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Review article

Medical nutrition therapy for post-bariatric hypoglycemia: practical insights

Emmy Suhl, M.S., R.D., C.D.E.[a], Sue-Ellen Anderson-Haynes, R.D.[a], Christopher Mulla, M.D.[a,b,c], Mary-Elizabeth Patti, M.D., F.A.C.P.[a,b,c,*]

[a]*Hypoglycemia Clinic, Joslin Diabetes Center, Boston MA*
[b]*Research Division, Joslin Diabetes Center, Boston, MA*
[c]*Harvard Medical School, Boston, MA*

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Abstract Hypoglycemia is increasingly recognized as a complication of bariatric surgery. Although medications are often required, medical nutrition therapy remains the key cornerstone for successful prevention of hypoglycemia in patients with post-bariatric hypoglycemia (PBH). We provide suggested approaches to the dietary management of PBH, incorporating data from both the medical literature and extensive clinical experience in an academic referral center for PBH. The overall goal of medical nutrition therapy for PBH is to reduce postprandial surges in glucose, which often trigger surges in insulin secretion and promote subsequent hypoglycemia. Thus, strategies focus on controlled portions of low glycemic index carbohydrates, avoidance of rapidly-absorbed carbohydrates, adjustment of timing of meals and snacks, and attention to personal and cultural barriers to implementation. (Surg Obes Relat Dis 2017;13:888–898.)

Keywords: Hypoglycemia; Bariatric surgery; Medical nutrition therapy

Hypoglycemia is an increasingly recognized complication of bariatric surgery, occurring after both Roux-en-Y gastric bypass and vertical sleeve gastrectomy [1–5]. Post-bariatric hypoglycemia (PBH) typically occurs 1–3 hours after meals, with increased severity after intake of high glycemic index carbohydrates [6,7]. In our clinical experience, some patients also experience hypoglycemia with even modest degrees of activity (e.g., household chores, grocery shopping).

Both insulin-dependent and insulin-independent mechanisms contribute to PBH. After eating, food rapidly enters into the proximal intestine, contributing to rapid rises in blood glucose (within 15 to 30 minutes), often to quite high levels (e.g., over 200 mg/dL) [7]. Food intake also stimulates excessive secretion of intestinal incretin hormones, including glucagon-like peptide-1 [7–10]. Both high glucose and incretin hormones trigger excessive insulin secretion, promoting subsequent rapid drops in glucose, with nadir typically between 90 to 180 minutes after eating [11]. Additionally, increased sensitivity of pancreatic β-cells to glucose, reduced insulin clearance, and insulin-independent glucose uptake may also contribute to hypoglycemia [7,12,13]. Fig. shows a typical postprandial glucose pattern in patient with PBH, with rapid increase in glucose early after the meal (typically within 30 minutes), followed by rapid decline to hypoglycemic range.

Recognizing potential symptoms of hypoglycemia in the post-bariatric patient is important to begin prompt diagnostic evaluation and treatment. Symptoms (Table 1) are varied and overlap with other conditions, including anxiety, cardiac arrhythmias, and seizures, sometimes delaying recognition.

*Correspondence: Mary-Elizabeth Patti, M.D., F.A.C.P., Joslin Diabetes Center, 1 Joslin Place, Boston, MA, 02215.
E-mail: mary.elizabeth.patti@joslin.harvard.edu

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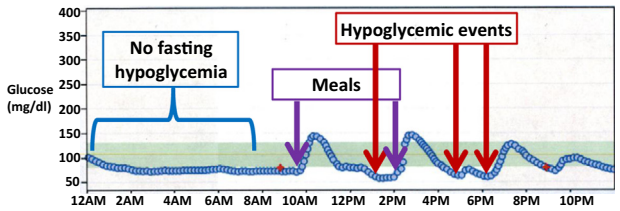

Fig. Typical patterns of glucose in the fasting state and after a meal in patients with PBH, as revealed by continuous glucose monitoring. In this patient, glucose levels are stable during the overnight fast.

