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Nutritional deficiencies following metabolic surgery

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Abstract

Nutritional deficiencies can develop into challenging problems in patients undergoing metabolic surgery for weight loss. In order to prevent the development of serious complications, effective screening algorithms and routine supplementation should be employed in the postoperative period. This paper outlines the nutritional function of different positions of the gastrointestinal tract, and common nutritional deficiencies associated with sleeve gastrectomy, Roux-en-Y gastric bypass, and duodenal switch. We present appropriate screening/supplementation protocols for each metabolic surgery, supplementation regimens when nutritional deficiencies develop, and surgical approaches to overcome nutritional deficiencies refractory to medical management.

Keywords: Nutritional deficiencies, metabolic surgery, bariatric surgery, screening algorithm, management guidelines

BACKGROUND

Gastrointestinal tract

The gastrointestinal tract is lined with specialized cells that allow digestion and absorption of different nutrients and elements along its path. Digestion begins in the oral cavity with a combination of mechanical and chemical enzymes (amylase and lipase), which help degrade food into smaller particles and start working on the digestion of starch and fats. Saliva also contains haptocorrin, a glycoprotein, which binds to Vitamin B12[1,2]. Digestion continues in the stomach, where food is broken down by gastric acid produced

by parietal cells, and pepsin which is activated by pepsinogen produced by gastric chief cells. The parietal cells in the stomach also produce intrinsic factor, which binds to Vitamin B12 and protects it from degradation to allow distal absorption in the ileum[3]. In the duodenum, contents from the stomach, in the form of semi-liquid chyme, combine with bile and pancreatic enzymes which further breaks down chyle into smaller molecules that can begin to be absorbed across enterocytes. Larger fat molecules are emulsified in the duodenum into chylomicrons, which are subsequently transported into the lymphatic system[4]. Figure 1 outlines the location in which different nutrients are absorbed in various segments of the gastrointestinal tract[5]. Using the figure below, one can anticipate which nutritional deficiencies may develop when surgery excludes a specific part of the intestinal tract.

Carbohydrate absorption

The majority of carbohydrate absorption occurs in the duodenum and jejunum. Glucose absorption requires coupled transport via a sodium-glucose transporter (SGLT-1) enzyme, which is located in the brush border of the small intestine. This enzyme relies on a sodium gradient generated by the Na^+, K^+-ATPase located on the basolateral cell membrane[6].

Protein absorption

Protein digestion begins via a mechanical breakdown in the mouth, followed by chemical denaturation of the protein structures in hydrochloric acid and pepsin in the stomach. From the stomach, larger protein molecules are digestion into amino acids by pancreatic enzymes, namely chymotrypsin, trypsin, and proteases. Once protein molecules are transformed into tripeptides, dipeptides, and single amino acids, they can enter the enterocytes via active transport systems. The recommended dietary intake of protein for a healthy adult is 0.8 g/kg of body weight per day[7].

Fat absorption

Lipid digestion begins in the oral cavity via lingual lipases and continues in the stomach through the effects of both lingual and gastric enzymes. The stomach is the major site for the emulsification of dietary fat and fat-soluble vitamins. After emulsification, lipid droplets entering the duodenum combine with bile and pancreatic enzymes which leads to micelle and chylomicron formation. Free fatty acids are taken up from the intestinal lumen into the enterocytes. Cholesterol is incorporated into bile acid micelles and passes through a diffusion barrier at the intestinal lumen-enterocyte membrane interface, and is transported across the cellular brush border[8].

Pre-existing nutritional deficiencies in bariatric patients

Nutritional deficiencies are not only prevalent in the general population, but also in the bariatric patient population, with deficiencies more pronounced in individuals with extreme obesity (BMI > 40)[9]. The underlying factors of nutritional deficiencies in obese individuals include poor nutritional habits, chronic inflammation, and hyperparathyroidism. The prevalence of nutritional deficiencies varies with reports of deficiency in Vitamin D3 of 25%, Vitamin B12 of 18%, Iron of 25%, folic acid of 24%, Selenium of 30%, and Zinc of 25%[10,11].

