Medical follow up after bariatric surgery: nutritional and drug issues
General recommendations for the prevention and treatment of nutritional deficiencies

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Abstract
This review is an update of the long-term follow-up of nutritional and metabolic issues following bariatric surgery, and also discusses the most recent guidelines for the three most common procedures: adjustable gastric bands (AGB); sleeve gastrectomy (SG); and roux-en-Y gastric bypass (GBP). The risk of nutritional deficiencies depends on the percentage of weight loss and the type of surgical procedure performed. Purely restrictive procedures (AGB, SG), for example, can induce digestive symptoms, food intolerance or maladaptive eating behaviours due to pre- or postsurgical eating disorders. GBP also has a minor malabsorptive component. Iron deficiency is common with the three types of bariatric surgery, especially in menstruating women, and GBP is also associated with an increased risk of calcium, vitamin D and vitamin B12 deficiencies. Rare deficiencies can lead to serious complications such as encephalopathy or protein-energy malnutrition. Long-term problems such as changes in bone metabolism or neurological complications need to be carefully monitored. In addition, routine nutritional screening, recommendations for appropriate supplements and monitoring compliance are imperative, whatever the bariatric procedure. Key points are: (1) virtually routine mineral and multivitamin supplementation; (2) prevention of gallstone formation with the use of ursodeoxycholic acid during the first 6 months; and (3) regular, life-long, follow-up of all patients. Pre- and postoperative therapeutic patient education (TPE) programmes, involving a new multidisciplinary approach based on patient-centred education, may be useful for increasing patients’ long-term compliance, which is often poor. The role of the general practitioner has also to be emphasized: clinical visits and follow-ups should be monitored and coordinated with the bariatric team, including the surgeon, the obesity specialist, the dietitian and mental health professionals.

Keywords: Bariatric surgery; Guidelines; Gastric bypass; Adjustable gastric band; Vertical banded gastroplasty; Sleeve gastrectomy; Nutritional deficiency; Supplementation; Therapeutic patient education; Review

Résumé
Prise en charge médicale après chirurgie bariatrique: prescriptions diététiques, médicamenteuses et suivis. Mesures générales indispensables
Dans cette revue sont présentés les principaux problèmes nutritionnels et métaboliques que pose le suivi à long terme des patients ayant bénéficié d’une chirurgie bariatrique et discutées les recommandations récemment publiées concernant l’anneau gastrique ajustable (AGA), la gastrectomie longitudinale (GL) et le court circuit gastrique (CCG). Le risque de carence nutritionnelle dépend de l’importance de la perte de poids et du type de chirurgie; les techniques purement restrictives (AGA, GL), peuvent induire des troubles digestifs, une intolérance pour certains aliments et des comportements alimentaires mal adaptés en rapport avec des troubles du comportement alimentaire pré ou post opératoires. Le CCG entraîne de plus une malabsorption intestinale modérée. La carence en fer est fréquente dans les 3 cas et concernent particulièrement les femmes non ménopausées. Le CCG augmente le risque de carences en fer, calcium-vitamine D et vitamine B12. Certaines carences rares conduisent à des complications sérieuses comme l’encéphalopathie ou la malnutrition protéino-énergétique.

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Le risque à long terme de maladies osseuses ou de complications neurologiques doit être connu et prévenu. Quelle que soit la technique chirurgicale, la surveillance nutritionnelle, la prescription de suppléments appropriés et la surveillance de l’adhésion des patients à ces mesures s’imposent. Les trois points clefs sont (1) la prise quasi systématique de minéraux et de multivitamines; (2) la prévention de la lithiase biliaire par l’acide ursodésoxycholique pendant les 6 premiers mois; (3) le suivi à vie des patients. L’éducation thérapeutique du patient (ETP) est une nouvelle approche, par nature multidisciplinaire, centrée sur la personne. Des programmes d’ETP doivent être mis en place avant et après la chirurgie pour améliorer l’adhésion et la compliance à long terme des patients, qui est souvent médiocre. Le rôle du médecin traitant est à valoriser car c’est lui qui peut coordonner et contrôler le suivi, en collaboration avec l’équipe médicochirurgicale qui comporte le chirurgien, le spécialiste de l’obésité, la diététicienne, le psychologue et le psychiatre.

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Mots clés : Chirurgie bariatrique ; recommandations ; courcircuit gastrique ; anneau gastrique ajustable ; gastroplastie verticale calibre ; gastrectomie en gouttière ; carence nutritionnelle ; supplémentation ; éducation thérapeutique du patient ; revue

1. Introduction

Current bariatric surgery includes solely restrictive gastric procedures—adjustable gastric bands (AGB), vertical banded gastroplasty (VBG) and sleeve gastrectomy (SG)—and a combined procedure, the roux-en-Y gastric bypass (GBP) [1]. GBP, characterized by a restrictive component and a minor malabsorptive state, is believed to affect the hormones [such as ghrelin, glucagon-like peptide-1 (GLP-1) and peptide YY (PYY)] that control eating behaviours and body weight [2]. Indeed, changes in gut peptide concentrations can cause a profound loss of appetite. SG also affects ghrelin secretion.

This is a review of the standard of practice for long-term nutritional management, mainly in relation to the most common bariatric procedures (AGB, GBP and SG). VBG is no longer performed in France, and biliopancreatic diversion (BPD), with or without duodenal switch (DS), is a complex procedure that is reserved for only very specific situations. The perioperative management of the obese patient and of any surgical complications are beyond the scope of this review.

Assessment of the metabolic and nutritional consequences of bariatric surgery is best guided by the type of surgical procedure involved. Both AGB and VBG have minor effects on normal physiological digestive processes and, as a result, selective nutritional deficiencies are presumed to be usual. However, caloric or nutritional restriction, maladaptive eating behaviours and digestive symptoms can lead to nutritional deficiencies. This is particularly true when weight loss is rapid and significant. On the other hand, it is well established that the anatomical changes imposed by malabsorptive surgical procedures can also increase the risk of nutrient deficiencies.