The first critical step is to determine whether symptoms are truly linked to hypoglycemia, requiring assessment of plasma glucose at the time of symptoms. This is often challenging, as patients may not be able to safely go to a laboratory for blood testing; a suboptimal but practical alternative is to use a glucometer or diagnostic continuous glucose monitoring. Hypoglycemia is less likely if glucose is normal at the time of symptoms; if so, dumping syndrome or cardiovascular causes should be considered. If low glucose is detected at the time of symptoms, then clinicians still need to verify low plasma glucose after a typical stimulus (e.g., provocative meal), and confirm that symptoms resolve with elevation of glucose. If these Whipple's triad criteria are fulfilled (symptoms, low venous glucose, resolution with elevation in glucose), the diagnosis of hypoglycemia is supported [14].

Assessment of hypoglycemia patterns, in relation to meals, fasting, activity, magnitude of alcohol consumption, medications, and other medical conditions, is important. PBH typically presents with postprandial hypoglycemia, occurring within 1–3 hours after eating. Hypoglycemia which also occurs in the fasting state should raise suspicion for autonomous secretion of insulin by an insulinoma or other hormonal or metabolic disorders [15]. Next, biochemical evaluation should be performed to determine whether hypoglycemia is associated with inappropriately increased insulin levels. Traditional approaches include either overnight outpatient fasting (if history suggests this can be accomplished safely) or prolonged inpatient fasting, with measurements of insulin, C-peptide, β-hydroxybutyrate, and the counterregulatory hormones cortisol and glucagon. In patients with PBH, glucose and insulin levels are normal with fasting, but insulin secretion in excessive in the postprandial state [7].

Once hypoglycemia has been fully evaluated and PBH is diagnosed, medical nutrition therapy (MNT) is the first step to reduce postprandial surges in glucose, as these "spikes" in glucose often trigger excessive insulin secretion and promote subsequent hypoglycemia. While medications may also be needed to control hypoglycemia in some patients (see Patti et al., 2015 [13], for more information), MNT remains the cornerstone of therapy.

In this review, we provide suggested approaches to the dietary management of PBH aimed at the practicing bariatric clinician, incorporating data from both the medical literature and extensive clinical experience in an academic referral center for PBH. Strategies focus on controlled portions of low glycemic index carbohydrates, avoidance of rapidly-absorbed carbohydrates, adjustment of timing of meals and snacks, and attention to personal and cultural barriers to implementation.

Prevention of hypoglycemia in post-bariatric patients

Once hypoglycemia has been fully evaluated, MNT is the cornerstone of treatment to prevent or reduce the frequency and severity of hypoglycemia, even when additional medications are also needed.

In our practice, we have successfully used a 10-point nutrition plan for the prevention of hypoglycemia, while ensuring adequate nutrient intake (Table 2). The overall goal is to reduce the magnitude and rate of the blood glucose rise after eating, reducing stimulus for insulin secretion and subsequent hypoglycemia. Key components include:

1. Control portions of carbohydrate—30 g per meal, 15 g per snack

Carbohydrate ingestion is a particularly robust stimulus for increasing blood glucose and thus insulin secretion in

Table 1
Symptoms which should raise concern for PBH

Adrenergic Symptoms	Neuroglycopenic Symptoms	Cholinergic Symptoms
Tremor	Weakness	Sweating
Palpitations	Difficulty concentrating/ thinking	Hunger
		Paresthesias
Anxiety	Seizure	Often nonspecific
	Coma	
	Unawareness or no symptoms	
	Drowsiness	
	Nightmares/bizarre dreams	
	Morning headaches	

PBH = Post-bariatric hypoglycemia

Table 2
10-Point nutrition plan for preventing hypoglycemia in post-bariatric hypoglycemia

1. Control portions of carbohydrate – 30 g/meal, 15 g/snack.
2. Choose low-glycemic carbohydrates.
3. Avoid high-glycemic carbohydrates.
4. Include (heart-healthy) fats in each meal or snack – 15 g/meal, 5 g/snack.
5. Emphasize optimal protein intake.
6. Space meals/snacks 3–4 h apart.
7. Avoid consuming liquids with meals.
8. Avoid alcohol.
9. Avoid caffeine.
10. Maintain post-bariatric vitamin and mineral intake.