Nutritional deficiencies post bariatric intervention

Sleeve gastrectomy

Sleeve gastrectomy has the least number of nutritional deficiencies, with the overall incidence estimated to be at 2.6%[12]. Sleeve gastrectomy has both restrictive and malabsorptive components, with malabsorption stemming from increased gastric emptying and alterations in gastrointestinal hormones[13]. Decreased intrinsic factor for Vitamin B12 absorption deficiencies is the most important deficiency. Other deficiencies include Iron, Vitamin B1, Vitamin D, folic acid, and Zinc deficiencies.

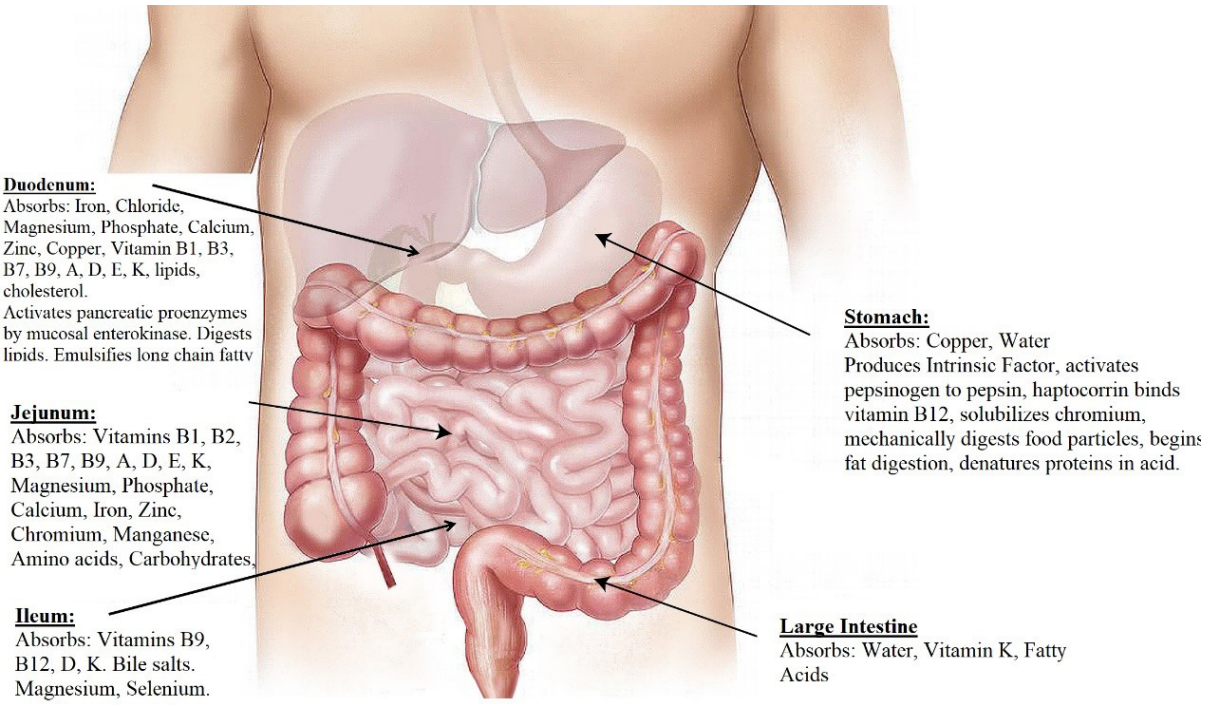

Figure 1. Different parts of the GI tract and their corresponding nutritional absorption.

Roux-en-Y gastric bypass

Roux-en-Y gastric bypass (RYGB) not only restricts the size of the stomach and gastrointestinal transit time, but also bypasses the duodenum, thereby leading to a wider range of nutritional deficiencies. These include intrinsic factor, Vitamin B12, Calcium, Iron, Vitamin B1, folate, Vitamins A, D, E, K, Copper, Selenium, Niacin, Biotin, and Zinc as described in Table 1.

Recommended supplements on regular bases include: Vitamin B12, Calcium, Iron, Vitamin B1, Folate, and Vitamins A, D, E, K. It is also recommended that screening laboratory testing be performed for the remainder of micronutrients outlined below.

