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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 comprehensive nutrition 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 adolescent undergoing WLS.

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

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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.

TABLE 1. Considerations for nutritional screening

<table>
<thead>
<tr>
<th>Nutrient deficiency</th>
<th>Prevalence in adults</th>
<th>Screening laboratories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamin (B₁)</td>
<td>15%–29% (more often in African Americans/Hispanics)</td>
<td>Blood thiamin level, erythrocyte thiamin transketolase, or transketolase urinary thiamin excretion</td>
</tr>
<tr>
<td>Cobalamin (B₁₂)</td>
<td>10%–13%</td>
<td>Serum homocysteine level, urine/serum methylmalonic acid level, and/or serum vitamin B₁₂ level</td>
</tr>
<tr>
<td>Iron</td>
<td>9%–16% of women (risk factors girl, anemic/heavy menses, low dietary intake)</td>
<td>Serum iron, serum ferritin, total iron-binding capacity</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>60%–70% (risk factors sedentary, indoors, darker skin)</td>
<td>25-Hydroxy vitamin D level</td>
</tr>
<tr>
<td>Folate</td>
<td>20% (risk factors high-fat diets)</td>
<td>Serum homocysteine level and/or serum folate or red blood cell folate level</td>
</tr>
</tbody>
</table>

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
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

<table>
<thead>
<tr>
<th>Initial nutrition assessment</th>
<th>Nutrition educational session regarding food quality choices</th>
<th>Nutrition education regarding food quantity choices for preoperative energy needs</th>
<th>Nutrition education regarding liquid meal plans</th>
<th>Review of accuracy of liquid meal plans and, if adequate, then nutrition education regarding smooth food meal plans</th>
<th>Review of smooth food meal plans and, if adequate, review of questions/concerns regarding post op meal plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>WLS = weight loss surgery.</td>
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</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Stage 1: ice chips, water, sugar-free clear liquids</th>
<th>Stage 2: full liquids, high protein</th>
<th>Stage 3: smooth consistency foods and liquids</th>
<th>Stage 4: soft foods</th>
<th>Stage 5: all textures—healthy foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roux-en-Y</td>
<td>1 oz/h for the first 24–48 h, then for 3–7 days ad lib</td>
<td>Wk 2–4</td>
<td>Wk 4–6</td>
<td>Wk 7–9</td>
</tr>
<tr>
<td>Gastric band</td>
<td>1 oz/h for the first 24–48 h</td>
<td>First 2 wk after surgery</td>
<td>Wk 3–4</td>
<td>Wk 5–6</td>
</tr>
<tr>
<td>Sleeve gastrectomy</td>
<td>1 oz/h for the first 24–48 h, then for 3–7 days ad lib</td>
<td>Wk 1–5</td>
<td>Wk 5–8</td>
<td>9–12 wk postop</td>
</tr>
</tbody>
</table>
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 4. Postoperative diet by stages

<table>
<thead>
<tr>
<th>Stage</th>
<th>Goals per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1: sugar-free clear liquids</td>
<td>4–6 oz of water or sugar-free clear liquids per hour (48–64 oz/day)</td>
</tr>
<tr>
<td></td>
<td>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</td>
</tr>
<tr>
<td></td>
<td>Sugar-free clear restrictions: no carbonated beverages, no caffeine, no red dye</td>
</tr>
<tr>
<td>Stage 2: high-protein full liquids</td>
<td>Calories: 500–600 kcal</td>
</tr>
<tr>
<td></td>
<td>Protein: 50–60 g</td>
</tr>
<tr>
<td></td>
<td>Fluid: 80–90 oz or based on estimated requirements</td>
</tr>
<tr>
<td></td>
<td>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</td>
</tr>
<tr>
<td></td>
<td>Meal pattern: 3–6 meals per day</td>
</tr>
<tr>
<td></td>
<td>Volume: ½ cup per meal for solid foods</td>
</tr>
<tr>
<td>Stage 3: smooth consistency high-protein foods</td>
<td>Calories: 500–700 kcal</td>
</tr>
<tr>
<td></td>
<td>Protein: 60 g</td>
</tr>
<tr>
<td></td>
<td>Fluid: 80–90 oz (or based on estimated requirements)</td>
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<tr>
<td></td>
<td>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</td>
</tr>
<tr>
<td></td>
<td>Consistency of food: smooth</td>
</tr>
<tr>
<td></td>
<td>Try new foods 1 at a time (¼ cup) every 2–3 d</td>
</tr>
<tr>
<td></td>
<td>Meal pattern: 3–4 meals per day</td>
</tr>
<tr>
<td></td>
<td>Volume: ½ cup per meal for solid foods or 5–6 oz per meal of protein drink</td>
</tr>
<tr>
<td>Stage 4: soft foods—other protein foods, fruit, vegetables, and grains</td>
<td>Calories: 700–800 kcal</td>
</tr>
<tr>
<td></td>
<td>Protein: 60 g</td>
</tr>
<tr>
<td></td>
<td>Fluid: 80–90 oz (or based on estimated requirements)</td>
</tr>
<tr>
<td></td>
<td>New foods introduced: protein foods: shaved delicatessen meats, low-fat cheese, lean pork, cooked beans</td>
</tr>
<tr>
<td></td>
<td>Fruit: soft or canned in own juice, no skin</td>
</tr>
<tr>
<td></td>
<td>Vegetables: soft cooked or canned</td>
</tr>
<tr>
<td></td>
<td>Grains: toast, low-sugar cereal, crackers, oat meal, rice, pasta, mashed potatoes (choose mainly whole-grain products, foods)</td>
</tr>
<tr>
<td></td>
<td>Meal pattern: 3–6 meals per day</td>
</tr>
<tr>
<td></td>
<td>Volume: ½–1 cup per meal solid foods or 1 cup (8 oz) protein drink</td>
</tr>
<tr>
<td>Stage 5: healthy foods for life</td>
<td>Calories 800–900 kcal</td>
</tr>
<tr>
<td></td>
<td>Protein: 60 g</td>
</tr>
<tr>
<td></td>
<td>Fluids: 80–90 oz (or based on estimated requirements)</td>
</tr>
<tr>
<td></td>
<td>New foods introduced: all healthy food choices</td>
</tr>
<tr>
<td></td>
<td>Meal pattern: 3–6 meals per day</td>
</tr>
<tr>
<td></td>
<td>Volume: Up to ¾ to 1½ cup per meal</td>
</tr>
</tbody>
</table>

