

Nutritional Strategy for Adolescents Undergoing Bariatric Surgery: Report of a Working Group of the Nutrition Committee of NASPGHAN/NACHRI

**Michell A. Fullmer*, †*Stephanie H. Abrams*, ‡*Kathleen Hrovat*, §*Lori Mooney*,
||*Ann O. Scheimann*, ‡*Jennifer B. Hillman*, and ¶*David L. Suskind*

ABSTRACT

Surgical options for the treatment of adolescent obesity have been gaining popularity. Adolescent patients present a particular challenge to clinicians, secondary to age-related issues, revolving around both mental and physical growth. These age-related issues require a unique approach to nutritional intervention for adolescents undergoing bariatric surgery as opposed to standardized approaches for adults. Despite the increasing numbers of adolescents undergoing obesity surgery, evidence-based nutritional guidelines have yet to be published. The goal of this document is to provide the clinician with recommendations on how to assess, educate, nourish, and monitor the adolescent who has undergone obesity surgery. A multidisciplinary panel composed of 3 pediatric gastroenterologists, 1 psychologist, and 3 registered dietitians from the Nutrition Committee for the North American Society of Pediatric Gastroenterology, Hepatology, and Nutrition and National Association of Children's Hospitals and Related Institutions, with experience in nutrition and adolescent weight loss surgery, reviewed the medical literature for evidence-based practice for nutritional strategies for patients undergoing bariatric surgery. In addition to this group, an adolescent medicine physician was consulted for matters related to reproductive health. The present article presents a consensus of recommendations based on a review of the literature. In areas for which there was a lack of evidence to support the recommendations, best-practice guidelines were used. The present article provides the clinician with an overview of the nutritional concerns for adolescent patients undergoing obesity surgery. These guidelines address the preoperative educational pathway, the post-operative diet progression, recognition of disordered eating, guidelines for female reproductive issues, and assistance for the adolescent in a school/college environment.

Key Words: adolescent obesity, bariatric surgery, nutrition education, nutritional assessment, nutritional deficiency, nutritional guidelines, nutritional needs

(*JPGN* 2012;54: 125–135)

Received May 15, 2011; accepted July 18, 2011.

From the *A.I. Dupont Children's Hospital, Wilmington, DE, the †Texas Children's Hospital, Houston, TX, the ‡Cincinnati Children's Hospital, Cincinnati, OH, the §Nationwide Children's Hospital, Columbus OH, the ||Johns Hopkins Hospital, Baltimore, MD, and the ¶Seattle Children's Hospital, University of Washington, Seattle, WA.

Address correspondence and reprint requests to David Suskind, MD (e-mail: david.suskind@seattlechildrens.org).

The authors report no conflict of interests.

Copyright © 2012 by European Society for Pediatric Gastroenterology, Hepatology, and Nutrition and North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition

DOI: 10.1097/MPG.0b013e318231db79

Obesity seen during adolescence is a multifactorial process with several contributing factors, including metabolic dysregulation, genes, environmental/socioeconomic stressors, and energy imbalance (1). Patients with obesity carry an increased morbidity and are at risk for obstructive sleep apnea, metabolic syndrome, orthopedic issues, hypertension, type 2 diabetes, and nonalcoholic steatohepatitis (1,2). These comorbid conditions affect an adolescent's quality of life and daily functioning (3). The obesity rates of children ages 2 to 19 are now 17.6%, with obesity being classified as a body mass index (BMI) above the 95th percentile (4). Obese adolescents have a 50% to 77% risk of becoming obese adults with an increase to approximately 80% given 1 obese parent (1,5). In view of this, surgical treatments for pediatric obesity have increased in popularity.

Although many weight management centers perform weight loss surgery (WLS) for the treatment of adolescent obesity, no standard for nutritional management exists for these patients. The present article describes recommendations from a multidisciplinary panel with a background in adolescent nutrition and WLS. The North American Society of Pediatric Gastroenterology, Hepatology, and Nutrition and National Association of Children's Hospitals and Related Institutions (NASPGHAN-NACHRI) Bariatric Nutrition Subcommittee included 3 pediatric gastroenterologists, 3 registered dietitians (RDs), and 1 psychologist with expertise in bariatric nutrition. The content of the article was initially outlined by the panel. Articles written in English were identified using PubMed and MEDLINE searches. No exclusions were made based on publication date. All of the human studies related to bariatric surgery and nutrition were reviewed. Additional articles identified by subcommittee members were also reviewed. A total of 417 articles related to bariatric surgery and nutrition were reviewed including case series and reports. Using the best available evidence from the literature, content was then evaluated and discussed. The subcommittee conferenced on 8 separate occasions; it based its recommendations on its study of the literature review combined with expert opinion and evidence available in the adult literature when pediatric evidence was insufficient. The present article is intended to be a guide for the clinicians involved in the nutritional care of obese adolescents undergoing bariatric surgery.

Nutritional recommendations for the treatment of the adolescent undergoing WLS can be classified into 4 areas: nutritional assessment, education, nutritional needs, and monitoring of nutritional status. The role of the RD is considered an integral component of a multidisciplinary WLS team. It is recommended that an RD with a certificate in pediatric weight management and/or experience in WLS clinically evaluate, educate, and monitor the nutritional status of the adolescent undergoing WLS.

PREOPERATIVE NUTRITIONAL ASSESSMENT

Before any WLS procedure, all adolescents should undergo an appropriate nutritional evaluation, including selective micronutrient measurements to identify nutritional and educational needs. Nutrition and meal planning guidance should be provided to the patient and family before WLS and during the postoperative hospital course and reinforced during future outpatient visits. In comparison with purely restrictive procedures, more extensive preoperative nutritional evaluations are required for malabsorptive procedures. A clinical session should be arranged with an RD who is a member of the WLS team. Before surgery some candidates may already have micronutrient deficits due to nutrient-poor food choices, lack of dairy, and low fruit and vegetable and/or whole grain intake. Listed in Table 1 are the recommended laboratory parameters to be considered as part of the nutritional evaluation. If preexisting nutritional deficiencies are identified in the initial assessment, then a dietary intervention to correct these deficiencies should be advised to the adolescent. For all adolescents, a preoperative multivitamin regimen should be put into place because of the high prevalence of micronutrient deficiencies in morbidly obese patients and to correct possible preexisting micronutrient deficiencies.

A food frequency/eating behavior questionnaire completed by the adolescent may provide additional nutritional information. A healthy balanced diet consisting of adequate protein, fruits, vegetables, and whole grains is advised during the preoperative period to assist in weight stability or weight loss. In addition, behavioral strategies for portion control are encouraged such as eating from small plates and using small utensils. Calorie needs based on height, ideal body weight, and age should be determined. Estimated energy, protein, and fluid intake as well as meal frequency patterns should be reviewed. Assessment of mindful eating habits may be of value in examining the underlying understanding, attitudes, and circumstances that lead to healthy eating patterns necessary for successful food choices.

A variety of factors influence food accessibility and food choices that ultimately influence outcome after WLS. Review of the family, family support, and home environment should be considered to be part of the initial assessment. The “family” for the adolescent requires definition because this may not be at the permanent address, but rather focus on the locations where significant time is spent routinely and where food/meals are available for consumption. All caregivers within the “family” network should be invited to attend any nutrition education sessions and participate in development of a sound home environment. The family should provide an environment that is nutritionally supportive of weight loss. This is defined as limited energy-dense and nutrient-poor

foods replaced by nutrient-dense foods. In the family in which there are members who are of varying body sizes (ie, healthy weight parent[s] or sibling[s]), the family should be encouraged to provide healthy foods for the entire family. In addition, there is evidence that supports limited eating out and family meals in the adolescent’s household to support weight management (6,7). Because of the greater independence of youths during the adolescent period, education regarding change in health behaviors should be directed to the adolescent. Consideration also needs to be given to striving to make change within the entire family because the parents or caregivers are often the individuals making the food purchasing decisions and supporting the adolescent undergoing bariatric surgery. The nutrition interview should include questions to ascertain the level of familial support. If families are having difficulty in providing a supportive environment for the adolescent, then a psychology consult should be considered. Family culture affects food preferences and availability. Culture may also change the interaction between the family and the traditional foods that are in the household. It is important to integrate dietary recommendations within a culturally sensitive framework because this may improve adherence (8–10).