Duodenal switch

The types of nutritional deficiencies in duodenal switch are similar to those of the Roux-en-Y gastric bypass. However, the rates of deficiencies are much higher due to a larger segment of the intestine being bypassed.

Rates of deficiencies without supplementation are described in Table 2.

NUTRITIONAL GUIDELINES

There are various dietary guidelines available post-bariatric surgery. The most commonly available and referenced include: Guidelines for perioperative care in bariatric surgery: ERAS Society Recommendations, 2008 ASMBS Allied Health Nutritional Guidelines, Academy of Nutrition and Dietetics Pocket Guide to Bariatric Surgery, and UpToDate Bariatric surgery: postoperative nutritional management[18].

Guidelines for perioperative care in bariatric surgery: ERAS Society Recommendations

The ERAS bariatric guidelines recommend multiple small meals each day, thoroughly chewing food without drinking beverages at the same time, and consuming fluids slowly. A balanced meal should include 5

Table 1. Rates of deficiencies without supplementation in Roux-en-Y gastric bypass[11,14,15]

Micronutrient	Deficiency incidence without supplementation
Vitamin B12	< 20%
Calcium	Up to 100%
Iron	20%-55%
Vitamin B1 (Thiamine)	1%-49%
Folate	Up to 65%
Vitamin A & D	70%-100%
Copper	10%-20%
Zinc	Up to 40%

Table 2. Rates of deficiencies without supplementation in duodenal switch[11,16,17]

Micronutrient	Deficiency incidence without supplementation
Vitamin B12	< 20%
Calcium	Up to 100%
Iron	13%-62%
Vitamin B1 (Thiamine)	1%-49%
Folate	Up to 65%
Vitamin A & D	70%-100%
Copper	Up to 90%
Zinc	Up to 70%

servings of fruit and vegetables, avoiding concentrated sweets. The average daily protein intake is suggested to be 60-120 g/day. Fluid intake of > 1.5 L daily. No specific guidelines on the amount of carbohydrates or fats per day. Additionally, the guidelines suggest avoiding/delaying concentrated sweets, carbonated beverages, fruit juice, high-saturated fat, fried foods, soft doughy bread, pasta, rice, tough, dry, red meat, nuts, popcorn, other fibrous foods, caffeine, and alcohol[19].

2008 ASMBS Allied Health Nutritional Guidelines

The ASMBS guidelines recommend a clear liquid diet on days 1-2 postoperatively, sugar free/low sugar full liquid diet for 10-14 postoperatively, blended/liquid mechanically soft foods after 2-6 weeks postoperatively, and regular textured food 6-8 weeks postoperatively. There are no specific macronutrient goals, other than obtaining adequate energy to support tissue postoperatively and preservation of lean body mass during extreme weight loss[20].

Academy of nutrition and dietetics pocket guide to bariatric surgery

The academy of nutrition recommends a clear liquid diet with low calories and free of caffeine, carbonation, and alcohol on days 1-2 postoperatively, followed by a full liquid diet on days 3-14 postoperatively, followed by a slow progression to textured, soft, semi-solid foods 3-5 times/day, followed by slow introduction of regular foods as tolerated. These guidelines suggest an intake of 48 oz/day of fluid for women and 64 oz/day of fluid for men. The guidelines do not define specific protein or carbohydrate goals[21].

UpToDate bariatric surgery: postoperative nutritional management

UpToDate guidelines recommend a clear liquid on days 1-2 postoperatively, followed by a full liquid/pureed diet on days 3-10 postoperatively, followed by solid foods with an emphasis on protein sources, some carbohydrates, and fiber on days 10-14 postoperatively. Long-term diet goals include a well-balanced diet containing essential nutrients. Protein: 46 g/day for women and 56 g/day for men.

Carbohydrates: ranging from 50 g/day in the early postoperative period up to 130 g/day in the late postoperative period. Fats: 20%-35% of the daily caloric intake, with the bulk of the fat intake being unsaturated fats[22].