The major issues summarized here are based on the recently published French, European and US guidelines [3–6] [all recommendations (R) are shown in italics], along with the few published expert recommendations [7–14] and our own accumulated experience. However, consensus is still lacking on many critical issues, probably because the long-term nutritional outcome data are scanty. Also, there are no evidence-based guidelines for an optimal postoperative supplementation strategy.

2. Preliminary comments on perioperative nutritional management

2.1. Preoperative management

Many patients have preoperative eating disorders or nutritional deficiencies that may persist after undergoing a bariatric procedure. There is now evidence to support the need for routine assessments of the patient’s protein and micronutrient status prior to bariatric surgery [15,16]. An appropriate nutritional evaluation, including selective micronutrient measurements, is absolutely necessary for all patients before any bariatric surgical procedure [5].

2.2. Early postoperative nutritional management (< 5 days)

In general, the following guidelines are used [3–6]: (1) clear liquids usually in the morning after any bariatric surgical procedure (R46) [5]; (2) gradual progression in food consistency over the subsequent weeks and months, depending on the type of surgical procedure (R48) [5]; and (3) nutritional and meal-planning guidance provided to the patient during the postoperative hospital course (R49) [5]. In addition, consultation with the dietician who was also a member of the bariatric surgery team is absolutely necessary (R47) [5].

3. Late postoperative nutritional management (≥ 5 days)

Follow-up of the morbidly obese patient who has been surgically treated can be divided into three periods: (1) the weight-loss phase (0–18 months, with the vast majority of weight loss accomplished by around 1 year); (2) the weight-regain phase [2–6 years after surgery, according to the Swedish Obese Subjects (SOS) study [17], in which about one-third of the initial weight loss was regained within 5 years]; and (3) the weight-stability phase (6–15 years, according to the SOS study).
3.1. Postsurgical eating behaviours and weight loss

Bariatric surgery requires a considerable change in eating behaviours [3,5,18]. Gastric restriction leads to a drastic reduction in the quantity of food eaten at each meal because of the limited volume capacity of the surgically created gastric pouch (30–60 ml for GBP) [5]. This physical restriction is the major mechanism of the weight loss.

As recommended by all experts, surgically treated patients need to adhere to a plan of multiple small meals per day; they must chew their food well and drink no beverages at the same time (> 30 min apart), and they need to stop eating as soon as they feel full (R50) [3-5]. Patients should also adhere to recommendations for a healthful lifestyle, including increased consumption of fruit and vegetables, while limiting foods that are high in saturated fats and simple carbohydrates (R51) [5].

Changes in body mass index (BMI), weight loss as percent of excess body weight (EBW) and weight loss as percent of initial weight are the most common parameters for assessing weight changes after bariatric surgery [3–5]. Success can be defined as the loss of at least 50% of EBW, with a minimal follow-up duration of 3–5 years [5,19].

Either dramatic or inadequate weight loss has to be monitored. The most rapid weight loss occurs during the first 3 months postoperatively, when dietary intake is highly restricted [3, 5], and the peak weight loss is achieved at 12–18 months following the procedure. After AGB, changes in weight are less rapid and a weight loss of 1.13 kg/week is advisable [5].

Inadequate weight loss after bariatric surgery (phase 1) may be observed after any procedure, but is especially commonly seen after AGB and VBG. This may be due to a poorly adjusted laparoscopic adjustable gastric band (LAGB) or loss of integrity of the gastric pouch (AGB, GBP, SG) [5]. More frequently, it is the result of the development of maladaptive eating behaviours: increased calorie intake; increased consumption of calorie-dense foods (sweets and ice cream); and grazing (continual eating of small amounts of food throughout the day), often associated with psychological disorders [3,5,7,8]. Clinical assessment then involves: (1) evaluation of current eating behaviour; (2) psychological evaluation; and (3) if indicated, imaging studies of the upper gastrointestinal tract (R79) [5].

Long-term weight maintenance (phases 2 and 3) is better with GBP than that reported with purely restrictive gastric procedures although, as already mentioned, weight regain is also observed 2–5 years after GBP [5,17]. For many patients, calorie intakes increase gradually over time. In the SOS study [20], self-reported intakes decreased within the first 6 months after surgery from about 2900 kcal/d to 1500 kcal/d, but then increased to around 2000 kcal/d over the next 6 years. Other factors may also be involved, such as a decrease in the frequency of ‘dumping’ (rapid gastric emptying) symptoms, resolution of food intolerances and a return to preoperative disordered eating [5].

3.2. Gastrointestinal symptoms

During the first few months of bariatric surgery, episodes of regurgitation—typically without nausea or true vomiting—are common when food is consumed in large volumes, or too quickly or without being thoroughly chewed [5].

3.2.1. Chronic vomiting

One- to two-thirds of patients report postoperative vomiting [3,5,8], especially during the first 6 months of surgery. Vomiting occurs in response to feelings of fullness, or to food lodged in the gastric pouch or upper digestive tract (‘plugging’). Frequent vomiting that persists for more than 6 months suggests: (1) obstruction, requiring evaluation with a gastrointestinal contrast study or endoscopic procedure; or (2) reflux, inflammation, stomal ulceration or stenosis, necessitating endoscopy [5]. Regurgitation or vomiting that occurs after an LAGB procedure can be managed with appropriate band adjustments and nutritional advice [3–5].

3.2.2. Diarrhoea

Diarrhoea is uncommon after bariatric surgery but, if it persists, an evaluation should be initiated (R132) [5].

3.3. General symptoms

Cold intolerance, hair loss and fatigue are common complaints, but tend to diminish as weight loss stabilizes [3,5].

3.4. Gastric bypass-specific problems

3.4.1. Dumping syndrome

Dumping syndrome—beginning 30–60 min after eating—is common, occurring in about 70% of patients who have undergone GBP [5], but often only transiently during the first postoperative year.

Calorie-dense liquids or foods (foods high in sugar, including ice cream and pastries) that bypass much of the stomach undigested will cause hyperosmolarity of the intestinal contents. Such an osmotic overload draws fluid into the intestinal lumen, with subsequent intestinal distention, fluid sequestration, decreased intravascular volume and hypotension. As has been recently suggested, the release of gut peptides may also be involved [5].

