Nutritional Deficiencies Following Bariatric Surgery

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Although bariatric surgery can aid patients in rapidly losing large amounts of unhealthy excess weight, nutritional complications that range from mild to severe can follow.

Introduction

Bariatric surgery is an effective tool for achieving durable weight loss and improving weight-related comorbidities with relatively low incidences of reported morbidity and mortality. Bariatric procedures induce weight loss by imparting restriction, malabsorption, or a combination of both. However, the caloric restriction and/or malabsorption that accompanies these weight-loss procedures can put patients at risk for developing significant nutritional deficiencies that can lead to metabolic bone disease, neurologic abnormalities, and protein malnutrition. Some of these deficiencies can develop rapidly after surgery, and most worsen with time as body stores of nutrients and vitamins are depleted within 1 year of surgery. Ironically, given the perception that weight gain is related to overeating, therefore leading the obese individual to get adequate nutrients, it has been reported that preoperative nutrient levels in many of these patients are suboptimal.

As more bariatric operations are performed, the potential increases for more patients to present with nutrient abnormalities. Therefore, health care practitioners must learn to recognize and treat the nutritional consequences of weight-loss operations as well as know how to screen for and prevent deficiencies.

This review begins with the B vitamins and iron, of which most practitioners are aware for the potential of health concerns. Calcium and vitamin D are addressed next because of their effect on bone health. The other fat soluble vitamins—A, E, and K—are then discussed, followed by the trace minerals that may be of concern postoperatively. Protein malnutrition is reviewed last.

The B Vitamins

The B vitamins are comprised of 8 essential nutrients. Levels have been analyzed in patients before and after weight-loss surgery. Reports show preoperative deficiencies of cyanocobalamin (vitamin B12), thiamine (vitamin B1), and pyridoxine (vitamin B6). All of these, along with folate (vitamin B9) and riboflavin (vitamin B2), have been shown to be low postoperatively.

Vitamin B12

Vitamin B12 deficiency is among the most common nutritional consequences of weight-loss surgery. Operations that limit stomach capacity significantly impair the body’s ability to absorb vitamin B12. Following bariatric surgery, the remaining smaller gastric pouch secretes less acid, which leads to incomplete release of vitamin B12, a food-bound vitamin. There is also less intrinsic factor—a protein produced by glands in the stomach lining—available to bind to the vitamin in the duodenum. Intrinsic factor and vitamin B12 form a complex that is later absorbed in the ileum. Also, many foods that are good sources of vitamin B12 may be difficult for the postoperative patient to tolerate, and are thus avoided (Table 1).
In 1 study, 5% of patients were found to be deficient in vitamin B12 preoperatively, whereas at least 3 other studies found that levels were adequate. Postoperatively, deficiency is common after vitamin stores are depleted, at approximately the 1-year mark. Symptoms of deficiency include glossitis, weakness, depression, poor appetite, megaloblastic anemia, peripheral neuropathy, and ataxia. The amount of vitamin B12 in standard multivitamin is not adequate to prevent deficiency or elevations in homocysteine levels. Treatment for deficiency can be given in many forms: oral crystalline tablets, sublingual preparations, intramuscular (IM) injections, and nasal sprays. One recommendation is 1,000 to 3,000 mcg of vitamin B12 given IM postoperatively and then repeated every 6 to 12 months.

**Thiamine**

A variety of food sources contain significant amounts of thiamine (Table 1). Rice-based diets, diets high in other refined starches, or chronic alcohol consumption put people at risk for developing thiamine deficiency, also known as beriberi. Bariatric surgery, malabsorption (thiamine is absorbed in the proximal jejunum), and prolonged vomiting can further increase this risk. Low preoperative thiamine levels were found in 15.5% and 29% of patients presenting for obesity surgery at centers in Florida and New York, respectively. Beriberi may be more common in blacks and Hispanics than in whites.

Early thiamine deficiency produces fatigue, poor memory, anorexia, and abdominal discomfort. Wernicke-Korsakoff syndrome may present with eye changes, ataxia, confusion, and encephalopathy, which may lead to coma. Cardiovascular changes (“wet beriberi”) may be recognized as high cardiac output with vasodilation and warm extremities, which can lead to heart failure.