post-bariatric patients. Some patients with PBH are even more sensitive to carbohydrates, potentially due to excessive intestinal glucose absorption. Thus, limiting carbohydrate reduces the postprandial glucose rise and insulin secretion. This concept was confirmed in one study, which demonstrated that a high carbohydrate (80 g), low protein (10 g) meal led to significant hyperinsulinemia and hypoglycemia, while an isocaloric very low carbohydrate (2 g), high protein meal (25 g) prevented excessive insulin secretion or postprandial hypoglycemia [16]. While this degree of carbohydrate restriction makes compliance challenging and may not be optimal for the long-term, few studies address the optimal quantity of carbohydrates. In one study, limiting a test meal to 30 g of solid carbohydrate or 28 g of liquid low glycemic index supplement was successful in preventing hypoglycemia in patients with PBH [17]. A third study in 10 patients with PBH evaluated the relative carbohydrate composition of a test meal; a high carbohydrate meal containing mostly sucrose provoked postprandial hypoglycemia, while an isocaloric high-carbohydrate meal composed of fructose was associated with lower glycemic peak, lower insulin secretion, and no induction of hypoglycemia [18]. The mechanisms responsible for the differential glycemic effect of fructose are not entirely clear. Fructose can stimulate both incretin and insulin secretion [19], but differential absorption patterns and hepatic metabolism of fructose versus glucose could contribute to differential prandial glucose patterns [20]. Moreover, an unanswered question is whether the greater effect of fructose to promote hepatic lipogenesis could produce long-term health effects [21]. Nevertheless, some patients utilize pure fructose (available commercially) as a substitute carbohydrate, especially for baking.

In our experience, 1g of carbohydrate can raise blood glucose an average of 3 mg/dL. Thus, a 30-g carbohydrate meal may increase glucose by $\approx$100 mg/dL, and a 15 g carbohydrate snack may increase glucose by $\approx$50 mg/dL. It is important to recognize that there is substantial variability in glucose "spikes" between individuals, and even from day to day, potentially related to rate of delivery of foods to the intestine, rates of glucose absorption by the proximal intestine, time of day, and other metabolic factors [22]. One recent study demonstrated that carbohydrate restriction to $<$30 g per meal was effective to reduce the frequency and severity of hypoglycemia episodes [23].

A registered dietician can teach patients how to count carbohydrate grams to meet these goals, with the assistance of online tools/apps (e.g., CalorieKing.com, GoMeals.com) and reference databases (e.g., USDA National Nutrient Database for Standard Reference: https://ndb.nal.usda.gov/ndb/search/list). Patients should be counseled that carbohydrates are needed as fuel for the body, so complete elimination is not advised, as this, too, could reduce carbohydrate stores (glycogen) and potentially promote more severe or prolonged hypoglycemia. Rather, limiting quantity and choosing only low glycemic index carbohydrates (#2) is critical. Of course, carbohydrate goals need to be individualized upon review of food diary and glucose patterns.

2. *Choose low glycemic index carbohydrates*

Low glycemic index carbohydrates are digested relatively slowly. We have found that low glycemic index carbohydrates slow the postprandial rise in glucose, resulting in fewer postprandial glucose "spikes" and, therefore, less postprandial hypoglycemia. Table 3 provides a list of low glycemic foods that have proved successful in limiting postprandial hypoglycemia for many of our patients. An extensive glycemic index table may be accessed at www.glycemicindex.com. In general, carbohydrates which are highly processed are not low glycemic index. As noted above, one study demonstrated that substitution of fructose for sucrose could reduce hypoglycemia [18]; the long-term effects of increasing fructose intake in this context remain unknown. Again, responses to specific foods vary considerably, so initial advice needs to be modified for each patient after reviewing glucose patterns.