Symptoms (abdominal pain and cramping, nausea, light-headedness, flushing, tachycardia, sweating and even syncope) lead to extremely uncomfortable feelings and immense fatigue [3,5]. Diarrhoea is infrequent, as there is usually sufficient distal bowel to absorb food [8].
For many patients, these adverse events encourage them to make more appropriate food choices. For others, however, dumping symptoms are persistent and aversive. In such cases, nutritional manipulations are useful, including: (1) avoiding simple sugars, and increasing intakes of dietary fibre and complex carbohydrates; (2) avoiding ingestion of liquids within 30 min of a solid-food meal; and (3) eating small, frequent meals [5].

3.4.2. Endogenous hyperinsulinaemic hypoglycaemia

Postprandial hypoglycaemia appears to be frequent after GBP. Previously, it was thought to be the result of ‘late dumping symptoms’. In fact, such reactive or poststimulative hypoglycaemia is the consequence of a state of endogenous hyperinsulinism, which is probably secondary to previous severe insulin resistance associated with central or morbid obesity. It might be considered an exaggerated reaction to incretin and insulin secretion in response to a mixed meal [21].

In some cases, hypoglycaemic episodes are severe, leading to neuroglycopenic symptoms—first described by Service et al. [22]—months or years after surgery. This complication, when refractory to nutritional and medical management, has necessitated partial pancreatectomy for relief of the symptoms and hypoglycaemia [22]. In such cases, pathological examination has, on occasions, shown pancreatic islet-cell hyperplasia (nesidioblastosis) [22]. However, nutritional manipulations are often helpful [23], and certain drugs (acarbose, verapamil) may be useful alternatives [24]. The extremely rare possibility of insulinoma should be also considered, although that is usually characterized by fasting hypoglycaemia.

4. Other key points for medical follow-up

4.1. Physical activity

The importance of regular physical activity for weight maintenance in conventional weight-loss treatment is well known [25]. Exercise limits the proportion of lean tissue lost in low-calorie regimens, limits the weight regained and has a favourable effect on health status (cardiovascular disease, diabetes, hypertension, cancer). The US National Weight Control Registry (of individuals successful at long-term weight maintenance) shows that those who lost weight by surgical means reported considerably lower levels of physical activity than those who lost weight by non-surgical means [26].

As underlined by Karlsson et al. [17], it appears to be necessary to propose treatment strategies that encourage and facilitate the adoption and maintenance of regular physical activity among bariatric surgery patients to improve their body composition. Patients should be advised to increase their physical activity (aerobic and strength training) to a minimum of 30 min/d, as well as to increase their general physical activity throughout the day as much as is tolerated (R86) [5].

In some departments, it is possible to measure body composition using dual-energy X-ray absorptiometry (DEXA), which may also be useful for characterizing the risk factors for changes in fat-free mass.

4.2. Psychological and quality-of-life outcomes

Health-related quality-of-life (HRQL) measures, including psychosocial functioning, perceived health, mood, anxiety, mobility, self-image and other obesity-specific problems, are improved in the majority of patients following anti-obesity surgery [3–5,31]. However, changes in HRQL after surgical treatment followed phases of weight loss, weight regain and weight stability, as demonstrated by the SOS study [17]. Indeed, the long-term effects of bariatric surgery on HRQL are attenuated by significant weight regain in large numbers of patients [17]. For this reason, it is recommended to assess HRQL in clinical practice [3].

4.3. Drug management

4.3.1. Prevention of gallstone formation

An increased risk of gallstone formation has been associated with obesity and with episodes of significant weight loss, and is a major problem with bariatric surgery. Gallstones and sludge formation have been reported in 30% of patients 6 months after GBP, but also with the other procedures (AGB, SG, BPD) [5,27–29]. Rapid weight loss (about 25% of initial weight) is the most important risk factor for the development of gallstones [5,29].

The effect of ursodeoxycholic acid therapy on gallstone formation has been clearly demonstrated in surgically treated patients [5,30]. Oral administration of ursodeoxycholic acid (Ursolvan® 200 mg three times a day, or Delursan® 250 mg twice a day) for at least 6 months postoperatively may be considered in patients not undergoing a prophylactic cholecystectomy (R145) [3,5].

4.3.2. Concomitant drug treatment

There is clear consensus in the management of preexisting medical conditions to make adjustments to concomitant drug treatment [3–5,31].

- In those patients without complete resolution of their T2DM, hyperlipidaemia or hypertension, continued surveillance and management should be guided by currently accepted practice guidelines for those conditions (R82) [5].
- In those patients in whom T2DM, hyperlipidaemia and hypertension have resolved, continued surveillance should be guided by recommended screening guidelines for the specific age group (R83) [5].
Diuretics induce magnesium, potassium and thiamine loss through the urine, and may increase vitamin and mineral requirements [12,14]. Diuretic treatments may also be responsible for dehydration, hypotension and loss of electrolytes [12]. Non-steroidal anti-inflammatory drugs (NSAIDs) should be used with extreme caution due to their potential to cause anastomotic ulcers [8].

Non-steroidal anti-inflammatory drugs should be used with extreme caution due to their potential to cause anastomotic ulcers [8].

5. Nutritional deficiencies: metabolic and nutritional surveillance

Which vitamins and/or minerals should be measured for which bariatric procedures, and which supplements should be given? It should be emphasized that the frequency of and recommended nutritional surveillance, as well as vitamin and mineral supplementation, remain empirical for surgically treated patients [5,7–13]. Such schedules have not been precisely delineated in the French guidelines [3], most likely because of the lack of evidence-based data. Moreover, such a schedule would be difficult to determine as the results so far are equivocal, given the wide range of definitions of deficiency, supplement protocols, duration of the studies and types of surgical procedures.

The main pathophysiological mechanisms are presented in Table 1, and guidelines are presented in Table 2. As for the most important recommendations, the main principles are clear in all guidelines. Routine metabolic and nutritional monitoring is recommended following all bariatric surgical procedures (US R85) [5]. In addition, all patients who have undergone bariatric procedures require regular life-long, qualified surveillance [4].