Neurologic effects (“dry beriberi”) include paresthesias of the toes, burning in the feet, muscle cramps in the calves, and hyporeflexia. Thaisetthawatkul et al noted that 16% of patients undergoing bariatric surgery had peripheral neuropathy, which was positively correlated with the rate and amount of weight loss, reduced serum albumin and transferrin, gastrointestinal complications, and attendance at a nutrition clinic. It should be noted that many other, more rare nutrient deficiencies—including vitamin E, vitamin B6, and copper—also cause neuropathies. It is unclear whether thiamine or another nutrient or combination of nutrients is responsible for the neuropathy seen after weight-loss surgery, which was recently termed acute postgastric reduction surgery neuropathy.

Thiamine deficiency has been seen in patients following both restrictive and malabsorptive operations. Most reports are of young women following a period of prolonged vomiting about 4 to 12 weeks after surgery, possibly because vitamin stores last approximately 3 to 6 weeks.

Because postoperative dietary assessments show inadequate thiamine intake, a daily multivitamin containing thiamine is recommended. Additional separate B vitamin supplementation in the form of a vitamin B complex may provide added prophylaxis against deficiency. Treatment options for suspected deficiency include 50 to 100 mg of I.V. or IM thiamine daily for 2 days followed by 20 mg orally for 2 weeks or 100 mg of thiamine, I.V. or IM, for 7 to 14 days followed by 10 mg orally daily. To treat encephalopathy, 100 mg I.V. every 8 hours has been recommended. Bariatric surgery patients who present with dehydration should be considered at high risk for thiamine deficiency. Because thiamine is required for metabolism of carbohydrates (dextrose), rehydration with I.V. fluids that contain dextrose can further deplete thiamine levels.

**Folate**

Inadequate levels of folate may result from foods having less exposure to gastric acid and to the upper section of the small intestine after surgery. Folate is an essential component in metabolic pathways and is necessary to form DNA and red blood cells. Many patients undergoing

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Food Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamine (B1)</td>
<td>Beef, pork, whole grains, dried beans, peas</td>
</tr>
<tr>
<td>Riboflavin (B2)</td>
<td>Enriched grains, liver, milk, wheat germ, yeast</td>
</tr>
<tr>
<td>Vitamin B6 (pyridoxine)</td>
<td>Whole grains, nuts, bananas, meats, beans</td>
</tr>
<tr>
<td>Folate* (B9)</td>
<td>Oranges, liver, beans, green leafy vegetables</td>
</tr>
<tr>
<td>Vitamin B12 (cyanocobalamin)</td>
<td>Beef, poultry, fish, liver, eggs, milk</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>Eggs, fish oil, sardines, salmon, liver, milk</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>Butter, margarine, eggs, milk, liver, fish oil, apricots, cantaloupe, carrots, pumpkin, sweet potato (beta-carotene sources)</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>Vegetable oils and margarine, green leafy vegetables, nuts, seeds, wheat germ</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>Green leafy vegetables, green tea, liver, soy beans, soybean oil</td>
</tr>
</tbody>
</table>

*Folic acid is the synthetic form of folate.
Vitamin B<sub>6</sub> and Riboflavin

A few studies have examined the vitamin B<sub>6</sub> and riboflavin status of bariatric surgery patients. Nutritionists are aware of health issues associated with deficiencies of these vitamins. Vitamin B<sub>6</sub> deficiency may cause anemia, dermatitis, seizures, and neuropathies. Riboflavin deficiency may cause anemia, stomatitis, rash, and impaired growth.