It is important to note differing parenting styles in working with families of adolescents undergoing bariatric surgery. Type of parenting style may affect adolescent functioning and likely plays a role in how families approach nutritional counseling around bariatric surgery. Baumrind (11) developed 4 models of parenting: authoritarian, authoritative, permissive, and disengaged. Authoritarian style is demonstrated via strict rule setting and abidance. These adolescents may be best motivated by a rule-setting approach. The authoritative style leads to parents being warm and involved, yet consistent and firm in limit setting. Permissive parents are those that are accepting and impose few rules and restrictions, so these adolescents may have difficulty around rule setting and may test the guidelines established by the clinician. Disengaged parents often present as disinterested and may not provide the support to help the adolescent with adherence. For those adolescents, reliance on the family to make change may be difficult; change may need to lie with the adolescent. Each one of these parenting styles may result in a specific set of behaviors demonstrated by the adolescents. Acknowledgment of these parenting styles may assist in optimizing educational outcomes.

NUTRITION EDUCATION

The preoperative pathway should be standardized to ensure that all adolescents receive the same information. Because of differing learning styles, information may need to be presented in a variety of different teaching methods. The initial visit with the

TABLE 1. Considerations for nutritional screening

Nutrient deficiency	Prevalence in adults	Screening laboratories
Thiamin (B ₁)	15%–29% (more often in African Americans/Hispanics)	Blood thiamin level, erythrocyte thiamin transketolase, or transketolase urinary thiamin excretion
Cobalamin (B ₁₂)	10%–13%	Serum homocysteine level, urine/serum methylmalonic acid level, and/or serum vitamin B ₁₂ level
Iron	9%–16% of women (risk factors girl, anemic/heavy menses, low dietary intake)	Serum iron, serum ferritin, total iron-binding capacity
Vitamin D	60%–70% (risk factors sedentary, indoors, darker skin)	25-Hydroxy vitamin D level
Folate	20% (risk factors high-fat diets)	Serum homocysteine level and/or serum folate or red blood cell folate level

RD should include the previously mentioned assessment of nutritional status and current intake. Education regarding basics of WLS postoperative nutrition principles should be included in this initial visit as well. It is recommended that the clinician establish nutritional goals together with the adolescent. These goals should be shaped around the principles that are similar to the postsurgical nutrition plan, such as elimination of sugared beverages, consuming 3 or 6 meals per day (depending on the procedure), and taking vitamins as directed.

Adolescents may present varied exposure to “dieting.” It should not be assumed that they are familiar with or knowledgeable about what constitutes a healthy lifestyle. The RD should consider standardized preoperative teaching regarding healthy eating to include appropriate serving sizes and food quality according to the dietary guidelines. During the preoperative phase, it is suggested that the adolescents be encouraged to maintain some method of self-monitoring such as food records, recording healthy foods that they are eating because self-monitoring has been documented to assist in weight maintenance (12). These food records can also be used as a way to educate the adolescent on how to quantify the protein in their current diet to provide familiarity with this concept in preparation of the postoperative meal planning process. A minimum of 6 preoperative nutrition visits are recommended to complete the nutritional assessment and educational components in preparation for WLS (Table 2).

It is recommended that educational information be provided in verbal and written fashion. The RD may want to consider taste testing or exposure to protein supplements to assist the adolescent in determining acceptability before WLS. Education regarding the soft and regular meal plans may be completed at the postoperative visits as completing this education preoperatively can be difficult for the adolescent to retain. Completion of the liquid and smooth food meal plans preoperatively assists the adolescent in becoming familiar with meal planning.

Because of differing learning styles and family support in the adolescent population, the designated visit number may require some flexibility. The clinician may need to adapt the teaching style to the adolescent before or during the nutrition education process. A consistent framework for education as well as small, agreed-upon goals may assist in the increase of retained information in these adolescents.

DIET PROGRESSION

The diet advancement protocols for Roux-en-Y gastric bypass (RYGB), vertical sleeve gastrectomy (VG), and laparoscopic adjustable gastric banding (LAGB) will vary by the number of meals per day, the consistency, texture, and progression of the amount of food consumed at a meal (13) (Tables 3–5).

TABLE 2. Recommended nutritional assessment and educational components in preparation for WLS

Initial nutrition assessment
Nutrition educational session regarding food quality choices (possibly in group session)
Nutrition education regarding food quantity choices for preoperative energy needs (possibly in group session)
Nutrition education regarding liquid meal plans
Review of accuracy of liquid meal plans and, if adequate, then nutrition education regarding smooth food meal plans
Review of smooth food meal plans and, if adequate, review of questions/concerns regarding post op meal plans

WLS = weight loss surgery.

The postoperative diet focuses on weight loss with preservation of lean body mass by recommending a diet high in protein (1.0–1.5 g protein/kg ideal body weight), low in simple carbohydrates, free of added simple sugars, and with modest fat intake.

MACRONUTRIENT NEEDS

Hydration

Daily recommended intake (DRI) for girls ages 14 to 18 years is 2.3 L of water per day, increasing to 2.7 L/day when older than 18 years. Boys have a higher fluid requirement with 14- to 18-year-old boys requiring 3.3 L/day; boys older than 18 years have a DRI of 3.7 L/day (14). After bariatric surgery, patients are at risk for dehydration usually because of inadequate intake, vomiting, or diarrhea. Given the nature of restrictive forms of WLS, many patients are not able to take in large volumes of water at 1 point in time and must consume their water in small volumes frequently throughout the day. Fluid requirements can vary for each patient and should be guided by thirst; however, a minimum of 48 to 64 oz of total fluids per day has been recommended in adult bariatric surgery patients (15,16). These liquids may equal 24 to 32 oz of clear liquids plus 24 to 32 ounces of full liquids such as nonfat milk, Lactaid or soymilk, or light yogurt (15). All of the liquids should be decaffeinated and sugar-free with low sorbitol content.

To maintain hydration, strategies for addressing vomiting in a patient postsurgery include adherence to serving size guidelines and chewing food extremely carefully before swallowing; ensuring that adolescents avoid liquid intake 30 minutes before and after meals may also aid in reducing vomiting. Diarrhea associated with dumping syndrome may contribute to dehydration in patients

TABLE 3. Diet advancement protocols for Roux-en-Y gastric bypass, vertical sleeve gastrectomy, and laparoscopic adjustable gastric banding

	Stage 1: ice chips, water, sugar-free clear liquids	Stage 2: full liquids, high protein	Stage 3: smooth consistency foods and liquids	Stage 4: soft foods	Stage 5: all textures—healthy foods
Roux-en Y	1 oz/h for the first 24–48 h, then for 3–7 days ad lib	Wk 2–4	Wk 4–6	Wk 7–9	Begins at wk 9 and for life
Gastric band	1 oz/h for the first 24–48 h	First 2 wk after surgery	Wk 3–4	Wk 5–6	Wk 7 and for life
Sleeve gastrectomy	1 oz/h for the first 24–48 h, then for 3–7 days ad lib	Wk 1–5	Wk 5–8	9–12 wk postop	At wk 13 and for life

