (i.e., albumin below 3.5mg/dl). Some studies have reported protein malnutrition for 13% of the patients 2 years after distal RYGB with Roux-limb at least 150cm, and for less than 5% of the patients with a Roux-limb less

than 150cm (76). Most of the time, protein deficiency occurs 3-6 months after surgery and it is attributed to the development of food intolerance to protein-rich foods (dairy products, eggs, fish, lean meat, soy products and legumes). It is the most severe macronutrient complication associated with malabsorptive surgical procedures (77). Protein malnutrition often causes annual hospitalization (1% per year) after malabsorptive procedures. It can also lead to morbidity such as cachexia, which is characterized by weight loss, reduced BMI, and reduce muscle mass with an underlying disease and an elevated inflammation activity (57,59). Protein-enriched food is advised in order to meet the recommended target, 60-120g of proteins/day or 1,1-1,5g/kg of ideal body weight (7,50,59).

### 3.2.3. Micronutrients

Micronutrients deficiencies after bariatric surgery are common and arise from two main factors: poor compliance of the patient for the treatment and malabsorption induced by a modification in the gastrointestinal tract (12). The deficiencies are also affected by other factors, such as the preoperative deficiencies, the presence of vomiting, regurgitation, food intolerance or poor eating patterns (62,78,79).

#### Iron

Iron deficiency has been reported for 5-44% patients before the surgery. After bariatric surgery, iron deficiency can reach 47% and occur two months or more after the bariatric surgery (69). Incidence may be higher for menstruating women and for those who become pregnant after the procedure (58). Iron deficiency can lead to fatigue, impaired work productivity, microcytic anemia and it is more common for women with menorrhagia. For this reason, prophylactic iron supplementation is required (67). After every bariatric surgery (restrictive and malabsorptive), 18-27 mg daily of elementary iron is recommended (ASMBS and American Association of Clinical Endocrinologists recommend 65 mg twice a day) (47,71). In case of deficiency and anemia, 300 mg elemental iron daily is recommended. In case of severe intolerance to oral therapy, parenteral therapy can be carried out. Vitamin C increases iron absorption and should be empirically included with iron supplementation.

#### Zinc

Zinc deficiency may develop in very early stages post-surgery because functional reserves or body storage of zinc is lacking. The absorption of zinc is significantly decreased starting 6 months post-surgery and persists at least until 18 months after the operation (67). Most of the patient with a deficiency report a hair loss, impaired sense of taste and sexual dysfunction (47). Zinc is important for the growth, tissue repair, wound healing

and immune response (76).

The recommended treatment dose of zinc deficiency is 60 mg of elemental zinc taken orally twice a day until the deficiency resolves (58). Further research is still needed to identify the optimal prophylactic zinc supplementation dose and regimen.

#### Copper

Copper deficiency has been reported for up to 18% of the patients after bariatric surgery (58). Routine copper screening is not recommended for the post bariatric surgery follow-up, but should be evaluated by patients with symptomatology. Deficiency can lead to hematological (anemia, leucopenia) and neurological signs (neuropathy, myelopathy or ataxia); it can be treated by 6mg of elemental copper daily during one week followed by a week of 4 mg daily and then 2 mg daily as a maintenance dose (67,69).

Currently, recommendations regarding prophylactic dose of copper after bariatric surgery are missing.

#### Selenium

Selenium is an antioxidant, such as vitamin E. Selenium deficiency was found for 14.5% of the patients after bariatric surgery without any clinical sequelae (76). Selenium deficiency can lead to haematological manifestation (anemia, leucopenia) and neurological signs (neuropathy, myelopathy or ataxia).

There are insufficient data to support routine screening for selenium deficiency or for prophylactic selenium supplementation (47,71).

### 3.2.4. New recommendations

Active nutritional patient education and clinical management to prevent and detect nutritional deficiencies are recommended for all patients undergoing bariatric surgery (80).