Table 1: Metabolic and nutritional problems after bariatric surgery according to surgical procedure

<table>
<thead>
<tr>
<th>Deficiency or complication</th>
<th>Prevalence (or risk)</th>
<th>Causal factors or circumstances</th>
<th>Complications or consequences</th>
<th>Laboratory test* or other investigations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vomiting</td>
<td>AGB: ++</td>
<td>Stuck food (AGB ++), anastomotic stenosis (GBP)</td>
<td>Hypokalaemia, dehydration, renal failure</td>
<td>Electrolytes, haematocrit (CBC)</td>
</tr>
<tr>
<td>Iron</td>
<td>AGB: +</td>
<td>Menstruating women, meat intake</td>
<td>Microcytosis, anaemia, fatigue, brittle nails</td>
<td>Vitamin B12, MMA (optional), holotranscobalamin II (optional), homocysteine (optional)</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>AGB: +</td>
<td>Meat and dairy intakes, malabsorptive procedure (GBP), extreme weight loss (i.e. low food intake)</td>
<td>Macrocytosis, anaemia, neuropathy</td>
<td>Vitamin B12, MMA (optional), homocysteine (optional)</td>
</tr>
<tr>
<td>Calcium, vitamin D</td>
<td>AGB: – or ±</td>
<td>Intake of calcium-rich foods, malabsorption of calcium and vitamin D</td>
<td>Osteomalacia, osteoporosis, fractures</td>
<td>1,25(OH)2D, PTH, alkaline phosphatase, calcemia: rare, DEXA (bone density)</td>
</tr>
<tr>
<td>Vitamin B9 (folate)</td>
<td>AGB: ±</td>
<td>Low intake, low compliance with supplements</td>
<td>Macrocytosis, anaemia, pregnant women: fetal neural-tube defects</td>
<td>Folate, CBC folate, homocysteine (optional)</td>
</tr>
<tr>
<td>Proteins</td>
<td>AGB: –</td>
<td>Low protein (and energy) intakes, intercurrent illness, extreme weight loss (i.e. low food intake)</td>
<td>Oedema</td>
<td>Albumin, prealbumin, DEXA (fat-free mass)</td>
</tr>
<tr>
<td>Vitamin B1 (thiamine)</td>
<td>AGB: ±</td>
<td>Recurrent vomiting (AGB), glucose intravenous infusion with no vitamin B1 supplementation</td>
<td>Neuropathy, Gayet–Wernicke encephalopathy</td>
<td>Thiamine</td>
</tr>
<tr>
<td>Zinc, selenium</td>
<td>AGB: +</td>
<td>Low intake, severe weight loss (i.e. low food intake)</td>
<td>Hair loss (zinc), selenium: no symptoms</td>
<td>Zinc RBC, selenium</td>
</tr>
<tr>
<td>Other vitamins (A, E, K)</td>
<td>AGB: –</td>
<td>Malabsorptive procedure (GBP), extreme weight loss (i.e. low food intake)</td>
<td>Vitamin A: night blindness, vitamin E: oxidative stress, vitamin K: bleeding disorder</td>
<td>Vitamin A, vitamin E, vitamin K1 + INR</td>
</tr>
</tbody>
</table>

*Based on plasma concentrations; –: very rare; ±: rare; +: frequent; ++: very frequent; (?): no data available; AGB: adjustable gastric bands; GBP: gastric bypass; SG: sleeve gastrectomy; CBC: complete blood cell count; DEXA: dual-energy X-ray absorptiometry; INR: international normalized ratio; MMA: methylmalonic acid; PTH: parathyroid hormone; RBC: red blood cells; All data are adapted from references 3–6, 8, 11, 12

VBG: vertical banded gastroplasty
Follow-up nutritional and metabolic visits need to be stratified by type of surgical procedure and presence of complications or co-morbidities [3–6]. These consultations have to be performed by a physician with expertise in nutritional and metabolic medicine [5]. Intestinal adaptation occurs after 1–3 years, so weight loss and metabolic or nutritional derangements should eventually be stabilized [5]—but only if the patient makes healthy food choices.

5.1. Vomiting consequences (AGB and VBG)

5.1.1. Dehydration

After gastric restriction, many patients have difficulties with drinking water separately from meals, and it is not easy to hold much fluid when the gastric pouch is small. Consequently, dehydration is a common problem. Patients need to learn how to sip fluids and not take large gulps [8].

5.1.2. Hypokalaemia

Control of kaliemia is necessary if vomiting is frequent or prolonged [3,5,12].

5.1.3. Thiamine deficiency and Gayet–Wernicke syndrome (see below)

Thiamine deficiency is mainly due to vomiting and the administration of intravenous glucose with no parenteral supplementation with thiamine [3,5,7].

5.2. Protein depletion and protein-energy malnutrition

Intolerance of protein-rich foods is common, especially in the form of meat products, within the year after bariatric surgery. For this reason, many patients fail to meet the recommended daily intake of protein, and limit their intake to less
than 50% of the recommended amount [5]. Protein depletion is rarely isolated, as energy intake is often extremely low in such cases [8], leading to a state of protein-energy malnutrition.

*Protein intake should average 60–120 g/d (R52) [5]. Regular assessment of protein intake should be performed periodically (R90) [5], and protein supplements have to be proposed if protein intake remains < 60 g daily (R91) [5].

Nevertheless, protein malnutrition is rare in morbidly obese surgically treated patients whatever the procedure (AGB, GBP, SG) [12,32], and the standard GBP is not associated with severe protein malnutrition [32], a condition characterized by oedema, loss of muscle mass and frank hypoalbuminaemia.

*Parenteral nutrition should be considered for patients with severe protein malnutrition who are not responsive to oral protein supplementation (R92) [5], and prompt hospital admission for initiation of nutritional support is necessary (R158) [5].

At our centre, artificial enteral nutrition (using nasogastric delivery) is used, if possible, based on the same considerations that guide treatment decisions for severely malnourished patients: the potential benefits and risks compared with parental nutrition.