TABLE 4. Postoperative diet by stages

	Goals per day
Stage 1: sugar-free clear liquids	4–6 oz of water or sugar-free clear liquids per hour (48–64 oz/day) Acceptable sugar-free clear liquids include water, clear broth or bouillon, sugar-free gelatin, sugar-free fruit-flavored drinks, fruit ice made with sugar-free fruit-flavored drink, sugar-free popsicles Sugar-free clear restrictions: no carbonated beverages, no caffeine, no red dye
Stage 2: high-protein full liquids	Calories: 500–600 kcal Protein: 50–60 g Fluid: 80–90 oz or based on estimated requirements New foods introduced: skim or 1% milk, low-fat soy or Lactaid milk, high-protein drinks, light yogurt (plain or vanilla) thinned out with milk Meal pattern: 3–6 meals per day Volume: 1/2 cup per meal for solid foods
Stage 3: smooth consistency high-protein foods	Calories: 500–700 kcal Protein: 60 g Fluid: 80–90 oz (or based on estimated requirements) New foods introduced: scrambled eggs, blenderized/minced turkey, chicken, flaked fish or mashed tofu, tuna, melted low-fat cheese low-fat cottage cheese (small curd only), low-fat ricotta cheese Consistency of food: smooth Try new foods 1 at a time (1/4 cup) every 2–3 d Meal pattern: 3–4 meals per day Volume: 1/2 cup per meal for solid foods or 5–6 oz per meal of protein drink
Stage 4: soft foods—other protein foods, fruit, vegetables, and grains	Calories: 700–800 kcal Protein: 60 Fluid: 80–90 oz (or based on estimated requirements) New foods introduced: protein foods: shaved delicatessen meats, low-fat cheese, lean pork, cooked beans Fruit: soft or canned in own juice, no skin Vegetables: soft cooked or canned Grains: toast, low-sugar cereal, crackers, oat meal, rice, pasta, mashed potatoes (choose mainly whole-grain products, foods) Meal pattern: 3–6 meals per day Volume: 1/2–1 cup per meal solid foods or 1 cup (8 oz) protein drink
Stage 5: healthy foods for life	Calories 800–900 kcal Protein: 60 g Fluids: 80–90 oz (or based on estimated requirements) New foods introduced: all healthy food choices Meal pattern: 3–6 meals per day Volume: Up to 3/4 to 1 1/2 cup per meal

After filling/adjustments for laparoscopic adjustable gastric banding, usually done 6 weeks after surgery and then every 6 weeks until satiety is reached, a full liquid diet for 1 to 2 days is recommended after fill with advancement to soft solids for 4 to 5 days thereafter as tolerated (1).

undergoing gastric bypass. These adolescents should be instructed to avoid table sugar, candy, honey, jelly, and other concentrated forms of sugar, which may increase osmolarity of contents entering the small intestine with subsequent diarrhea.

Protein

Although true protein requirements postbariatric surgery are unclear, DRI for the public state that girls older than 13 years have a DRI of 46 g of protein per day. Boys ages 14 to 18 years have a DRI of 52 g/day, increasing to 56 g/day for boys older than 18 years (14). Given the nature of WLS, which aims to restrict exogenous energy

intake, it is not surprising that protein deficiency is seen in as much as 13% of patients after RYGB but is less likely in patients with a Roux limb <150 cm in length (17,18). Protein malnutrition is the most severe macronutrient deficiency seen after pancreaticobiliary diversion (15).

Present studies indicate that patients lose fat mass in relation to fat-free mass at a ratio of 4:1 with restrictive surgeries such as banding or RYGB (19,20). Because the goal of bariatric surgery is to preferentially decrease fat mass, adequate protein intake is imperative to prevent the loss of lean body mass. In adults undergoing bariatric surgery, the recommendation is an intake of at least 60 to 90 g of protein per day for RYGB and 80 to 120 g/day for patients with a biliopancreatic diversion (15,21,22). Because many

TABLE 5. Dietary tips for adolescents undergoing weight loss surgery

Avoid high-sugar foods and/or fat content to prevent “dumping syndrome.” Symptoms may include cramping, clammy feeling, sweating, heart racing, vomiting, and/or diarrhea. Late dumping may occur up to 2 h after eating foods high in sugar or fat.

Meals should be eaten in approximately 20 min.

Adolescents should be encouraged to stop drinking 30 min before a meal and not to drink until 30 min after a meal. Eating and drinking at the same time may decrease satiety and/or increase incidence of vomiting.

Encourage the patient to eat slowly, taking small bites. Make sure food is cut into small pieces. Chew food well until it has a pureed consistency.

Do not eat or drink past the first feeling of fullness. When feeling full, stop eating and put food away or discard what is left. To prevent dehydration, it is important to encourage the patient to continually sip fluids throughout the day, preferably water. Consider limiting caffeinated products.

Do not lie down within 1 h after meals.

patients have a difficult time maintaining adequate protein intake, they use protein supplements that are high in protein and low in calories and sugar to reach protein intake guidelines. Protein intake should be quantified periodically by the medical team to ensure adequate education and implementation of the prescribed diet. Parenteral supplementation should be considered in patients with severe protein malnutrition that is not responsive to oral protein supplements (15). Given the current practices in the pediatric population, 60 to 90 g of protein per day is recommended in adolescents undergoing RYGB, lap band, and gastric sleeve procedures.

Energy Needs

Total energy expenditure should be calculated based on the clinical center’s preestablished route of ascertaining energy expenditure to elicit weight loss. This value should be reassessed with significant changes in weight or when expected weight loss is not evident. Recent use of Bod Pod, an air displacement plethysmograph, that uses whole-body densitometry to determine body composition (fat and fat-free mass), may be a useful tool in both adults and children in determining total energy expenditure.

MICRONUTRIENT NEEDS

Vitamin and mineral deficiencies are not uncommon in Westernized diets. The 2 most common deficiencies noted are iron and vitamin D. Because obesity itself is a malnourished state, there is increased risk of these as well as other vitamin and mineral deficiencies. This risk of micronutrient deficiency can be compounded by bariatric surgery. It is important to address these potential deficiencies before any bariatric procedure. Minimal preoperative laboratory studies should include evaluation of the more common deficiencies found including vitamin D and calcium; complete blood cell count with iron, transferrin, and ferritin, red blood cell folate (homocysteine level recommended in some centers for folate monitoring), vitamins B₁, B₆, B₁₂, and 25-hydroxy vitamin D level should be obtained. Supplementation with a

complete multivitamin should occur in all candidates undergoing bariatric procedure. For those adolescents noted to have a specific micronutrient deficiency, correction of the deficient state should occur before the bariatric procedure.

Vitamin and mineral supplementation is important after bariatric surgery to avoid sequelae from nutrient deficiencies. Attention to the type of supplementation is important as studies report differences in vitamin and mineral content. In the case of iron, over-the-counter supplements can range from 0% to 230% of the labeled iron content; generic brands (36%) had less than commercially labeled amounts (81%). Specially formulated vitamin supplements contained 183% and 230% of reported iron amount (23).

Vitamin B₁ (Thiamin)

Thiamin is a coenzyme in the oxidation of α -keto acids and 2-keto sugars, which function in pyruvate metabolism and synthesis of acetylcholine. Thiamin deficiency leads to accumulation of lactate and alanine, and reduced high-energy phosphate synthesis (24). There are minimal stores present in the body; total body thiamin deficiency can occur within 18 days following dietary restriction (25). Thiamin is actively absorbed in the jejunum and ileum but can be taken up via passive diffusion at higher concentrations (26).