Some patients find that avoiding high glycemic index carbohydrates, especially pasta and bread, is very challenging. Patients might consider substituting pasta made from 100% whole wheat or protein-supplemented pasta in carefully measured, small quantities. Pasta-like products made from thinly-sliced vegetables (e.g., zucchini, spaghetti squash) may be helpful. Asian noodles made from glucomannan can provide desired pasta flavor/texture, but it is important that these noodles be consumed with plenty of fluid, and not at bedtime, to avoid risk of obstruction [24]. Some patients find that enzyme-enriched high fiber wheat products (e.g., carbalose) are useful as a substitute for regular flour when baking. High doses of pectin (e.g., 14.5 g), a complex plant-based polysaccharide, have been shown to reduce postprandial hypoglycemia in postgastric surgery patients when added to meals containing carbohydrates; however, quantities sufficient to prevent hypoglycemia are often poorly tolerated, and lower doses are ineffective [25,26].

Table 3
Low glycemic index carbohydrates to choose

- Steel-cut oats (regular, not quick-cook or instant)
- Oat bran cereal
- Beans/legumes (e.g., garbanzo, navy, kidney, lima, pinto, black-eyed and pea beans, edamame [soybeans], lentils)
- Bean products (e.g., hummus, tofu)
- Pearled barley, cooked al dente
- Yams
- Some fruits (e.g., grapefruit, apples, pears, berries, apricots, peaches)
- Some pasta (e.g., Barilla Plus pasta), cooked al dente
- Some whole grain breads (e.g., Ezekiel bread, Joseph's Flax, Oat Bran & Whole Wheat Pita/Lavash/Tortillas)
- Some whole grain crackers (e.g., RyKrisp, RyVita, Wasa)

3. Avoid high glycemic index carbohydrates

High glycemic index carbohydrates are digested relatively quickly, contributing to rapid increases in blood glucose, further stimulation of excessive secretion of insulin postprandially, and more postprandial hypoglycemia compared with low glycemic index carbohydrates. Table 4 provides a list of high glycemic index carbohydrates that typically exacerbate postprandial hypoglycemia in our patients.

4. Include heart-healthy fats in each meal and snack

Fat can reduce gastric emptying and reduce postprandial "spikes" in glucose in patients with type 1 diabetes [27]. However, the magnitude of this effect is reduced in patients who have had gastric bypass, since emptying of foods from the pouch to the roux limb occurs very rapidly. While fat intake before a meal prolonged overall intestinal transit time, glucose excursions were not markedly affected by a fat preload in a recent study [28]. Nevertheless, fats are also beneficial as they are a source of calories which do not typically trigger insulin secretion/hypoglycemia independently, and thus may be considered a more "safe" food [22]. While any fat can produce this result, we recommend heart-healthy fats (Table 5). While many patients have difficulty overcoming the ingrained notion that fats are high-calorie foods which should be avoided at all cost, emphasizing that healthy fats are not only required for good health but also can serve as a substitute calorie source to compensate for the reduction in carbohydrates may be helpful.

5. Emphasize adequate protein intake

A general rule of thumb is that post-bariatric patients should consume about 30 g of protein at each meal [29,30]. The American Society of Metabolic and Bariatric Surgery recommends at least 60–80 g/d [31], while other guidelines suggest 1.5–2.1 g/kg of ideal weight or .91 g/kg actual weight [32]. We typically begin with .9 protein/kg actual weight to estimate protein needs. Preferred protein sources are those with high biological value such as meat, chicken, egg whites, fish, and milk, and high quality non-animal proteins such as soy.

Excessive protein intake is not desirable, as it may displace other nutrients in the diet. In some patients, excessive liquid protein intake may also contribute to hypoglycemia, as proteins also robustly stimulate insulin secretion [28]. If the patient consumes protein shakes, the shake should be moderately low in carbohydrate and include a high quality source of protein. 100% Whey protein isolate powder is preferred, but soy protein powder is an option. According to the Obesity Action Coalition, whey protein isolates have lower lactose and more protein compared with whey protein concentrates [33]. We recommend that the shake contain 20–30 g protein, 15 g carbohydrate, and about 10 g of fat per serving. Protein can be blended with low-fat or skim milk, low glycemic index fruits or ice, and optional flavor extracts. Natural nut butters (containing no added sugar or corn syrup) can be added as a source of healthy fat, and uncooked cornstarch added to provide very complex, slowly metabolized carbohydrate.