ROUTINE POSTOPERATIVE SUPPLEMENTATION

Recommended supplements on regular bases include: Vitamin B12, Calcium, Iron, Folate, Vitamins A, D, E, K, Copper and Zinc. Screening laboratory testing should be performed for the remainder of micronutrients as described in Table 3.

SCREENING GUIDELINES

Screening guidelines developed for post metabolic procedures to effectively and timely identify nutritional deficiencies are listed in Table 4. Adhering to these guidelines can identify deficiencies earlier and allows for intervention before development of clinical symptoms.

SYMPTOMS OF NUTRITIONAL DEFICIENCY AND SUPPLEMENTATION RECOMMENDATIONS

It is important to be able to recognize signs and symptoms of nutritional deficiencies, which is detailed in Table 5, along with the suggested supplementation dosing. It should be noted that despite the appropriate dosage of supplementation, certain individual patients may still be unable to absorb adequate amounts of macronutrients, in which case intravenous (IV) supplementation should be considered.

Invasive interventions for supplementation

Interventions in a setting of nutritional deficiencies unresponsive to oral supplementation after 5 to 7 days include both enteral and parenteral nutrition. Addition of pancreatic enzymes may be useful for absorption of fat and fat-soluble nutrients. In general, enteral supplementation is preferred, thus placement of a feeding tube in remnant stomach in a setting of RYGB can be considered. For patients in whom surgical feeding access is unable to be placed, total parenteral nutrition nutrition can be initiated.

SURGICAL REVISION

Surgical revision may be considered if a patient is unable to obtain adequate oral intake despite the addition of fluids, supplements, and nutritional support. Additional indications include mechanical complications such as strictures or partial obstructions that limit the ability of a patient to obtain adequate supplementation. It should be noted that prior to revisional surgery, vitamin deficiencies should be corrected with intravenous supplementation to mitigate risks of surgical complications and improve healing.

Sleeve gastrectomy

Since the gastric remnant is removed at the time of surgery, reversal of the procedure is not possible. The surgical approach depends on the root cause of the problem. If there is a mechanical problem, such as a distal stricture of gastric pouch or hiatal hernia limiting nutritional intake, conversion to Roux-en-Y gastric bypass can be considered. If there are no mechanical problems exist with the sleeve, then placement of a permanent feeding jejunostomy is an option.

Roux-en-Y gastric bypass

Option #1: Complete reversal of the bypass. This is done by resecting the Roux limb. In order to accomplish this, a stapler is fired proximally to the gastro-jejunostomy, followed by another stapler fired proximally to the jejuno-jejunostomy. The excluded stomach is then reconnected to the remnant stomach pouch via a

Table 3. General supplementation guidelines post metabolic procedures[18]

	Sleeve gastrectomy	Roux-en-Y bypass	Duodenal switch
Multivitamins with Iron and Minerals	x	x	x
Calcium citrate (mg/day)	1200-1500	1200-1500	1800-2400
Vitamin D (at least 3000 U/day)	x	x	x
Vitamin B12	x	x	x
Hydration > 1.5 L/day	x	x	x
Protein 46-120 g/day	x	x	x
Other supplementation based on deficiency	x	x	x

Table 4. Screening guidelines post metabolic procedures[18]

	Sleeve gastrectomy	Roux-en-Y bypass	Duodenal switch
DEXA scan at 2 years	x	x	x
Urinary calcium excretion	N/A	N/A	At 6 months, then annually
Vitamin B12 annually (q3-6 months if requiring supplementation)	x	x	x
Folate, Iron, Vitamin D, PTH, Serum Ca, Vitamin A	x	x	x
Copper, Zinc, Selenium, Thiamine, Vitamin E, Vitamin K - if abnormal findings	x	x	x

circular stapler. (The circular stapler is introduced into the stomach via a gastrotomy and connected to the anvil, which is brought down to the remnant stomach via the esophagus)[23]. Circular anastomosis offers the possibility of future sleeve gastrectomy if weight loss is desired in the future.

Option #2: Converting Roux-en-Y limb to a gastrojejunostomy, or gastro-gastrostomy. This is done by first stapling proximally to the jejuno-jejunostomy anastomosis. The remnant Roux-en-Y limb can then be shortened and anastomosed to the proximal duodenum or the excluded stomach via a side-to-side anastomosis[24,25].