Moderate-to-severe thiamin deficiency has been previously found in 10% to 20% of obese women (27). High-carbohydrate diets have been associated with thiamin deficiency (28). After WLS, thiamin deficiency appears most likely to occur in patients who experience persistent vomiting and/or excessive weight loss after surgery (29). Among adults, after gastroplasty and gastric bypass, thiamin levels are below normal in 50% of patients, often accompanied by symptoms of thiamin deficiency (30). The incidence of acute postgastric reduction surgery neuropathy has been estimated at 5.9/10,000 adult WLS cases; common symptoms include weakness, hyporeflexia, and vomiting (31). In adolescents, thiamin deficiency has been reported in girls after gastric bypass surgery presenting 4 to 6 months after bypass with increasing lower extremity weakness, pain in the lower extremities in stocking distribution, nystagmus, and hearing loss (32).

Current published DRI for thiamin is 1.2 mg/day for boys ages 14 to 18 years and 1.0 mg/day for girls ages 14 to 18 years (33,34). Adolescents who have undergone bariatric surgery should be receiving a minimum of 50 mg of thiamin per day, which can be supplied by including an additional B complex in the vitamin regimen. For patients with significant protracted emesis, addition of thiamin to parenteral nutrition during the postoperative period is recommended (29).

Vitamin B₆ (Pyridoxine)

The DRI for vitamin B₆ is 1.2 mg/day for girls ages 14 to 18 years and 1.3 mg/day for boys ages 14 to 18 years (33,34). In adults after gastroplasty, intake of vitamin B₆ at current adult girl DRI (1.6 mg) is inadequate to maintain coenzyme saturation of erythrocyte aminotransferases (35). It is recommended that individuals undergoing WLS take a multivitamin that includes vitamin B₆.

Vitamin B₉ (Folic Acid)

Folic acid is found in fortified breakfast cereals, leafy green vegetables, and liver and kidney. It requires hydrolysis to allow jejunal absorption and serves as a cofactor in the single carbon atom transfer needed for amino acid metabolism, purine/pyrimidine

syntheses, and generation of S-adenosylmethionine. Deficiency in folic acid consequently results in elevation of serum homocysteine levels. Low levels of folic acid found in 7% of obese women have been attributed to the consumption of a high-carbohydrate diet (36). One year after WLS in adults, increased homocysteine levels were found in 32% to 66% of patients attributed to decreased folic acid (37).

Among teens, the DRI for folic acid for both boys and girls is 400 μg daily (33,34). Recommended supplementation after bariatric gastric bypass or biliopancreatic diversion based on adult experience is between 400 μg and 1 mg daily (38). Because folic acid is absorbed throughout the small intestine, a multivitamin containing folic acid should suffice for restrictive procedures such as LAGB.

Vitamin B₁₂ (Cobalamin)

Cobalamin found in fish, milk, eggs, meat, and poultry serves as a substrate for cofactors of enzymes including methionine synthase, glutamate mutase, dioldehydratase, and methyl malonyl coenzyme A mutase. It is cleaved by gastric acid and released from salivary R-protein by proteases. It then binds to intrinsic factor and goes to the ileum where it is released, and migrates from the brush border to transcobalamin proteins.

Vitamin B₁₂ deficiency develops in restrictive and malabsorptive operations but rarely arises after gastroplasty or banding unless there is decreased intake. Two-thirds of gastric bypass patients in 1 series had low vitamin B₁₂ levels (39) attributed to the lack of acid production in the pouch (40).

The DRI for cobalamin is 2.4 μg /day for boys and girls ages 14 to 18 years (33,34). For individuals undergoing malabsorptive/restrictive procedures, supplementations using the 500- μg sublingual form or monthly injections are recommended. Recommended treatment for vitamin B₁₂ deficiency in adult bariatric patients is recommended as oral (350 μg daily), 1000 μg im q-2 to q-3 months or 500 μg /week nasal spray.

Vitamin A

Fat-soluble vitamin deficiencies have been reported after bariatric surgery, more commonly after biliopancreatic diversion, which alters fat mixing with pancreatic enzymes and bile salts more than with gastric bypass. In an adult series, vitamin A deficiency has been reported in 10% of patients after bypass surgery manifested as night blindness (39). The DRI for vitamin A is 900 μg /day for boys ages 14 to 18 years and 700 μg /day for girls ages 14 to 18 years. Supplementation with vitamin A at the current DRI is recommended for adolescents postbariatric surgery. This amount is usually found in a daily multivitamin. For individuals undergoing more extensive malabsorptive procedures such as duodenal switch or long-limb gastric bypass, additional supplementation may be required.

Vitamin D/Calcium

Vitamin D is a prohormone that is essential for the normal absorption of calcium in the gastrointestinal tract. Deficiency in vitamin D leads to hypocalcemia, hypophosphatemia with resultant nutritional rickets in children, and osteomalacia in adults. In adults, vitamin D deficiency has also been linked to cardiovascular disease, insulin resistance, and hypertension. In addition to a number of large case studies, the National Health and Nutrition Examination Survey (NHANES III) has emphasized the high prevalence of vitamin D deficiency in industrialized nations with up to 14% in

the United States (41,42). The resurgence of vitamin D deficiency is likely caused by a number of dietary and environmental factors, including BMI, milk ingestion, and sun exposure (43).

Calcium can be absorbed by all segments of the small intestines, although the duodenum and jejunum are most active. Vitamin D is absorbed principally in the jejunum. Data on vitamin D status after bariatric surgery have shown mixed results (29). It does appear that vitamin D deficiency is more common in malabsorptive/restrictive procedures than in restrictive procedures alone. Given the predisposing factor of obesity in developing vitamin D deficiency, it is believed by most adult bariatric centers that patients undergoing bariatric surgery are at risk for developing bone mineral density and metabolism issues after procedure (29,44). Although there are no current national guidelines for adults undergoing bariatric surgery in regard to calcium and vitamin D supplementation, many bariatric centers provide supplements (38).

The DRI for vitamin D and calcium is 400 IU/day and 1300 mg/day, respectively, for boys and girls ages 14 to 18 years (33,34). Bariatric programs that performed bariatric surgery on adolescent patients were surveyed; most prescribed calcium with vitamin D in the form of calcium citrate or calcium carbonate with vitamin D. The minimum recommended dose of calcium is 1300 mg/day; the minimum vitamin D intake should be 600 IU (45). Some pediatric programs prescribe up to 2000 IU/day. If vitamin D deficiency is detected, supplementation of 1000 to 5000 IU may want to be considered for correction of deficiency (46).

Iron

Although the prevalence of iron deficiency among 1-year-old infants in the United States has declined because of improved iron supplementation during the first year of life (47,48), the rate of iron deficiency in older children and adolescents has remained relatively unchanged during the last 4 years (49). Adolescent girls who are obese have a higher risk of developing iron deficiency than their nonobese counterparts (50). The DRI for iron in boys 14 to 18 years is 11 mg daily and 15 mg daily for girls 14 to 18 years (33,34).

Iron deficiency has been reported in 15% to 50% of adults after gastric bypass, with similar numbers with biliopancreatic diversion secondary to the decreased absorption from achlorhydria or because of the use of acid suppression therapy coupled with decreased intake/tolerance of iron-rich food (51,52). Iron deficiency rarely occurs after gastroplasty or gastric banding, but mild iron deficiency has been reported in long-term series secondary to meat intolerance (53). To prevent iron deficiency in gastric bypass or biliopancreatic diversion, treatment with ferrous sulfate 300 mg daily with vitamin C has been advocated by (51). A multivitamin containing iron should suffice for adolescents undergoing restrictive bariatric procedures if they develop mild meat intolerance. With individuals undergoing restrictive procedures who are ingesting a diet including a good source of iron, which include liver, beef, whole-grain breads, cereals, eggs, and dried fruit, supplementation may not be required. It is important to remember that vitamin C can increase iron absorption by 50% (54).