Given that dietary strategies for PBH center on limiting carbohydrates to minimize postprandial glycemic surges, it is clear that protein and healthy fats must make up the difference for a weight maintenance meal plan. This is a very individualized and iterative process. We begin with limiting carbohydrates to a suggested cap of 30 g per meal and 15 g per snack [23], regardless of weight. Protein and healthy fats will make up the balance to achieve protein and calorie goals. Recommendations for protein are typically .9 g/kg of actual weight. We typically initiate fat intake goals using a ratio of 2 g of fat for every 3 g of carbohydrate. These calculations typically yield a caloric distribution of $\approx$ 30% carb, 45%–50% fat, and 20%–25% protein but differ according to patient weight (in which case protein percentage will be higher) and glucose patterns in response to initial dietary plan.

6. Space meals/snacks 3–4 hours apart

A small meal or snack will likely be completely digested in 3–4 hours. We recommend a healthy meal/snack (following the above guidelines) every 3–4 hours, especially if the patient engages in physical activity.

7. Avoid consuming liquids with meals and chew foods slowly and thoroughly

Hypoglycemia is sometimes a component of the "dumping syndrome" and can follow both gastric bypass and

Table 4
High glycemic index carbohydrates to avoid

- Refined breakfast cereals (e.g., Corn Flakes, Rice Krispies, Cream of Rice, instant oatmeal)
- Regular pasta
- Most starchy vegetables (e.g., white potatoes, corn, winter [orange] squash)
- White rice, rice cakes
- Popcorn, pretzels, chips
- Some fruits (e.g., ripe bananas, pineapple, mango, watermelon, grapes)
- All fruit juices and sweetened drinks (e.g., sodas, sweetened iced tea)
- Bread, rolls, bagels, English muffins, and crackers made with refined flour
- Sweets (e.g., candy, cake, cookies, ice cream, syrup)

Table 5
Heart-healthy fats

- Nuts, nut butters
- Avocado, guacamole
- Olives
- Most plant oils (e.g., olive, canola, peanut, soy, sunflower, sesame)
- Most seeds (e.g., sunflower, flax, sesame/sesame tahini)
- Oily fish (e.g., salmon, bluefish, mackerel, tuna, sardines)

sleeve gastrectomy [34]. Indeed, hormonal responses in patients with "dumping" are similar to those in patients with severe post-bypass hypoglycemia, including rapid surges in glucose and incretin and insulin secretion [35,36]. Dietary management of the dumping syndrome includes recommendations to avoid ingesting liquids with meals, to attenuate rapid delivery of nutrients to the intestine, glucose absorption, and increased insulin secretion [37]. Thus, water or noncarbonated low calorie caffeine-free beverages should be separated from meals by at least 30–60 minutes. Eating slowly, over 30–60 minutes, with thorough chewing of small bites of food, is a challenging goal but can also be helpful to reduce dumping symptoms [36].

8. Avoid alcohol

During metabolism of alcohol by the liver, the production of glucose by the liver is reduced, increasing the risk for hypoglycemia. Alcohol intake can also compromise B vitamin absorption, such as B1 and B12, and is thus undesirable in bariatric patients already at risk for vitamin deficiency.

9. Avoid caffeine

Among caffeine-sensitive individuals, caffeine can rapidly increase blood glucose via increased hepatic glucose production and decreased glucose uptake into skeletal muscle; in some studies, caffeine increased insulin levels [38]. While the net impact is uncertain for any specific patient, we advise patients to attempt a trial of caffeine reduction to assess impact on hypoglycemia.

10. Maintain post-bariatric vitamin and mineral intake

Patients with PBH typically present for evaluation of hypoglycemia several years postoperatively. A frequent misconception is that strict attention to vitamin and mineral supplementation is no longer needed. While we are unaware of any evidence that vitamin deficiencies contribute to frequency or severity of hypoglycemia, evaluation of vitamin and mineral status is critical for any post-bariatric patient. This may be especially important for in patients with hypoglycemia who may be attempting to self-treat hypoglycemia by limiting specific foods. Recommendations by the American Society for Metabolic and Bariatric Surgery include: multivitamins with minerals, oral or sublingual B12, iron, B complex vitamins, calcium citrate, and vitamin D (Table 6). Repeated emphasis on the importance of vitamins and mineral supplements is often helpful.