A multidisciplinary team including primary care physician, endocrinologist or gastroenterologist, dietitian is required to follow all patients before and after the surgery (3,50,81).

Management involves preoperative assessment of nutritional state, rigorous life-long clinical and biochemical follow-up after intervention and supplements. It is recommended that patients who have undergone obesity surgical procedure to have follow-up controls of blood cell count, albumin, iron, ferritin, folic acid, vitamin B12, prothrombin time, magnesium, zinc, phosphorus, calcium, vitamin D, parathyroid hormone, and alkaline phosphatase levels. The micronutrient status should be evaluated every 3 months the first year, biannually the second and annually afterward. A life-long monitoring is advised in case of RYGB and SG (3). The recommended follow-up is illustrated in Table 4.

Most of the studies recommend blood and urinary calcium monitoring, plasma vitamin D status and BMD

Table 4. — Follow-up bariatric surgery. Markers “A”, “S” and “E” denote recommendations by the American Society for Metabolic and Bariatric Surgery (ASMBS), the Swiss Society for the Study of Morbid Obesity and Metabolic Disorder (SMOB) and the European Guidelines on Metabolic and Bariatric Surgery, respectively. Labels “(b)” and “(o)” indicate post bypass and optional recommendations, if these are provided.

	Pre-op	1 month	3 months	6 months	12 months	18 months	24 months	Annually (up to 5 years)
Radiology– DEXA	S						S(b)	
	E				E		E	E
Hemogram – Blood cell count	S	S	S	S	S	S	S	S (1x/6mo.)
	E	E	E	E	E	E	E	E
Hemoleukocyte formula	S	S	S	S	S	S	S	S (1x/6mo.)
	E		E	E	E	E	E	E
K <sup>+</sup> Ca <sup>2+</sup> Mg <sup>2+</sup> P	SEA	S(o) A	S(o)EA	S(o)EA	S(o)EA	EA	S(o)EA	S(o)EA
	S(o)EA	S(o)	S(o)E	S(o)EA(b)	S(o)EA(b)	EA(b)	S(o)EA(b)	S(o)EA(b)
Iron – Ferritine – Transferrine	S				S(b)		S(b)	S(b)
	E		E	E	E		E	E
Vitamins	A			A(b)	A(b)	A(b)	A(b)	A(b)
B1	SE	S	A(o)	SEA(o)	A(o)	A(o)	EA(o)	EA(o)
B9	SEA			SEA(b)	SA(b)	SA(b)	SEA(b)	SEA(b)
B12	SEA			SEA(b)	SA(b)	SA(b)	SEA(b)	SEA(b)
Albumin – Prealbumin	E		S(o)	S(o)(b)	S(o)(b)		S(o)(b)	S(o)(b)
	A		E	E	E		E	E
Blood glucose	S	S(o)	S	S	S		S	S
	A	A	A	A	A	A	A	A
Vitamin D PTH	SEA		S	SA(b)	SEA(b)	A(b)	SEA(b)	SEA(b)
	SEA			SA(b)	SEA(b)	A(b)	SEA(b)	SEA(b)
Vitamin A	S		S(o)(b)	S(o)(b)	S(o)(b)		S(o)(b)	S(o)(b)
	A						A(o)	A(o)
Zinc	S		S		S(b)		S(b)	S(b)
	A			A(o)	A(o)		A(o)	A(o)

by DXA before surgery and during the follow-up. However, some studies recommend DXA two years after the surgery and nothing after, whereas some others recommend one DXA every year until the fifth year after surgery (82,83). For the ASMBS the BMD determination is optional for preoperative and postoperative surveillance.

At this time, a more specific study is needed to better determine the long term consequences of bariatric surgery on bone health and bone mineral density (84).