Zinc and Magnesium

The DRI for zinc is 11 mg daily for boys and 9 mg daily for girls ages 14 to 18 years (33,34). There are minimal reports of zinc deficiency after bariatric surgery aside from alopecia noted after gastric bypass surgery among adults that reversed after zinc supplementation and zinc deficiency noted among bypass patients with severe protein energy malnutrition. Because zinc absorption is

dependent upon fat absorption, patients undergoing biliopancreatic diversion or duodenal switch are at risk for zinc deficiency (55). Zinc deficiency is unlikely to occur in restrictive procedures alone.

Low levels of magnesium in 5% of patients have been documented after BPD, but no significant clinical complications are reported in the literature (56). Although it should be noted that hypomagnesemia can be a cause of recalcitrant hypocalcemia. Recently, the Food and Drug Administration announced a drug safety communication regarding the long-term use of proton pump inhibitors and the development of hypomagnesemia (57). This should be taken into consideration when evaluating bariatric patients, given the high use of acid-blocking medication in this patient population. Zinc and magnesium supplementation are recommended as needed based on clinical suspicion and serum levels.

Copper

The DRI for copper is 890 µg daily for boys and girls between 14 and 18 years. Copper deficiency has been reported after gastric bypass (58). Among a recent series of patients with development of posterior myelopathy after gastric bypass, 5 of 8 patients were copper deficient (59). In 1 case series it was noted that 25% of subjects with copper deficiency presenting clinically as anemia and neutropenia had undergone bariatric surgery (60). The clinician may want to consider a review of the multivitamin preparation that the adolescent is taking to ensure that it does contain copper, especially if iron deficiency is not easily corrected as this may be caused by copper deficiency (61).

Omega-3 Fatty Acids

There is evidence to support the role of ensuring adequacy of omega-3 fatty acid intake in adults with cardiovascular disease in particular. The current recommendation of the American Heart Association is a minimum of 8 oz of fatty fish per week for adults. Of note are concerns regarding mercury contamination of fish and/or supplements, but it is believed that the benefits outweigh the potential risks (62). Because of the restrictive nature of most obesity surgery procedures, the quantity of consumption of fatty fish may already be limited in the adolescent undergoing WLS. The clinician may want to consider a careful analysis of the intake of the adolescent to determine adequacy of omega-3 in the diet and educate regarding high omega-3 food choices or supplement to promote nutritional adequacy.

Other Micronutrients

Although other micronutrient deficiencies can occur especially in restrictive/malabsorptive procedures, they are not as well defined as the aforementioned nutrient deficiencies. Supplementation

with a complete multivitamin daily should suffice for these other micronutrients.

NUTRITIONAL MONITORING

This risk of developing micronutrient deficiency increases with bariatric surgery. It is important to address these nutritional deficiencies in a timely manner. Additionally, clinicians should consider the long-term nutritional monitoring needs and therefore develop a transitional plan to an adult bariatric care center to provide for long-term monitoring for nutritional deficiencies. Minimal postoperative laboratory studies should include a core set of nutritional laboratories: a complete blood cell count, iron, ferritin, thiamin, vitamin B₁₂, methylmalonic acid, 25-hydroxy vitamin D, albumin, calcium, magnesium, phosphorus, red blood cell, and/or serum folate levels semiannually and annually. For those individuals with extensive weight loss nutritional laboratories should be obtained every 3 months. If concerns for osteomalacia exist, consideration of pre- and postprocedure dual-energy x-ray absorptiometry scan may be beneficial. It is important to ensure that a patient's weight does not exceed the machine's capacity because many dual-energy x-ray absorptiometry scans can only accommodate up to 300 lb.

When monitoring micronutrients, it is imperative to use age-appropriate cutoffs to appropriately diagnose and treat nutritional deficiencies. Table 6 addresses age-appropriate laboratory parameters to diagnose iron deficiency anemia. Table 7 addresses additional nutritional parameters to monitor.

Ferritin concentrations are often first decreased when iron intake is inadequate; however, ferritin is not recommended as a screening tool because it can be affected by other issues (eg, inflammatory process).

OTHER CONSIDERATIONS

Hunger Assessment

Volume of food consumed is decreased after WLS (65). It is unclear by which mechanism, hormonal or mechanical, food intake is limited. Despite which mechanism may be responsible, it makes sense that recognition regarding hunger/satiety cues would aid in improved outcomes. Teaching hunger satiety cues before and after surgery may assist in recognition of the adolescent for the need for less volume of food after obesity surgery. One method of teaching hunger/satiety is the use of a hunger scale. This may be accomplished by asking the adolescent to record hunger/satiety on a scale of 1 to 10 before and in the middle of a meal (with the number 1 being the number for extreme hunger and 10 being the number for extreme fullness). If they record a number >7 at the middle of the meal, then they should be asked to consider ending the meal. Teaching and encouraging intuitive eating before and after WLS may assist in growing awareness of hunger and satiety and therefore, may limit the volume of food consumed, which may affect overall postsurgical weight loss.

TABLE 6. Fifth percentile cutoffs for measure of iron deficiency in childhood

Population	Hgb, g/dL	HCT, %	MCV, fL	% TIBC sat.	Ferritin, µg/L
12–15-yr-old girl	<11.8	<35.7	<81	<16	<18
12–15-yr-old boy	<12.5	<37.3	<82	<16	<15
>15-year-old girl	<12	<35.7	<85	<16	<15
>15-year-old boy	<13.3	<39.7	<85	<16	<15

Data from the Centers for Disease Control and Prevention. HCT = hematocrit; Hgb = hemoglobin; MCV = mean corpuscular volume; TIBC = total iron-binding capacity.

TABLE 7. Age-appropriate laboratory parameters to be monitored postadolescent obesity surgery

Nutritional factor	Laboratory parameter	Normal value	Effects of deficiency
Thiamin (B ₁)	Red blood cell transketolase stimulation	<15%	Beriberi, neuritis, edema, cardiac failure, anorexia, hoarseness, restlessness, aphonia
Pyridoxine (B ₆)	Plasma PLP	<20 nmol/L	Neuropathy, photosensitivity
Folic acid (B ₉)	Serum folate, RBC folate, homocysteine	>6 ng/mL, >160 ng/mL	Megaloblastic anemia, irritability, paranoid behavior
Cobalamin (B ₁₂)	Urine/serum B ₁₂ *	<3.60 mmol/mol creatinine or 200–900 pg/mL	Pernicious anemia, neurological deterioration
Vitamin A	Plasma retinol	20–72 µg/dL	Night blindness, xerophthalmia, dermatomalacia, impaired resistance to infection, follicular hyperkeratosis, poor bone growth
Calcium	Ionized calcium	4.48–4.92 mg/dL	Numbness and tingling in the fingers, muscle cramps, convulsions, lethargy, poor appetite, and abnormal heart rhythms
Vitamin D	Serum 25-OHD	<50 nmol/L	Rickets, osteomalacia
Vitamin C	Plasma vitamin C	0.2–2 mg/dL	Bleeding gums, diarrhea, perifollicular hemorrhage, scurvy
Vitamin E	Plasma α-tocopherol	0.7–10 mg/dL	Hyporeflexia spinocerebellar and retinal degeneration
Zinc	Serum zinc	0.75–1.2 mg/L	Anorexia, hypogeusia, delayed growth or sexual maturation, impaired wound healing
Magnesium	Serum magnesium	1.5–2.0 mg/dL	Convulsions, neuropsychiatric disorders, hypomagnesemia
Copper	Serum copper	1.10–1.45 mg/L	Microcytic, hypochromic anemia, delayed growth osteoporosis, neutropenia

This table is a guide. Many laboratories have variability in the parameters that are checked as well as normal values. It is recommended that the clinician become familiar with the laboratory that typically serves their patients. If a deficiency is diagnosed, then it is recommended to repeat the nutrient as per traditional nutrient repletion guidelines (34,63,64). 25-OHD = 25-hydroxy vitamin D; PLP = pyridoxal-5-phosphate; RBC = red blood cell.