Key components for successful MNT education

Clinical experience in working with patients with PBH has revealed several key components for successful MNT.

Emphasize food as friend rather than foe. Changing food habits is difficult. Typically, PBH patients have spent years, if not decades, trying to lose weight. They have tried multiple diets which promised weight loss if only they would eat this instead of that, and received meal plans from weight loss centers or dieticians. Typically, they have gotten the message that protein foods are "good" and carbohydrate and fat are "bad." With the onset of hypoglycemia, many patients are advised to eat frequently (e.g., every 2 h or with symptoms). Not surprisingly, changing messages and resulting weight gain can lead to frustration.

Table 6
Recommended vitamin supplementation after bariatric surgery [29,31]

Supplement	Recommendations for the Post-bariatric Surgery Patient
Multivitamin-multimineral: • Begin with chewable or liquid, progress to whole tablet/capsule	200% of daily value (2 per d)
Vitamin B12: • Sublingual tablets, liquid drops, or mouth spray; if inadequate response, intramuscular injection may be needed • Note >1000 mg of supplemental folic acid combined with multivitamin supplements may mask B12 deficiency	1000 μg/mo intramuscularly Sublingual/oral tablet dose: 350-500 ug/day to start, may need to increase dose
Calcium Citrate and Vitamin D3 • Begin with chewable or liquid, progress to whole tablet/capsule • Split into 500–600 mg dose • Do not combine with iron containing supplements. Wait >2 h after taking multivitamin or iron supplement	1500–2000 mg/d Calcium Citrate 1500–2000 IU/d Vit D3 (with dose adjustments guided by laboratory assessment of vitamin D levels)
Iron • Recommended for menstruating women and those at risk for anemia. Begin with chewable or liquid, progress to tablet.	18–27 mg/d elemental iron
B complex vitamins • Liquid form, avoid time-released tablets	Vitamin B-50 complex 1 per d

Thus, to be successful, we need to partner with patients to convince them that the 10-point nutrition plan can help them with their problem, that is, that food can be their friend instead of their enemy. We usually suggest trying the meal plan for a week to assess impact on reducing frequency of hypoglycemia. If not, they can abandon it without incurring either side effects or significant expense. If the plan helps them, they will gain relief and may even begin to lose at least some of the weight they may have recently regained.

Careful dietary assessment is essential! Individuals vary significantly in their response to foods, requiring detailed and personalized assessment of response to different foods/food combinations.

This is best accomplished with the aid of a food diary, which includes records of hypoglycemic events and the foods consumed during several hours before each hypoglycemic event. Pay particular attention to foods/food combinations and time of day that are repeatedly associated with hypoglycemia. It is helpful to use food models to assess portion sizes and elicit preparation methods. Do not assume that low glycemic index foods are unrelated to low blood glucoses, as responses differ from person to person.

Careful dietary assessment can help our patients discover which foods/meals work for them and which do not. Emphasize that instructions are general, and need to be modified as experience is gained.

Continuous glucose monitoring systems (CGMS), while not perfect, can improve the utility of a comprehensive dietary assessment. CGMS record interstitial fluid glucose levels every 5 minutes. If properly calibrated, CGMS-measured interstitial glucose closely approximates blood glucose levels at steady-state, but may lag behind blood glucose when glucose is changing rapidly, as in the postprandial state [39]. With CGMS, a patient's glucose response to food can be immediately and precisely captured and then correlated with the patient's food diary. CGMS are particularly useful for detecting hypoglycemia overnight, when the patient may not be aware of hypoglycemia. Thus, foods and other provocative factors can be identified.