Boylan et al found preoperative vitamin B<sub>6</sub> deficiency in 46% of patients.<sup>24</sup> A second study concluded that postoperative vitamin B<sub>6</sub> levels were insufficient in most patients despite taking a supplement containing 1.6 mg daily, which was the US recommended daily allowance at the time of the study.<sup>32</sup> (Note that the 2004 Dietary Reference Intake [DRI], still in use today, is actually lower, at 1.3 mg per day.) Other studies conclude that in the absence of prolonged vomiting, a supplement containing the DRI for vitamin B<sub>6</sub> should be adequate for these patients.<sup>6,38</sup> High-protein diets increase the need for vitamin B<sub>6</sub>.<sup>39</sup> Also, there is evidence that supplementation of vitamin B<sub>6</sub> may improve the symptoms of carpal tunnel syndrome.<sup>40</sup>

Iron deficiency and anemia are frequent concerns regarding pre- and postoperative bariatric patients. The 3 most common causes for iron deficiency appear to be decreased absorption of iron because of bypass of the duodenum; less gastric acid, so iron is therefore not reduced to its more absorbable ferrous form; and lower iron intake from avoiding certain foods (Table 2). Iron is necessary for numerous oxidation-reduction reactions and as a means of oxygen transport in hemoglobin. Common symptoms of deficiency are fatigue, glossitis, stomatitis, and impaired temperature regulation (complaints of feeling cold). There have been reports of pica—strong cravings for non-nutritive substances such as ice or clay—after gastric bypass, which were treated with iron supplementation.<sup>41</sup>

There have been reports of preoperative iron deficiency ranging from 14% to 44% of patients.<sup>17,22</sup> Studies show that iron levels continuously decline after surgery. Iron deficiency does not appear to correlate with the amount of weight lost.<sup>4</sup> Incidence as high as 74% has been reported following distal Roux-en-Y gastric bypass (RYGB).<sup>42</sup> The risk is highest for menstruating women, who lose 30 mcg/kg per day of iron during bleeding.<sup>43</sup> Supplementation is recommended for all patients undergoing weight-loss operations, although the amount of iron in multivitamins is inadequate to prevent deficiency in most.<sup>4,42,44</sup> Noncompliance with prescribed supplements is a concern, and because of gastrointestinal intolerance and constipation,<sup>24,44,45</sup> different dosages and forms of iron supplementation have been suggested. One such regimen is 40 to 65 mg of ferrous iron as gluconate, sulfate, or fumarate 3 times per day.<sup>27</sup> Another suggestion is 320 mg of ferrous sulfate twice per day.<sup>34</sup> The addition of vitamin C to iron therapy following gastric bypass may be beneficial.<sup>3</sup> At least 1 practice has reported it regularly treats deficiency with I.V. iron.<sup>46</sup>

Calcium and Vitamin D

There are multiple reports of increased bone turnover and reduced bone mineral density following bariatric surgery. Calcium is absorbed in the duodenum and jejunum, whereas vitamin D is absorbed in the jejunum and ileum.<sup>47</sup> The anatomical changes from surgery along with limited intake of dairy products because of intolerance can decrease both calcium and vitamin D absorption and intake.<sup>35</sup> High-protein intakes also tend to increase urinary calcium excretion.<sup>47</sup>
Vitamin D plays an essential role in calcium absorption. Deficiencies of vitamin D and calcium cause an elevation of parathyroid hormone (PTH), which subsequently increases calcium resorption from bone. The exact etiology of deficiency in the obese is still unclear, but it is affected by climate, wearing sunscreen and covering skin, and skin pigmentation, because vitamin D is synthesized in the skin from sun exposure. Another explanation is decreased vitamin D bioavailability due to enhanced uptake and clearance by adipose tissue. Malabsorption of fat-soluble vitamins caused by the delayed mixing of bile and pancreatic enzymes with fat also contributes to lowering vitamin D levels postoperatively. Malabsorptive procedures such as biliopancreatic diversion (BPD) and duodenal switch (DS) carry a higher risk of metabolic bone disease.

It should be noted that vitamin D deficiencies and elevated PTH levels are seen both pre- and postoperatively. Buffington et al found that 62% preoperative obese subjects were vitamin D deficient, and Sanchez-Hernandez et al found that number to be 69%. Additionally, there was a negative correlation between vitamin D levels and body mass. Postoperatively, there are reports of hypocalcemia, elevated alkaline phosphatase, PTH, and N-telopeptide levels, as well as decreased bone density at the total hip, trochanter, and total body. Patients with early bone disease may present with fatigue, hypocalcemic tetany, arthralgia, and myalgia that can progress to osteomalacia, diffuse bone pain from microfractures, and, ultimately, spontaneous fractures.