* If borderline low level, confirm deficiency with serum methylmalonic acid may be check.

Weight Regain

Understanding the factors that contribute to postsurgical weight regain may assist in a better understanding of how to prevent/minimize weight regain. The factors that may contribute to weight regain have yet to be determined, but these factors can vary from anatomical and physiological adaptations over time (66) to compliance issues (67), food urges (68), abnormal eating habits (69), to severely decreased postoperative well-being (68). More recently, a study showed that decreased resting metabolic rate correlated with those individuals who had weight regain (70). The clinician may want to consider encouraging self-monitoring and assisting the adolescent with control over food urges as well as reinforcing the need for follow-up, all of which have been shown to correlate with decreased postsurgical weight regain.

Academic Environment

Adolescent patients present issues related to the academic environment that adult WLS patients do not encounter. For adolescents in middle or high school, the clinician should advise them to carry a water bottle to sip on fluids throughout the day, request lunch be between 11 AM and 1 PM, possibly allow for a snack or protein supplement during class time, and preferably pack lunch to provide the healthiest options. A letter to the school nurse or administrator may be necessary to communicate the special needs of the WLS population.

Adolescents attending college on campus should plan ahead to follow the recommended portion controlled eating pattern. Using campus services such as the food service director or college nutritionist can help them to navigate the system at their school. Most dining halls/eating plans at college provide a variety of nutritious options, with lean protein sources readily available. Many campuses offer a program through which food can be purchased by the ounce, cup, or half portion. Students should plan the timing and frequency of their meals that realistically accommodates their class schedule. Keeping their dorm room stocked with protein-rich foods, whole-grain snacks, water, and sugar-free drinks will allow them to make healthy, appropriate choices and minimize unplanned snacking on high-sugar, high-fat foods that provide much energy but few nutrients.

Reproductive Health

The American College of Obstetrics and Gynecology recommends avoiding pregnancy for 12 to 18 months post-WLS (71). Little is known about the safety of a developing fetus in the setting of rapid weight loss and energy and nutritional restriction that occurs after WLS. Nutritional deficiencies are another concern for any patient having had a malabsorptive procedure that would place her at increased risk of folic acid and vitamin B₁₂ deficiency, which in turn increases the risk of an open neural tube defect. To date, there have been 7 infants with neural tube defects ranging from spina bifida to anencephaly born to mothers more than 12 months after gastric bypass surgery (72–74). Considering that there is

documentation of the lack of long-term noncompliance with taking vitamin supplements as directed, special attention should be focused on girls after WLS, especially those who have had malabsorptive procedures (75,76). Counseling should include the risk to the fetus if vitamins are not used in the first few months of pregnancy, often when a girl is unaware she is yet pregnant. For the majority of girls beyond the 12 to 18 months after WLS, there is good evidence that mothers and infants have no increased risk of complications related to prior WLS aside from biliopancreatic diversion (77). Additionally, because of the dramatic improvement in comorbidities such as hypertension, type 2 diabetes mellitus, and polycystic ovary syndrome after bariatric surgery, many experts argue that surgery may be beneficial in terms of reproductive health outcomes, in addition to the benefits already documented.

WLS programs should include either counseling regarding reproductive health concerns and recommendations as part of their pre- and postoperative assessments or referral to someone who is familiar with the commonly observed reproductive health problems among severely obese girls. These concerns include anovulatory menstrual cycles, polycystic ovary syndrome, increased risk of endometrial hyperplasia, increased infertility, and concerns related to gestational and type 2 diabetes mellitus. Additionally, there should be direct instruction regarding the recommendation to avoid pregnancy in the 12 to 18 months after surgery. Counseling regarding appropriate methods to prevent pregnancy should be provided to any sexually active girl planning WLS. Postoperatively, providers should continue to monitor for vitamin deficiencies, paying special attention to folic acid, vitamin B₁₂, and iron replacement for girls desiring to become pregnant. Continuation of appropriate dietary intake in the WLS patient along with vitamin and mineral supplementation is important after delivery to ensure appropriate growth and development of the breast-fed infant (77,78). Inadequate weight gain reversed with the use of formula has been reported in a breast-fed infant born postgastric bypass with inadequate protein intake (79). Congenital vitamin B₁₂ deficiency with pancytopenia, global developmental delay, and cortical atrophy has been reported in breast-fed infants born to mothers several years after gastric bypass surgery (80,81). Consultation with a pediatric dietician and lactation consult during infancy can help ensure appropriate growth and development for the infant.

Predictors of Success

Success after bariatric procedures requires significant behavioral changes that are dependent on the patient's ability to successfully implement lifestyle changes (82). Because of concerns about the ability to comprehend and implement longitudinal changes after bariatric surgery, many adult centers exclude patients with significant cognitive impairment. A recent survey of bariatric programs conducted by Bauchowitz et al (83), reported that 81.5% of the respondents would exclude individuals with an IQ <50 from consideration for bariatric procedures. There is a paucity of published data on bariatric procedures in adolescents with cognitive impairment, aside from patients with Prader-Willi syndrome (PWS), an imprinting disorder arising from the loss of the paternal copy of 15q11.2–13 with impairment in satiety and propensity to severe obesity as primary features. Bariatric procedures in children with PWS should be considered with extreme caution. A recent review of bariatric surgical outcomes in individuals with PWS noted poor results in comparison to nonsyndromic obese individuals (84).

The goal of bariatric surgical procedure is weight loss. In neither restrictive procedures, such as lap band, nor restrictive-malabsorptive procedures, such as RYGB, does weight loss lead to a

person reaching his or her ideal body weight. Often a percentage of excess weight (% EWL), the amount of excess weight that a patient has relative to his or her ideal weight, is the measure used to describe the success after a bariatric procedure. For bariatric surgery % EWL ranges from 58% to 64%. Restrictive procedures such as lap band have less % EWL (40%–54%), whereas the restrictive-malabsorptive procedures such as RYGB have greater mean % EWL, 56% to 74% (85). Change in BMI is also used to describe weight loss after a bariatric procedure. BMI is defined as the individual's body weight divided by the square of his or her height. Changes in BMI have also been used to define successful bariatric procedure. Presently there are good standards correlating BMI to cardiovascular risk factors. Finally, resolution or improvement with obesity-related comorbidities is another method of defining successful bariatric procedure. Resolution can be seen in type 2 diabetes mellitus, hyperlipidemia, hypertension, and obstructive sleep apnea.

Although there is a lack of data on predictive factors of success for pediatric patients undergoing bariatric surgery, extrapolation from the adult data would indicate the best chance for success surgery, defined as EWL >50% in individuals younger than 40 years with initial BMI <50 kg/m², willingness to change eating habits, and willingness to increase physical activity (85). Although adult patients with extreme obesity do not seem to have good EWL, in adolescent patients this may not hold true. Data also exist highlighting the importance of the experience of the surgical team in conjunction with a multidisciplinary approach to weight loss, including behavior modification as important factors for optimal outcomes (86).

CONCLUSIONS

Careful considerations should be made when assessing, educating, and monitoring the adolescent WLS patient. Most of these recommendations are based on the best practices of those currently working with this population. The recommendations in this article are meant to provide a guide when developing a new program or as a tool to reevaluate an existing program. At this point, there is limited evidence-based practice. Because of this, many WLS programs often vary in their approach, diet progression, and the like. It is anticipated that there will be more research in this area, and this assists in establishing more uniform protocols in WLS programs.