#### Nutritive supplementation

The nutritive supplementation is essential after bariatric surgery. The Swiss society for the Study of Morbid Obesity and Metabolic Disorders (SMOB)

systematically recommends vitamins and trace elements supplementation after all types of bariatric surgery for the first 24 months. They also recommended a life-long monitoring supplementation in minerals and micronutrients after RYGB (52). This multi-vitamin supplements have to be taken every day and should contain at least double the daily recommended dose in Iron, Zinc, Selenium, Folic Acid, Vitamin A, Vitamin E and Vitamin B9 (47,67,71). For the prevention of osteoporosis, a systematic supplementation in calcium (2g) and vitamin D (1000-2000 IU) is required for all patients after bariatric surgery. Regarding proteins, adults need is related to the body weight, and the reference intakes represent the acceptable protein range as 10-35% of total energy. After bariatric surgery, restrictive or malabsorptive, it is recommended to eat protein-enriched



Table 5. — Nutrient recommendations post bariatric surgery.

	Sleeve gastrectomy/ Lap band	Roux-en-Y Bypass
<b>Multivitamins complements</b>		
<b>(Iron, Zinc, Selenium, Vitamins B9, A, E)</b>	Until stable weight	Lifetime
<b>Calcium</b>	No recommendation	1,2-1,5g/day
<b>Vitamin D</b>	No recommendation	800-2000 UI/day
<b>Vitamin B12</b>	No recommendation	350-500µg/ day PO 1000µg/month IM
<b>Iron</b>	18-27 mg/day of elemental iron	18-27 mg/day of elemental iron
<b>Proteins</b>	≥60g/day or ≥1g/kg of the ideal weight	≥60g/day or ≥1g/kg of the ideal weight

Table 6. — Complications of bariatric surgery (restrictive/malabsorptive).

	Sleeve gastrectomy/ Lap band	Roux-en-Y Bypass
<b>Dumping Syndrome</b>	Up to 30%	From 40 to 76%
<b>Gastro-esophageal reflux</b>	Increase symptoms	Decrease symptoms
<b>Diabetes mellitus</b>		62% remission after 6 years
<b>Osteopenia – osteoporosis</b>	Osteopenia: 18%	Osteopenia: 24%
	Osteoporosis: 3%	Osteoporosis: 3%
<b>Nutrients deficiencies</b>		
<b>Vitamins ADEK</b>	+/-	++
<b>Vitamin B1</b>	+ (Especially when vomiting)	+ (Especially when vomiting)
<b>Vitamin B9</b>	++ (Especially in pregnant women)	++ (Especially in pregnant women)
<b>Vitamin B12</b>	+/-	++
<b>Proteins</b>	+/-	+
<b>Iron</b>	+ (Especially in pregnant women)	+ (Especially in pregnant women)
<b>Zinc</b>	++	++
<b>Copper</b>	+	+
<b>Selenium</b>	+	+

food to meet the target, at least 60-120g proteins/day or 1,1-1,5g/kg of ideal body weight (7,50,59 (Table 5).

At this time, studies with long term follow-up are still lacking but the nutritional assessment after bariatric surgery should certainly be life-long in malabsorptive procedures.

#### 4. Conclusion

Bariatric surgery provides weight loss but can also have a number of consequences. The two types of complications are metabolic and nutritional. Metabolic complications such as DS appear especially after RYGB (12), and GERD after SG or lap band (32) Osteopenia or osteoporosis may appear after both surgery, restrictive

or malabsorptive (53). Nutritional complications appear most of the time after malabsorptive surgery, such as RYGB (58). (Table 6)

Preoperative nutritional deficiencies must be detected and treated before the bariatric surgery (65).

Clinicians have to be aware of the symptoms of metabolic or nutritional complications and have good management options. Nutritional deficiencies are common after bariatric surgery and may lead to severe consequences ; therefore they require an appropriate diagnostic and treatment. The prevention strategy for every patient should include a multivitamins supplement and a regular assessment of serum levels.

Each member of the healthcare team should be actively involved in the bariatric patient's care, including

a counseling on the importance of proper nutrition and compliance with supplementation.

### 5. Conflicts of interest

The authors have no conflict of interest.

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