### 5.3. Iron

Surgically treated patients are at high risk of developing iron deficiency [3–6, 9]; this is true for both the restrictive and malabsorptive procedures. In fact, iron stores continuously decline after GBP surgery [8]. *Iron status should be monitored in all bariatric surgery patients and then appropriately treated as in any medical or surgical patient (R109) [5].*

After GBP, iron supplementation could be provided routinely and systematically to menstruating women, or when ferritin levels or siderophilin saturations are low. *Orally administered ferrous sulphate, fumarate or gluconate (320 mg twice a day) may be needed to prevent iron deficiency in patients who have undergone malabsorptive bariatric surgical procedures, and especially menstruating women (R110) [5]. Vitamin C supplementation should be added because vitamin C can increase iron absorption and ferritin levels (R111) [5]. Intravenous iron infusion with iron dextran, ferric gluconate or ferric sucrose (Venofer®) may be needed if oral iron supplementation is ineffective at correcting the iron deficiency (R112) [5].

| Table 3 Follow-up and laboratory tests after AGB, GBP and SG* |
|---------------------------------------------------|---|---|---|---|---|---|
| 1 month | 3 months | 6 months | 12 months | 18 months | 24 months | Annually |
| **Chemistry panel: CBC** | AGB | AGB | AGB | AGB | AGB | AGB |
| | GBP | GBP | GBP | GBP | GBP | GBP |
| | SG | SG | SG | SG | SG | SG |
| **Iron (% transferrin saturation), ferritin** | AGB | AGB | AGB | AGB | AGB | AGB |
| | GBP | GBP | GBP | GBP | GBP | GBP |
| | SG | SG | SG | SG | SG | SG |
| **Vitamin B12 (± MMA)** | AGB | AGB | AGB | AGB | AGB | AGB |
| | GBP | GBP | GBP | GBP | GBP | GBP |
| | SGa | SGa | SGa | SGa | SGa | SGa |
| **RBC, folate** | AGBa | AGBa | AGBa | AGBa | AGBa | AGBa |
| | GBP | GBP | GBP | GBP | GBP | GBP |
| | SGa | SGa | SGa | SGa | SGa | SGa |
| **Calcaemia + 25OH D** | GBP | GBP | GBP | GBP | GBP | GBP |
| | GBP | GBP | GBP | GBP | GBP | GBP |
| | GBP | GBP | GBP | GBP | GBP | GBP |
| **Intact PTH** | GBP | GBP | GBP | GBP | GBP | GBP |
| **DEXA, bone density** | GBP | GBP | GBP | GBP | GBP | GBP |
| **Albumin (prealbumin)** | AGB | AGB | AGB | AGB | AGB | AGB |
| | GBP | GBP | GBP | GBP | GBP | GBP |
| | SG | SG | SG | SG | SG | SG |

*Data adapted from references 3–6, 8, 11, 12; intensive clinical follow-up is recommended after AGB during the first year at month 1, 2, 3, 4, 6, 8, 10 and 12 (if necessary) [6];

* For patients non-compliant with oral multivitamin supplementation during weight-loss phase or according to clinical symptoms; *if deficiency is suspected; CBC: complete blood cell count; DEXA: dual-energy X-ray absorptiometry; MMA: methylmalonic acid; PTH: parathyroid hormone; RBC: red blood cells.
From a practical point of view, patients need to take iron supplementation and other supplements at different times, as iron interferes with the absorption of calcium, magnesium and zinc [12].

5.4. Vitamin B12

Vitamin B12 deficiency is a common consequence of GBP [7]. GBP produces changes in vitamin B12 physiology, but the risk of B12 deficiency may also be increased by restrictive surgery if patients have a low intake of meat or dairy products. The consequences are serious: there is a risk of irreversible neuropathy if the deficiency is maintained over a long period of time. Fortunately, the body storage of vitamin B12 is substantial, and deficiencies are usually described after 1 or more years following bariatric surgery. However, SG may theoretically be the cause of an intrinsic factor deficit for anatomical reasons, although long-term data are lacking.

Evaluation for vitamin B12 deficiency is recommended in all bariatric surgery patients (R113) [5]. It should be done annually in patients who have undergone GBP (R116) [5]. After GBP, oral supplementation with crystalline vitamin B12 at a dosage of ≥ 350 μg daily may be used to maintain vitamin B12 levels (R114) [5]. Parenteral supplementation with either 1000 μg of vitamin B12 monthly or 1000–3000 μg every 6–12 months is necessary if vitamin B12 sufficiency cannot be maintained by means of oral supplementation (R115) [5].

5.5. Vitamin B9 (folate)

Folic acid supplementation (400 μg/d) is provided as part of a routine multivitamin preparation (R117) [5]. However, there is no need for specific supplementation, as folate deficiency is uncommon except for patients who do not eat vegetables.

Folic acid supplementation should be provided in all women of childbearing age because of the risk of fetal neural-tube defects with folic acid deficiency (R118) [5].

5.6. Vitamin D and calcium

At present, there are no conclusive data regarding the association of altered calcium and vitamin D homoeostasis with AGB surgery [5]. However, calcium deficiency and metabolic bone disease can occur in patients who have undergone GBP [5]. Calcium absorption is especially reduced due to the loss of acid action. Also, it needs to be emphasized that rapid and extreme weight loss is associated with bone loss, even in the presence of normal vitamin D and parathyroid hormone (PTH) levels [5].

An increase in serum intact PTH is indicative of a negative calcium balance or vitamin D deficiency, or both. Secondary hyperparathyroidism, which is commonly seen after GBP (30–40%), promotes bone loss while increasing the risks of osteopenia and osteoporosis [5]. Elevated levels of bone-specific alkaline phosphatase and osteocalcin levels, indicative of increased osteoblastic activity and bone formation, are often the initial abnormalities [5].

Vitamin D supplementation can be provided by ergocalciferol or cholecalciferol (Table 2), and parenteral vitamin D supplementation can also be used. Calcitriol [1,25-(OH)2D] therapy is generally unnecessary, and can increase the risk of hypercalcaemia and hyperphosphataemia [5].