REFERENCES

1. Inge TH, Krebs NF, Garcia VF, et al. Bariatric surgery for severely overweight adolescents: concerns and recommendations. *Pediatrics* 2004;114:217–23.
2. Daniels SR, Arnett DK, Eckel RH, et al. Overweight in children and adolescents: pathophysiology, consequences, prevention, and treatment. *Circulation* 2005;111:1999–2012.
3. Trasande L, Chatterjee S. The impact of obesity on health service utilization and costs in childhood. *Obesity (Silver Spring)* 2009;17:1749–54.
4. Ogden CL, Carroll MD, Flegal KM. High body mass index for age among US children and adolescents, 2003–2006. *JAMA* 2008;299:2401–5.
5. Whitaker RC, Wright JA, Pepe MS, et al. Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med* 1997;337:869–73.
6. Boutelle KN, Fulkerson JA, Neumark-Sztainer D, et al. Fast food for family meals: relationships with parent and adolescent food intake, home food availability and weight status. *Public Health Nutr* 2007;10:16–23.
7. Larson NI, Neumark-Sztainer D, Hannan PJ, et al. Family meals during adolescence are associated with higher diet quality and healthful meal patterns during young adulthood. *J Am Diet Assoc* 2007;107:1502–10.

8. Caballero B, Clay T, Davis SM, et al. Pathways: a school-based, randomized controlled trial for the prevention of obesity in American Indian schoolchildren. *Am J Clin Nutr* 2003;78:1030–8.
9. Kumanyika SK, Story M, Beech BM, et al. Collaborative planning for formative assessment and cultural appropriateness in the Girls Health Enrichment Multi-site Studies (GEMS): a retrospective. *Ethn Dis* 2003;13:S15–29.
10. Wadden TA, Stunkard AJ, Rich L, et al. Obesity in black adolescent girls: a controlled clinical trial of treatment by diet, behavior modification, and parental support. *Pediatrics* 1990;85:345–52.
11. Baumrind D. Patterns of parental authority and adolescent autonomy. *New Dir Child Adolesc Dev* 2005;(108):61–9.
12. Wing RR, Phelan S. Long-term weight loss maintenance. *Am J Clin Nutr* 2005;82:222S–5S.
13. Aills L, Blankenship J, Buffington C, et al. ASMBS Allied Health Nutritional Guidelines for the surgical weight loss patient. *Surg Obes Relat Dis* 2008;4:S73–108.
14. US Department of Agriculture, National Agricultural Library. Dietary guidance. DRI tables. http://fnic.nal.usda.gov/nal_display/index.php?info_center=4&tax_level=3&tax_subject=256&topic_id=1342&level_3_id=5140. Accessed November 29, 2011.
15. Mechanick JI, Kushner RF, Sugerman HJ, et al. American Association of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic & Bariatric Surgery medical guidelines for clinical practice for the perioperative nutritional, metabolic, and non-surgical support of the bariatric surgery patient. *Obesity (Silver Spring)* 2009;17(suppl 1):S1–70.
16. Parkes E. Nutritional management of patients after bariatric surgery. *Am J Med Sci* 2006;331:207–13.
17. Faintuch J, Matsuda M, Cruz ME, et al. Severe protein-calorie malnutrition after bariatric procedures. *Obes Surg* 2004;14:175–81.
18. Brolin RE. Weight gain after short- and long-limb gastric bypass in patients followed for longer than 10 years. *Ann Surg* 2007;246:163–4. author reply 4.
19. Giusti V, Suter M, Heraief E, et al. Effects of laparoscopic gastric banding on body composition, metabolic profile and nutritional status of obese women: 12-months follow-up. *Obes Surg* 2004;14:239–45.
20. Strauss BJ, Marks SJ, Growcott JP, et al. Body composition changes following laparoscopic gastric banding for morbid obesity. *Acta Diabetol* 2003;40(suppl 1):S266–9.
21. Marcason W. What are the dietary guidelines following bariatric surgery? *J Am Diet Assoc* 2004;104:487–8.
22. Stocker DJ. Management of the bariatric surgery patient. *Endocrinol Metab Clin North Am* 2003;32:437–57.
23. Yeager SSL, Still CD. *Multivitamins: What Are We Really Prescribing to Our Gastric Bypass Patients*. New Orleans: NAASO; 2007.
24. Butterworth RF, Heroux M. Effect of pyridoxamine treatment and subsequent thiamine rehabilitation on regional cerebral amino acids and thiamine-dependent enzymes. *J Neurochem* 1989;52:1079–84.
25. Ziporin ZZ, Nunes WT, Powell RC, et al. Thiamine requirement in the adult human as measured by urinary excretion of thiamine metabolites. *J Nutr* 1965;85:297–304.
26. Mahan LK, Escott-Stump S. Vitamins. In: *Krause's Food, Nutrition, and Diet Therapy*. Philadelphia: Saunders; 2004:93–5.
27. Patrini C, Grizziotti A, Ricciardi L. Obese individuals as thiamin storers. *Int J Obes Relat Metab Disord* 2004;28:920–4.
28. Ben Ghorbel I, Veit V, Schleinitz N, et al. Acute neuromyocarditis secondary to diet-induced beriberi. *Rev Med Intern* 2000;21:989–92.
29. Malone M. Recommended nutritional supplements for bariatric surgery patients. *Ann Pharmacother* 2008;42:1851–8.
30. MacLean LD, Rhode BM, Shizgal HM. Nutrition following gastric operations for morbid obesity. *Ann Surg* 1983;198:347–55.
31. Chang CG, Adams-Huet B, Provost DA. Acute post-gastric reduction surgery (APGARS) neuropathy. *Obes Surg* 2004;14:182–9.
32. Towbin A, Inge TH, Garcia VF, et al. Beriberi after gastric bypass surgery in adolescence. *J Pediatr* 2004;145:263–7.
33. Trumbo P, Schlicker S, Yates AA, et al. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. *J Am Diet Assoc* 2002;102:1621–30.
34. Food and Nutrition Board, Institute of Medicine. *DRI Dietary Reference Intake for Thiamin, Riboflavin, Niacin, Vitamin B₆, Folate, Vitamin B₁₂, Biotin, and Choline*. Washington DC: National Academy Press; 1998:58–86.
35. Turkki PR, Ingerman L, Schroeder LA, et al. Thiamin and vitamin B6 intakes and erythrocyte transketolase and aminotransferase activities in morbidly obese females before and after gastroplasty. *J Am Coll Nutr* 1992;11:272–82.
36. Updegraff TA, Neufeld NJ. Protein, iron, and folate status of patients prior to and following surgery for morbid obesity. *J Am Diet Assoc* 1981;78:135–40.
37. Borson-Chazot F, Harthe C, Teboul F, et al. Occurrence of hyperhomocysteinemia 1 year after gastroplasty for severe obesity. *J Clin Endocrinol Metab* 1999;84:541–5.
38. Shikora SA, Kim JJ, Tarnoff ME. Nutrition and gastrointestinal complications of bariatric surgery. *Nutr Clin Pract* 2007;22:29–40.
39. Halverson JD. Micronutrient deficiencies after gastric bypass for morbid obesity. *Am Surg* 1986;52:594–8.
40. Doscherholmen A, Swaim WR. Impaired assimilation of egg Co 57 vitamin B 12 in patients with hypochlorhydria and achlorhydria and after gastric resection. *Gastroenterology* 1973;64:913–9.
41. Robinson PD, Hogler W, Craig ME, et al. The re-emerging burden of rickets: a decade of experience from Sydney. *Arch Dis Child* 2006;91:564–8.
42. Ward LM. Vitamin D deficiency in the 21st century: a persistent problem among Canadian infants and mothers. *CMAJ* 2005;172:769–70.
43. Looker AC, Pfeiffer CM, Lacher DA, et al. Serum 25-hydroxyvitamin D status of the US population: 1988–1994 compared with 2000–2004. *Am J Clin Nutr* 2008;88:1519–27.
44. Goldner WS, O'Dorisio TM, Dillon JS, et al. Severe metabolic bone disease as a long-term complication of obesity surgery. *Obes Surg* 2002;12:685–92.
45. Institute of Medicine. *Dietary Reference Intakes for Calcium and Vitamin D*. Washington, DC: Institute of Medicine; 2010.
46. Misra M, Pacaud D, Petryk A, et al. Vitamin D deficiency in children and its management: review of current knowledge and recommendations. *Pediatrics* 2008;122:398–417.
47. Yip R, Binkin NJ, Fleshood L, et al. Declining prevalence of anemia among low-income children in the United States. *JAMA* 1987;258:1619–23.
48. Sherry B, Bister D, Yip R. Continuation of decline in prevalence of anemia in low-income children: the Vermont experience. *Arch Pediatr Adolesc Med* 1997;151:928–30.
49. Brotanek JM, Gosz J, Weitzman M, et al. Iron deficiency in early childhood in the United States: risk factors and racial/ethnic disparities. *Pediatrics* 2007;120:568–75.
50. Tussing-Humphreys LM, Liang H, Nemeth E, et al. Excess adiposity, inflammation, and iron-deficiency in female adolescents. *J Am Diet Assoc* 2009;109:297–302.
51. Decker GA, Swain JM, Crowell MD, et al. Gastrointestinal and nutritional complications after bariatric surgery. *Am J Gastroenterol* 2007;102:2571–81.
52. Smith CD, Herkes SB, Behrns KE, et al. Gastric acid secretion and vitamin B12 absorption after vertical Roux-en-Y gastric bypass for morbid obesity. *Ann Surg* 1993;218:91–6.
53. Avinoah E, Ovnat A, Charuzi I. Nutritional status seven years after Roux-en-Y gastric bypass surgery. *Surgery* 1992;111:137–42.
54. Rhode BM, Shustik C, Christou NV, et al. Iron absorption and therapy after gastric bypass. *Obes Surg* 1999;9:17–21.
55. Slater GH, Ren CJ, Siegel N, et al. Serum fat-soluble vitamin deficiency and abnormal calcium metabolism after malabsorptive bariatric surgery. *J Gastrointest Surg* 2004;8:48–55.
56. Dolan K, Hatzifotis M, Newbury L, et al. A clinical and nutritional comparison of biliopancreatic diversion with and without duodenal switch. *Ann Surg* 2004;240:51–6.
57. FDA Drug Safety Communication: low magnesium levels can be associated with long-term use of proton pump inhibitor drugs (PPIs). <http://www.fda.gov/Drugs/DrugSafety/ucm245011.htm>. Accessed November 29, 2011.
58. Kumar N, Ahlskog JE, Gross JB Jr. Acquired hypocupremia after gastric surgery. *Clin Gastroenterol Hepatol* 2004;2:1074–9.