Although there is universal support for supplementing both nutrients, there are mixed results as to whether supplementation leads to improvements in PTH levels or other bone markers. Weight loss independently causes bone loss. Daily supplementation to a level of 1,200 mg of calcium and 8 mcg of vitamin D (equivalent to 320 IU) or even 1,200 mg calcium and 800 IU in addition to dietary sources, may not be sufficient protection. Riedt et al supplemented gastric bypass patients with a total intake of 1,800 mg of calcium daily and tested their calcium absorption. Calcium absorption decreased but remained within a normal range, whereas markers of bone resorption increased significantly after surgery. In the authors’ New York City practice, patients often require daily therapy with 1,600 mg of calcium and 2,400 IU of vitamin D3 (or 14,000 IU vitamin D2) to suppress PTH levels (unpublished data). It is inconclusive as to whether gastric acid affects calcium absorption, yet most recommendations are for calcium supplements in the citrate form because its absorption is less affected by a low-acid environment.

Other Fat-Soluble Vitamins: A, E, and K

The mechanism whereby inadequate exposure of nutrients to biliopancreatic secretions imparts malabsorption is mentioned above. Malabsorption of fat and fat-soluble vitamins has significant nutritional consequences. There are at least 4 published accounts of vitamin A, K, and E deficiencies in the literature. Patients undergoing malabsorptive surgeries clearly raise more serious concerns than those whose operations impart merely restriction. Calculating fecal fat measurements in 10 DS and 9 RYGB patients, Gagner et al found that DS patients excreted 81% of the fat they consumed—significantly more than the RYGB group.

Hypovitaminosis A is most commonly linked with eye disease. In addition to night blindness, eye-related symptoms of vitamin A deficiency include xerophthalmia, Bitot’s spots, and keratomalacia. Skin signs include xerosis and petechiae. There are at least 4 accounts of post-bariatric surgery night blindness. Treatments varied between 10,000 IU of oral vitamin A daily; 100,000 IU of IM vitamin A 3 times daily; and 300,000 IU of IM vitamin A twice weekly for 4 weeks along with 100,000 IU of oral vitamin A daily (1 case study did not detail supplement dosing). Many multivitamins contain 3,500 to 5,000 IU of vitamin A, but this may be inadequate.
Marceau et al suggested 25,000 IU daily for patients undergoing BPD and DS.\textsuperscript{13} A review of patients with BPD and DS in New York and Australia found inadequate serum vitamin A levels in 52\% (n=46) after 1 year and 69\% (n=28) after 4 years.\textsuperscript{54} In patients with distal RYGB, only 10\% demonstrated deficiency.\textsuperscript{42}

Less is known about vitamins K and E. Available data on the incidence of vitamin K deficiency show that between 42\% and 68\% of patients are deficient after malabsorptive surgeries.\textsuperscript{54} Low levels of this vitamin alter clotting and result in an increased tendency for bleeding, which may present as excessive bruising or bleeding gums. One suggestion is to supplement vitamin K for international normalized ratio greater than 1:4.\textsuperscript{21}

Reports of vitamin E deficiency rarely appear in patients who receive multivitamin supplements containing vitamin E. Low levels of this antioxidant vitamin have been associated with neurologic abnormalities.\textsuperscript{6} Boylan et al found that 23\% of patients had marginal tocopherol levels preoperatively, and postoperatively, levels correlated with vitamin E supplement intake.\textsuperscript{24} More recently, Dolan et al\textsuperscript{14} and Slater et al\textsuperscript{54} found only 4\% and 5\% of patients, respectively, to be deficient. Most programs do not currently measure vitamin E levels.\textsuperscript{20}

**Zinc**

Low zinc levels may be associated with hair loss, dermatitis, impaired immunity, and delayed wound healing. There is very little research relating zinc deficiency with hair changes following bariatric surgery. Situations that likely play a role in deficiency include the primary site of zinc absorption being bypassed in weight-loss operations that alter the gastrointestinal tract, a reduced intake of foods that provide good sources of zinc (Table 2), and increased stool losses via steatorrhea.