Option #3: Limb-length-alteration. In cases where a large segment bypass was performed, the length of the bypassed portion can be altered to decrease the length of the bypassed intestine. This can be performed by stapling across the proximal portion of the jejuno-jejunostomy and forming a new side-to-side anastomosis to a more proximal piece of the jejunum.

Duodenal switch

Similar to option #3 of the Roux-en-Y bypass, the length of the common channel can be increased by moving the anastomosis upstream to the alimentary limb. This approach decreases the length of the intestine bypassed and can allow for improvements in nutritional deficiencies. Another option is to create a Braun entero-enterostomy by forming an additional anastomosis as high as possible near the ligament of Treitz.

SUMMARY

- Bariatric surgery impacts nutrition and can cause important nutritional deficiencies.
- Important to screen for deficiencies / treat deficiencies appropriately.
- Nutritional support can be done via enteral and parenteral routes.
- Rarely surgical revision may be necessary.

Table 5. Symptoms of various deficiencies and associated supplementation dosing[18]

Nutrient	Symptoms	Supplementation dosing
Vitamin B1 (Thiamine)	Nausea/vomiting (first deficiency with n/v), loss of appetite, food intolerance, fatigue, irritability, reduced reflexes, tingling, weakness, blurred vision, bradycardia, shortness of breath, delirium, Wernicke Encephalopathy (opthalmoparesis, nystagmus, ataxia, confusion)	Oral: 100 BID-TID IV: 200 mg TID or 500 mg BID × 5 days, then 250 mg/day until symptoms resolve
Vitamin B12	Fatigue, lethargy, shortness of breath, headache, palpitations, tinnitus, glossitis, aphthous ulcers, paresthesia, disturbed vision, ataxia, mental decline	1000 ug/day until levels normalize
Folate	Fatigue, lethargy, gray hair, tongue swelling, aphthous ulcers, paresthesia	1000 ug/day until levels normalize
Iron	Anemia, fatigue, weakness, pale skin, chest pain, tachycardia, shortness of breath, headache, dizziness or lightheadedness, cold hands and feet, glossitis, brittle nails	Up to 300 mg TID
Calcium	Muscle aches, cramps, spasms, numbness, tingling, fatigue	500-600 mg TID
Copper	Fatigue, weakness, immune deficiency, weak and brittle bones, memory problems, trouble walking, cold sensitivity, pale skin, gray hair, vision loss	Mild - 3-8 mg/day PO Severe - 2-4 mg/day IV
Zinc	Loss of appetite, impaired immune function, hair loss, diarrhea, impotence, eye and skin lesions	Protocol with 8-15 mg of Zinc per 1mg of Copper
Selenium	Infertility, weakness, fatigue, encephalopathy, hair loss, weak immune system, cardiomyopathy, arrythmia, pale skin	2 μg/kg/day
Vitamin A	Dry skin, dry eyes, night blindness, poor healing	10,000-25,000 IU/day until clinical improvement. IF corneal changes 50,000-100,000 IM/day × 3 days, then 50,000 IU IM/day × 2 weeks
Vitamin E	Muscle weakness, immune deficiency, loss of feeling/control, vision deficiency	100-400 IU of Vitamin E/day
Vitamin D	Fatigue. Bone pain. Muscle weakness, muscle aches, or muscle cramps. Mood changes	Up to 6000 IU/day
Vitamin K	Excessive bleeding, petechiae, easy bruising	1-2 mg/day PO

BID (bis in die): Twice a day; TID (ter in die): three times a day; ug: micro-grams; mg: milligrams; PO (per os): oral intake; IV: intravenous; kg: kilogram; IU: International Units.

DECLARATIONS

Authors' contributions

Made substantial contributions to conception and design of the study and performed data analysis and interpretation: Basishvili G, Pryor A

Availability of data and materials

Not applicable.

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Conflicts of interest

Dr. Pryor receives honoraria for speaking and/or consulting from Ethicon, Merck, Medtronic, Stryker, and Gore. Dr. Givi Basishvili declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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