59. Iverson D, McKenzie M. Neurologic complications of gastric bypass surgery for morbid obesity. *Neurology* 2008;70:324.
60. Bloomberg RD, Fleishman A, Nalle JE, et al. Nutritional deficiencies following bariatric surgery: what have we learned? *Obes Surg* 2005;15:145–54.
61. von Drygalski A, Andris DA. Anemia after bariatric surgery: more than just iron deficiency. *Nutr Clin Pract* 2009;24:217–26.
62. Lichtenstein AH, Appel LJ, Brands M, et al. Diet and lifestyle recommendations revision 2006: a scientific statement from the American Heart Association Nutrition Committee. *Circulation* 2006;114:82–96.
63. American Academy of Pediatrics. *Pediatric Nutrition Handbook*. Elk Grove Village, IL: AAP; 2009.
64. Institute of Medicine Food and Nutrition Board. *Dietary Reference Intakes: Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride*. Washington, DC: National Academy Press; 1997.
65. Biesemeier CK GJ. *ADA Pocket Guide to Bariatric Surgery/Weight Management Dietetic Practice Group*. Chicago: American Dietetic Association; 2009.
66. Brolin RE, LaMarca LB, Kenler HA, et al. Malabsorptive gastric bypass in patients with superobesity. *J Gastrointest Surg* 2002;6:195–203.
67. Warde-Kamar J, Rogers M, Flancbaum L, et al. Calorie intake and meal patterns up to 4 years after Roux-en-Y gastric bypass surgery. *Obes Surg* 2004;14:1070–9.
68. Odom J, Zalesin KC, Washington TL, et al. Behavioral predictors of weight regain after bariatric surgery. *Obes Surg* 2010;20:349–56.
69. Sallet PC, Sallet JA, Dixon JB, et al. Eating behavior as a prognostic factor for weight loss after gastric bypass. *Obes Surg* 2007;17:445–51.
70. Faria SL, Kelly E, Faria OP. Energy expenditure and weight regain in patients submitted to Roux-en-Y gastric bypass. *Obes Surg* 2009;19:856–9.
71. ACOG Committee Opinion number 315, September 2005. Obesity in pregnancy. *Obstet Gynecol* 2005;106:671–5.
72. Moliterno JA, DiLuna ML, Sood S, et al. Gastric bypass: a risk factor for neural tube defects? *J Neurosurg Pediatr* 2008;1:406–9.
73. Haddow JE, Hill LE, Kloza EM, et al. Neural tube defects after gastric bypass. *Lancet* 1986;1:1330.
74. Martin L, Chavez GF, Adams MJ Jr, et al. Gastric bypass surgery as maternal risk factor for neural tube defects. *Lancet* 1988;1:640–1.
75. Rand C, MacGregor A. Adolescents having obesity surgery: a 6-year follow-up. *South Med J* 1994;87:1208–13.
76. Coupaye M, Puchaux K, Bogard C, et al. Nutritional consequences of adjustable banding and gastric bypass: a 1-year prospective study. *Obes Surg* 2009;19:56–65.
77. Cunningham E. What effect does weight-loss surgery have on pregnancy outcomes? *J Am Diet Assoc* 2009;109:772.
78. Kombol P. ILCA's Inside Track: a resource for breastfeeding mothers. Breastfeeding after weight loss surgery. *J Hum Lact* 2008;24:341–2.
79. Martens WS 2nd, Martin LF, Berlin CM Jr. Failure of a nursing infant to thrive after the mother's gastric bypass for morbid obesity. *Pediatrics* 1990;86:777–8.
80. Celiker MY, Chawla A. Congenital B12 deficiency following maternal gastric bypass. *J Perinatol* 2009;29:640–2.
81. Wardinsky TD, Montes RG, Friederich RL, et al. Vitamin B12 deficiency associated with low breast-milk vitamin B12 concentration in an infant following maternal gastric bypass surgery. *Arch Pediatr Adolesc Med* 1995;149:1281–4.
82. Powers PS, Rosemurgy A, Boyd F, et al. Outcome of gastric restriction procedures: weight, psychiatric diagnoses, and satisfaction. *Obes Surg* 1997;7:471–7.
83. Bauchowitz AU, Gonder-Frederick LA, Olbrisch ME, et al. Psychosocial evaluation of bariatric surgery candidates: a survey of present practices. *Psychosom Med* 2005;67:825–32.
84. Scheimann AO, Butler MG, Gourash L, et al. Critical analysis of bariatric procedures in Prader-Willi syndrome. *J Pediatr Gastroenterol Nutr* 2008;46:80–3.
85. Buchwald H, Avidor Y, Braunwald E, et al. Bariatric surgery: a systematic review and meta-analysis. *JAMA* 2004;292:1724–37.
86. Chevallier JM, Paita M, Rodde-Dunet MH, et al. Predictive factors of outcome after gastric banding: a nationwide survey on the role of center activity and patients' behavior. *Ann Surg* 2007;246:1034–9.