5.7. Vitamin B1

The prevalence of vitamin B1 deficiency is low, but the consequences can be serious [3–5]. Irreversible polyneuropathy and Gayet–Wernicke encephalopathy (ocular disorders with nystagmus, ataxia, and mental disturbances and confusion) have been described [33–41]. High glucose intakes (dietary or glucose intravenous infusion) may precipitate a deficiency in patients who have low vitamin B1 reserves [5,7–12].

The following US guidelines [5] are clear and specific:

- All bariatric surgery patients should be provided with an oral multivitamin supplement that contains thiamine (R124);
- Routine screening for thiamine deficiency or additional empirical thiamine treatment (or both) is not recommended in bariatric surgery patients who are already routinely receiving a multivitamin supplement that contains thiamine (R125);
- Patients with protracted vomiting should be screened for thiamine deficiency (R126);
- In patients with persistent vomiting after any bariatric procedure, aggressive supplementation with thiamine is imperative; intravenously administered glucose should be provided judiciously in this situation because it can aggravate thiamine deficiency (R127);
- In patients presenting with neurological symptoms suggestive of thiamine deficiency (that is, Wernicke encephalopathy and peripheral neuropathy), aggressive parenteral supplementation with thiamine (100 mg/d) should be administered for 7–14 days (R128);
- Subsequent oral thiamine supplementation (100 mg/d) should be continued until neurological symptoms resolve (R129).

The optimal dose and duration of thiamine treatment for prophylaxis or treatment of Gayet–Wernicke encephalopathy remain controversial [42].

5.8. Selenium

Few clinical studies have been published of selenium deficiency after the usual bariatric procedures [9, 43]. In our experience, around 25% of patients have low selenium
plasma concentrations, but no clinical symptoms. In addition, there are insufficient data to support routine screening for selenium deficiency or empirical selenium supplementation in patients who have undergone a bariatric surgical procedure (R120) [5].

5.9. Zinc

Low zinc concentrations have been described following gastroplasty due to reduced dietary zinc intake [3,5,9,12]. Hair loss is often considered a consequence of zinc deficiency, although evidence is lacking [8]. One study reported resolution of alopecia using high-dose zinc sulphate in patients who had undergone VBG [44]. However, hair loss may also be associated with the ‘stress of weight loss’ [8], or linked to protein or iron deficiencies [12].

5.10. Vitamins A, E and K

Deficiencies in vitamins A, E and K are evidently extremely rare after standard GBP [3,5,12,13].

6. Severe long-term nutritional complications

6.1. Osteoporosis

The impact of obesity surgery on bone metabolism has been reviewed by Wucher et al. [45]. Bone loss frequently occurs after bariatric surgery and particularly after GBP. Early bone loss due to bone resorption has been described, as suggested by an increase in bone markers. The mechanisms may involve adipokines such as leptin and adiponectin [45].

As long-term studies of the risk of osteoporosis are lacking [3, 5, 7, 9], it is difficult to view the future with confidence for young women who do not like dairy products and/or are not compliant with calcium or vitamin D supplementation. Significant changes in bone mass could be problematical 20 to 40 years later. On the other hand, postmenopausal women with other risk factors for osteoporosis are at high risk of decreased bone mass after bariatric surgery [5, 7, 8]. For this reason, regular DEXA assessments of bone density (Table 3) should be scheduled for patients who are at high risk of osteoporosis.

6.2. Neurological complications

A wide spectrum of serious neurological conditions can occur after bariatric surgery (GBP, VBG and AGB) [33–35], and most often manifest as encephalopathy, myelopathy, optic neuropathy, polyradiculoneuropathy and polyneuropathy [34]. Encephalopathy and polyradiculoneuropathy are acute, and early complications are associated with rapid weight loss [34]. Myelopathy is a late severe complication that has been observed around a decade after surgery [34]. A retrospective study [33] revealed three clinical patterns of peripheral neuropathy after bariatric surgery: sensory-predominant polyneuropathy; mononeuropathy; and radiculoplexus neuropathy. Their pathogenesis is still a subject of debate, but malnutrition, inflammation and altered immunity may be involved [33,34]. The role of vitamin B1 has been already emphasized in Gayet–Wernicke encephalopathy, and, in general, these patients have multiple nutritional deficiencies (such as vitamin B12 and copper) [3,5,33,34].

A newly described syndrome—‘acute postgastric reduction surgery neuropathy’—is characterized by vomiting, weakness, hyporeflexia, pain, numbness, incontinence, visual loss, hearing loss, attention loss, memory loss, nystagmus and severe proximal symmetrical weakness in the lower extremities [5]. The underlying cause is thought to be insufficient thiamine in addition to other nutritional deficiencies [5].

6.3. Multifactorial nutritional anaemia

Nutritional anaemias resulting from malabsorptive bariatric surgical procedures can also involve deficiencies in protein, copper and selenium, requiring evaluation of these nutrients when routine screening for iron, vitamin B12 and folic acid deficiencies is negative (R119) [5].

6.4. Cardiovascular diseases

Hyperhomocysteinaemia, an independent risk factor for coronary artery disease, has been associated with folate and vitamin B12 deficiencies in bariatric surgery patients [46]. An increase in homocysteine levels was observed in two-thirds of gastroplasty-treated patients in the Lyon study [46], with clear-cut hyperhomocysteinaemia (> 15 micromol/L) in 32%. Changes in homocysteine concentrations were significantly correlated with weight loss and with decreases in plasma folate concentrations. Although the long-term SOS study [47] results indicated a decrease in the risk of cardiovascular mortality, the debate is still open for vulnerable groups at risk of nutritional deficiency, especially patients who are non-compliant with folate supplementation.

7. High-risk groups or situations

7.1. Pregnant women

Pregnancy is not recommended in the 12–18 months after surgery, as various deficiencies of vitamins and micronutrients could play a role in causing fetal malformations or complications. Assessing nutritional status and the supplements to be prescribed have been reported by Poitou et al. [12]. Iron, vitamin D/calcium and folate are the three priorities in terms
of nutritional deficiencies that require careful monitoring (before conception, if possible) [12]. It is also important to look out for overdoses, especially of vitamin A. In addition, a contraceptive strategy may be proposed if necessary.