Barriers to successful MNT

In our experience, the barriers to dietary change can be formidable, including:

1. Suboptimal nutrition knowledge

Unfortunately, many patients who have embarked on a bariatric surgical program have limited nutrition background and prior professional counseling. Many enter the program with high anxiety, unrealistic goals for weight loss and postoperative body changes, and inadequate understanding of the long-term dietary changes and attention to nutrition that are needed for successful weight loss and health. Despite robust preoperative counseling, many patients who present with hypoglycemia (typically 2–3 yr postoperatively) may require a refresher of basic nutrition concepts as well as specific counseling about medical nutrition therapy tailored to avoidance of hypoglycemia.

2. Food habits

Suboptimal food habits, either longstanding or learned in the early postoperative period, are often deleterious for the patient with hypoglycemia. For example, frequent eating outside the home or takeout meals, skipping meals, drinking with meals, drinking sweetened beverages, alcohol intake, and a diet high in added sugar are common before surgery. Moreover, disordered eating/eating disorders, such as binge eating, emotional eating, and bulimia, may have been present before surgery and persist to some extent after surgery [40], making dietary changes more challenging. After surgery, patients sometimes forget to separate beverages from foods, or may form a new habit of using liquid protein supplements as a major source of food.

3. Food traditions and cultural considerations

The food traditions of many cultures include the daily use of high glycemic index carbohydrates, such as corn meal, white rice, or bread/pasta made with refined flour. While these foods can trigger dumping syndrome and/or PBH, it is often difficult to completely eliminate a food that is a staple in their culture. Preserving a patient's most cherished food tradition may increase compliance for dietary changes and reduce stress.

Taste and texture define the palatability of food, so we aim to preserve these qualities as much as possible. We encourage our patients to substitute low glycemic index carbohydrates for their traditional high glycemic carbohydrates, but to prepare them in traditional fashion by using similar spices and condiments. For example, suggesting that patients use barley instead of white rice to make rice and beans using similar ethnic spices, instead of eliminating the grain accompanying beans entirely, may make low glycemic index carbohydrates more acceptable.

4. Burnout with post-bariatric medical care

With time, bariatric patients are less likely to maintain follow-up care. This may be due, in part, to their perception that they can manage on their own. Additionally, costs of recurrent medical visits and co-pays, transportation to visits, and unreimbursed medication and vitamin costs are a challenge to nearly all patients. In our experience, these issues may collectively pose a barrier to nutrition therapy, both initial and follow-up visits, as well as costs associated with selecting fresh foods.

5. The need for convenience

Patients may rely on dining out/takeout, using microwaveable meals, ready-made bars or protein shakes, or simply skip meals because it is convenient. Planning meals in a structured manner to prevent hypoglycemia is often challenging but may become easier with practice. Providing patients with easy-to-prepare meal ideas or even daily menus can be key to engaging patients in the low glycemic index meal preparation process, and often requires several visits with nutrition staff.

6. Lack of family support

Regrettably, some patients do not have the support of their family and friends. In some cases, family/friends can even undermine the patient's efforts to follow their nutrition plan. It may be helpful to meet with both patient and family members to suggest supportive strategies. In extreme cases, referral to a behavioral medicine provider may be considered.

7. Guilt

It is important to reinforce that PBH is not the patient's fault. While it is true that hypoglycemia occurs in response to food intake, the metabolic and hormonal factors which initiate hypoglycemia are not under direct control of the patient. Rather, making good food choices can lessen the frequency and severity of hypoglycemia.

8. Patient as family food preparer

The majority of bariatric patients are women, who often continue to serve as the primary meal providers for their families. It is often difficult for patients to prepare food for the family and a separate meal to meet their needs. Identifying low glycemic index carbohydrates that are acceptable to family and patients alike is key. Some patients find that baking with alternative flours and sweeteners, such as carbalose and fructose, will allow them to prepare "treats" that are satisfying to all family members. Emphasizing that changing the content of family meals can yield improved health and weight for patient, spouse, and children alike may provide an extra incentive to make meal changes.