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).
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 (25).

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 stockinette 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 gastropasty 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 ages 14 to 18 years (33,34). For individuals undergoing malabsorptive/restrictive procedures, supplemenations 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 postsurgical 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 gastropasty 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 anecdotally 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 (e.g., 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 rate 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

<table>
<thead>
<tr>
<th>Population</th>
<th>Hgb, g/dL</th>
<th>HCT, %</th>
<th>MCV, fL</th>
<th>% TIBC sat.</th>
<th>Ferritin, μg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>12–15-yr-old girl</td>
<td>&lt;11.8</td>
<td>&lt;35.7</td>
<td>&lt;81</td>
<td>&lt;16</td>
<td>&lt;18</td>
</tr>
<tr>
<td>12–15-yr-old boy</td>
<td>&lt;12.5</td>
<td>&lt;37.3</td>
<td>&lt;82</td>
<td>&lt;16</td>
<td>&lt;15</td>
</tr>
<tr>
<td>&gt;15-year-old girl</td>
<td>&lt;12</td>
<td>&lt;35.7</td>
<td>&lt;85</td>
<td>&lt;16</td>
<td>&lt;15</td>
</tr>
<tr>
<td>&gt;15-year-old boy</td>
<td>&lt;13.3</td>
<td>&lt;39.7</td>
<td>&lt;85</td>
<td>&lt;16</td>
<td>&lt;15</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Nutritional factor (B₃)</th>
<th>Laboratory parameter</th>
<th>Normal value</th>
<th>Effects of deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamin (B₁)</td>
<td>Red blood cell transketolase stimulation</td>
<td>&lt;15%</td>
<td>Beriberi, neuritis, edema, cardiac failure, anorexia, hoarseness, restlessness, aphonia</td>
</tr>
<tr>
<td>Pyridoxine (B₆)</td>
<td>Plasma PLP</td>
<td>&lt;20 nmol/L</td>
<td>Neuropathy, photosensitivity</td>
</tr>
<tr>
<td>Folic acid (B₉)</td>
<td>Serum folate, RBC folate, homocysteine</td>
<td>&gt;6 ng/mL, &gt;160 ng/mL</td>
<td>Megaloblastic anemia, irritability, paranoid behavior</td>
</tr>
<tr>
<td>Cobalamin (B₁₂)</td>
<td>Urine/serum B₁₂⁺</td>
<td>&lt;3.60 mmol/mol creatinine or 200–900 pg/mL</td>
<td>Pernicious anemia, neurological deterioration</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>Plasma retinol</td>
<td>20–72 μg/dL</td>
<td>Night blindness, xerophthalmia, dermatomalacia, impaired resistance to infection, follicular hyperkeratosis, poor bone growth</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ionized calcium</td>
<td>4.48–4.92 mg/dL</td>
<td>Numbness and tingling in the fingers, muscle cramps, convulsions, lethargy, poor appetite, and abnormal heart rhythms</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>Serum 25-OHD</td>
<td>&lt;50 nmol/L</td>
<td>Rickets, osteomalacia</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Plasma vitamin C</td>
<td>0.2–2 mg/dL</td>
<td>Bleeding gums, diarrhea, perifollicular hemorrhage, scurvy</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>Plasma α-tocopherol</td>
<td>0.7–10 mg/dL</td>
<td>Hyporeflexia spinocerebellar and retinal degeneration</td>
</tr>
<tr>
<td>Zinc</td>
<td>Serum zinc</td>
<td>0.75–1.2 mg/L</td>
<td>Anorexia, hypoguesia, delayed growth or sexual maturation, impaired wound healing</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Serum magnesium</td>
<td>1.5–2.0 mg/dL</td>
<td>Convulsions, neuropsychiatric disorders, hypomagnesemia</td>
</tr>
<tr>
<td>Copper</td>
<td>Serum copper</td>
<td>1.10–1.45 mg/L</td>
<td>Microcytic, hypochromic anemia, delayed growth osteoporosis, neutropenia</td>
</tr>
</tbody>
</table>

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.

Reproductive Health

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.
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 a breast-fed infant born postgastric bypass 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 dietitian 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 Bauchwitz 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