7.2. Adolescents

Bariatric surgery is being more and more discussed for ‘super-obese’ adolescents. However, the consequences on adolescent growth and development are yet to be carefully evaluated for the long term [7]. Moreover, it is well known that compliance with multivitamin supplements is often low among patients in this age category.

7.3. Eating disorders

The impact of pathological eating and, especially, binge-eating disorder (BED) on postsurgical outcomes is of particular interest for several reasons [18,48]: (1) the prevalence of BED is high among the massively obese patients who seek surgical treatment (10–50% or more); (2) uncontrolled eating has deleterious effects on weight management after surgery; and (3) the frequency of psychiatric co-morbidities in this subgroup of obese patients is high. However, studies that have examined the impact of BED on postsurgical outcomes have, so far, yielded equivocal results [18,48].

As highlighted by Marcus et al. [18], binge eating that starts or reemerges after surgery is associated with less weight loss and with weight regain. One difficulty in assessing BED according to the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM IV) definition is that the loss of control over eating is usually more subjective than objective. From an anatomical point of view, binge eating is difficult with the small gastric pouch, but BED can lead to stretching of the pouch or of the gastrojejunal anastomosis, which is a severe complication.

In our experience, some individuals with BED resume objective binge eating in the short term, during the weight-loss phase, but its reemergence in the maintenance period (phase 2) leads to weight regain. However, the de novo appearance of disordered eating—the so-called ‘post-surgical eating-avoidance disorder’—has been described by Segal et al. [49], and is characterized by a number of features, including very rapid weight loss, excessive reduction of food intake, the use of a purgative strategy and body-image dissatisfaction or distortion.

7.4. Concomitant illness and major aggression

Major trauma, aggression, fever or any severe concomitant illness (such as infectious disease or heart failure) can accelerate the clinical manifestations of nutritional deficiencies because of the increased energy, protein, vitamin or mineral requirements brought about by such events [3, 5]. This suggests that all surgically treated obese patients should be considered as potentially severely malnourished patients.

Parenteral nutrition (PN) should be considered in high-risk patients, such as critically ill patients unable to tolerate sufficient enteral nutrition for > 5–7 days or non-critically ill patients unable to tolerate sufficient enteral nutrition for > 7–10 days (R56) [5]. However, as already stated, in our experience, artificial enteral nutrition and hydration often constitute a better solution.

7.5. Depression and risk of suicide

Mood disorders appear to be the most common psychiatric co-morbidity in this patient population. The impact of depression or other psychiatric disorders on postsurgical outcomes remains unclear, given the lack of specific data [3,5,18]. Marcus et al. [18] recently reported that a lifetime history of mood or anxiety disorder was associated with poorer short-term weight loss at 6 months after GBP. However, the SOS study [17] found a substantial positive long-term effect of weight reduction on depression symptoms that was at least partly dependent on weight loss.

However, negative psychological responses to bariatric surgery have been reported in a significant minority of patients, and any improvements in psychosocial status have been lost 2–3 years after surgery [5]. The reasons for this remain unclear and require further investigation. Also, some published reports show an increased risk of suicide after bariatric surgery [50,51] and, again, further specific studies are needed to explore this important issue.

7.6. Addictive behaviours

The prevalence of ‘addictive’behaviours, such as alcohol abuse, gambling, addiction to medications, compulsive shopping and driven sexual behaviours, may be increased in the morbidly obese population, and may also be a problem for bariatric surgery patients[18]. Indeed, in our experience, BED resolves in some patients, but a new addictive behaviour then emerges. This suggests that there is probably a relationship between substance abuse and eating problems. It may be prudent to monitor patients’alcohol use following bariatric surgery, as has been recommended by Marcus et al. [18].

8. Specific management and frequency of follow-up visits by surgical procedure

The frequency of follow-up visits should be modified according to the patients’ weight loss over time, occurrence of clinical symptoms or complications and type of procedure performed [3–6]. Closer clinical follow-up is more necessary after AGB than after GBP, whereas the reverse is true for perioperative nutritional evaluations [3–6].
8.1. Adjustable gastric bands

All experts agree that regular consultations for advice and adjustments are critical for achieving good weight loss, at least during the first postoperative year [3–6]. At that time, follow-ups should take place at least every 3 months, starting 2–4 weeks postoperatively until a clinically satisfactory rate of weight loss is achieved, and with repeated band fills if necessary. Thereafter, follow-up should be at intervals of no greater than 1 year for as long as the device has not been reverted or removed [3–5].

Appropriate AGB adjustments should be performed according to the individual patient’s weight loss and the type of the implant as a medical/clinical decision, by trained medical or paramedical staff with adequate experience (such as a surgeon, medical physician, nurse practitioner or dedicated radiologist) [4].

Metabolic and nutritional statuses, including vitamin and micronutrient blood levels, should be regularly monitored to prevent nutritional deficiencies and to allow appropriate supplementation [4,5]. Vitamin and micronutrient supplements should compensate for their possible reduced dietary intakes [3–6].

8.2. Non-adjustable gastric bands and other purely restrictive operations

For these procedures, the recommendations are similar to those for AGB except that band adjustments are not required [4,5]. There are no specific published nutritional guidelines for SG, although a decrease in ferritin plasma concentrations has been reported by Toh et al. [16] in a small group of SG-treated patients.

8.3. Gastric bypass procedures

With GBP, the clinical follow-up is often easier than with solely restrictive procedures, as digestive symptoms (regurgitation, vomiting, plugging) are uncommon [3–5]. Weight loss is also usually more rapid, making the clinical follow-up protocol less restrictive [3–6].

Nevertheless, routine laboratory surveillance for nutritional deficiencies is recommended after GBP (Table 3), even in the absence of calorie or nutrient restriction, vomiting or diarrhoea. European guidelines [4] recommend the following protocol: checkup after 1 month, then follow-up at a minimum of every 3 months during the first year, every 6 months during the second year and annually thereafter.