Preoperative zinc deficiency was reported in 5.2\% to 16.7\% of patients;\textsuperscript{65} postoperatively, reports are varied. Approximately 10.5\% to 50\% of malabsorptive surgery patients have been found to have low zinc levels.\textsuperscript{14,54,65} However, zinc blood levels alone are not considered an accurate measure of zinc status.

A recent study analyzed plasma, erythrocyte, and urinary zinc levels after RYGB and found changes that might lead to long-term deficiency as well as lower zinc intakes.\textsuperscript{18} The authors concluded that zinc supplementation is necessary beginning 2 months postoperatively in patients who present with normal levels preoperatively. They also recommended that zinc dietary intake, as well as plasma and urinary levels, should be monitored regularly after surgery. Another study correlated cessation of hair loss with supplementation of 200 mg zinc sulfate 3 times daily, but blood levels were not checked in this report.\textsuperscript{66}

**Copper**

Copper is a trace mineral that plays an essential role in the structure and function of the nervous system.
selenium after bariatric surgery, although there have been reports of both preoperative and postoperative deficiencies. Prior to RYGB and laparoscopic adjustable gastric band (LAGB), 6% and 6.3% of patients, respectively, had low selenium levels. One year following surgery, these numbers increased to 7.7% of RYGB and 40% of LAGB patients. However, a different study found less selenium deficiency after one year—58% preoperatively versus 3% following surgery. The authors suggested this may have been due to compliance with selenium-containing multivitamins. Another study reported selenium deficiency in 14.5% of patients following malabsorptive surgery.

There is a case report of selenium deficiency following BPD surgery. The report, published in 2007, describes a woman who received total parental nutrition as treatment for malnutrition after losing 100 kg of body weight over 9 months. During the treatment, she developed acute heart failure, which was later believed to be due to selenium deficiency. It is important to note that this patient’s total parenteral nutrition formula did not contain selenium, and also that she was deficient in many other micronutrients in addition to selenium.

**Protein**

Considerable research has been devoted to the incidence and implications of protein malnutrition in bariatric surgery patients. Statistics vary widely on the percentage of affected patients. Hypoalbuminemia has been described as ranging from 1.3% to 33% of patients. The variations may reflect largely on the surgical program’s degree of preoperative nutrition education and postoperative follow-up.

Protein malnutrition is commonly precipitated by complications such as stricture, excessive vomiting, or what authors consider noncompliance. There is more frequent and more severe hypoalbuminemia in patients who undergo more malabsorptive procedures such as BPD and DS, but it can present after RYGB. In many cases, conventional treatment with nutritional counseling can be effective in reversing malnutrition. Helping patients increase their intake of protein via foods and liquid supplements so they are consuming 1.5 g/kg ideal body weight or 105 g of protein daily is often an effective intervention. Pancreatic enzymes can be used to counteract the effects of malabsorption. More aggressive treatment with total parenteral nutrition may be required. Ultimately, a small number of patients will require partial or total reversal of their surgeries to correct deficiencies.

**Conclusion**

Although there are numerous benefits to the weight loss attributed to bariatric surgery, there is growing evidence that nutritional consequences exist. Significant nutritional deficiency may be seen in the obese both before and after their procedures. These nutritional abnormalities may be difficult to detect, with symptoms ranging in severity from mild to life-threatening. Caring for patients who undergo weight-loss surgery presents a challenge for health care professionals. Noncompliance with follow-up care and supplementation may contribute to the undesirable consequences of surgery. A team of physicians, nutritionists, and psychologists who monitor blood values, reinforce the importance of regular supplementation, and address the psychological needs of these patients can help improve and possibly prevent significant side effects from bariatric surgery.

**References**

2. Coates PS, Fernstrom JD, Fernstrom MH, Schauer PR, Greenspan SL. Gastric bypass surgery for morbid obesity leads to an increase in bone turnover and a decrease in bone mass. J Clin Endocrinol Metab. 2004;89(3):1048-1052.