Daily supplementation with a multivitamin–mineral preparation (1 or 2 tablets) is often inadequate, so additional iron and vitamin B12 supplements are usual after GBP [5]. If necessary, iron and calcium plus vitamin D may also be given for a few months or even continuously [3–5].

As recently demonstrated by Gasteyger et al. [52], nutritional deficiencies after GBP are commonly seen and cannot be prevented by standard multivitamin supplementation. Almost all patients required one or more nutritional supplements 2 years after surgery. This study also suggests that the prevalence—and probably the severity—of nutritional deficiencies will increase over time, at least during the first few years after GBP.

9. Multidisciplinary team

The pre- and postoperative management of bariatric surgery patients is clearly multidisciplinary [3–6]. The treating physician (in our experience, the nutritionist, who, in France, is a physician) and surgeon are responsible for the treatment of co-morbidities before the operation and for the follow-up after the operation [4]. Complementary follow-up pathways (surgical and medical) should be provided to all patients [4]. The surgeon is responsible for all possible short- and long-term events directly related to the operation. The medical physician is responsible for the long-term post-surgery follow-up, and management of obesity and obesity-related diseases and operation-related non-surgical consequences [4].

The US guidelines define the primary team as comprising the bariatric surgeon, the obesity specialist and the dietitian [5]. Yet, as general practitioners (GPs) or family physicians play a pivotal role in many health-service systems [3], it is crucial that GPs find their true place in both the pre- and postoperative management of these patients.

In addition, the intervention of mental-health professionals should be facilitated to help patients adjust to the psychosocial changes they will experience postoperatively. Regardless of the bariatric procedure, psychiatric counselling can benefit all bariatric surgery patients [5]. This is especially true when eating disorders or psychiatric co-morbidities are present [3].

10. Therapeutic patient education and patient responsibility

Behavioural treatments, generally considered a necessary component of any adequate obesity-treatment programme, are paradoxically rarely proposed after bariatric surgery. According to the guidelines, it is recognized that: (1) the patient takes lifelong responsibility for adhering to the follow-up rules [4]; and (2) treatment outcome is significantly dependent, among other factors, on patients’ compliance with long-term follow-up [4]. All patients should be encouraged to participate in ongoing support groups after discharge from the hospital (R87) [5].

10.1. Adherence to nutritional treatment

As it is well known that the compliance rate with nutritional treatment is dramatically low [3–5], it is appropriate that
compliance be regularly assessed and encouraged during the postoperative follow-up. However, taking several pills every day is a problem for many patients, and the cost of treatment is probably a major barrier to adequate compliance. Gasteyer et al. [52] calculated that, at 2 years after GBP, a patient in Switzerland will have spent, on average, $35 a month for nutritional supplements alone. In addition, the costs related to extensive biological nutritional assessments are also high, averaging $360 per patient per sample at the Lausanne center, or $2100 for the six blood samples obtained during the entire follow-up period [52].

10.2. Therapeutic patient education by a multidisciplinary team

It is clear that disordered eating patterns, psychological difficulties and coping problems are present in many surgically treated patients, and that they are a cause of weight regain. Indeed, the conclusions of the SOS study [17] should be taken into account in clinical practice: “Difficulties among surgical patients to control and maintain weight loss over time should not be ignored. Many surgical patients may benefit from behavioural support programmes, and future research should systematically study whether the long-term efficacy of bariatric surgery may be further enhanced by implementing lifestyle-modification techniques in the postoperative management of patients” [17].

It is now well established that education enables the patient to acquire greater knowledge and understanding of obesity and energy balance, self-management skills and psychosocial competencies. This approach is called ‘therapeutic patient education’ (TPE). The healthcare teams in charge of the education of surgically treated patients are increasingly focusing on education (patient-centred education), and not only on weight loss and eating behaviours. One major objective is to overcome the constraints that are derived from all sorts of barriers (psychosocial, cultural, ethnic, geographical) to TPE.

In fact, TPE could be a part of the patient’s preoperative management, as it is crucial to determine a person’s readiness to change behaviour before bariatric surgery. For example, emotional eating could be taken into account before any weight regain occurs 2–3 years after the surgical treatment. Emotional distress—especially depression and anxiety—interferes with self-management. As many obese patients take an ‘all-or-nothing’ approach to their eating behaviours, it may be that any antiobesity surgery would be unsuccessful. This suggests that the best approach may be to have, before surgery, well-informed patients who have received support and guidance from trained healthcare professionals working within a healthcare system that is able to respond to patients’ needs. In addition, from a practical point of view, nutrition and meal-planning guidance should be provided to the patient and family before bariatric surgery (R49) [5].

11. Conclusion

Severe obesity is a serious chronic clinical condition that requires the application of long-term strategies for its effective management and prevention. Bariatric surgery has a major impact on obesity-related co-morbidity [52], and decreased mortality rates in surgically treated obese patients are now relatively well documented [47,53,54]. Yet, bariatric surgery is not a ‘magic bullet’. Intensive preoperative nutritional and psychosocial counselling is believed to be important not only in the immediate postoperative period, but also in the long-term patient follow-up. It can promote greater adherence to diet, and improve weight loss and psychosocial functioning.

Furthermore, as follow-up should be considered lifelong, it is essential to involve the patient’s GP in the long-term postoperative management. Surprisingly, little is known of the factors that can facilitate and disrupt weight maintenance after surgical weight-loss treatment, and little scientific attention has been paid to ensure its long-term success [17].

As the incidence of nutritional deficiencies is known to be related to the magnitude of weight loss, attention should be focused on those patients who achieve extreme weight losses even with purely restrictive procedures (AGB). However, any deficiencies can easily be avoided by an adequate strategy of nutritional supplementation, which is important as serious complications related to the development of nutritional deficiencies have been described, including neurological dysfunction due to multivitamin deficiency, and osteoporosis because of calcium and vitamin D deficiencies. Moreover, an important question yet to be answered is: What happens in the long run?

Clinical guidelines have been developed and recently published, and it is now time to put them into practice and to verify that established standards of postoperative management of bariatric surgical patients are applied in real life.

Conflicts of interests

The authors have reported no conict of interests.

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