Other components of education to improve safety in the patient with hypoglycemia

Acute treatment of hypoglycemia. When post-bariatric patients experience hypoglycemia, we recommend immediate treatment with glucose tablets or gels to optimize safety. We recommend treatment if the glucose is under 70 mg/dL according to the "rule of 15": consume 15 g of glucose, such as 4 glucose tablets or 1 tube of glucose gel, then wait 15 minutes to recheck blood glucose. If glucose is not at least 80 mg/dL, repeat treatment with 15 g of glucose. Blood glucose <50 mg/dL typically requires treatment with 30 g of glucose. Glucose tablets need to be chewed and swallowed. Gels can be swallowed, but for faster glucose absorption, glucose gels can be held between gum and cheek for absorption via the buccal mucosa. Liquid glucose may be preferred by some patients, but it is typically much more expensive than tablets or gels. Use of glucose, rather than sucrose-containing treatments, is especially important for patients who are being treated with acarbose, as acarbose will slow digestion of nonglucose carbohydrates.

While this treatment protocol is designed to rapidly increase the patient's glucose level, thus improving safety, rapid spikes in blood glucose may also trigger later hypoglycemia in PBH patients. If this is a consistent pattern, a lower initial glucose treatment dose, (e.g., 8–12 g) may be suggested, with careful testing to ensure adequate treatment of hypoglycemia. In addition, we recommend that patients eat a low glycemic index snack after treating hypoglycemia to avoid repeated hypoglycemia.

Glucagon. Glucagon is used to treat severe hypoglycemia with neuroglycopenia. If blood glucose falls below 30–40 mg/dL, the patient's cognitive function may be temporarily impaired and the patient may be unable to self-treat hypoglycemia. Glucagon injected subcutaneously stimulates glucose release from the liver, thus raising glucose. Others who live/work with the patient should be taught to mix and inject glucagon for emergency use. Glucagon should be kept immediately available for use wherever the patient lives/works.

Activity counseling. Hypoglycemia in patients with PBH is often exacerbated by physical activity. In our experience, this appears to be especially true for patients whose carbohydrate intake is severely limited. Physical activity increases insulin sensitivity and causes muscle uptake of glucose to fuel muscular activity. If liver glycogen stores are compromised, hypoglycemia may result.

We routinely counsel patients with PBH to check their blood glucose to ensure that it is at least 80 mg/dL, and to consume a low glycemic index snack (15 g low glycemic index carbohydrate and 5–8 g fat) before physical activity. Because the effect of activity can persist for many hours, we also recommend more frequent monitoring after activity.

CGMS as tool for hypoglycemia prevention. CGMS devices not only measure interstitial glucose, but can also alert patients when their glucose levels are *trending* toward preset low or high levels or changing at a rapid rate, as often occurs when hypoglycemia is developing after a meal. For example, we often recommend that the patient ingest glucose (e.g., 8–12 g) when glucose is dropping rapidly (as guided by alarm indicating rapid rate of decline greater than 2–3 mg/dL/min), even before the sensor glucose is overtly low. This allows patients to take action to *prevent* hypoglycemia, rather than merely to react to hypoglycemia after it occurs.

Use of cornstarch. Uncooked cornstarch is a very low glycemic index carbohydrate which has been shown to stabilize blood glucose levels and has been used to prevent hypoglycemia in individuals with type 1 diabetes [41]. Cornstarch can be added to protein shakes, yogurt, or milk. It is the "active ingredient" in several commercial products, including Extend Nutrition products (bars, shakes, crisps) (www.extendbar.com) and UCAN powders. While the impact of cornstarch on glycemia in PBH has not been formally studied, we have anecdotally observed improved stability of blood glucose levels, particularly when consumed at bedtime to reduce nocturnal hypoglycemia.

Severity of illness. If dietary measures are insufficient to keep the patient safe, the patient should be counseled to see an endocrinologist for further diagnostic workup and possible treatment with medications.

Considerations for preoperative evaluation. With increasing recognition of the relatively high prevalence of PBH, we suggest that previous hypoglycemia should be queried during the preoperative history. One study demonstrated that patients who subsequently develop hypoglycemia after bariatric surgery have a lower glucose value during preoperative testing, still within the normal range [42,43]. However, if a patient has signs or symptoms of hypoglycemia preoperatively (Table 1), we would recommend a full medical evaluation to guide decision-making about surgery and choice of procedure based on metabolic profiles. Until ongoing research identifies markers of individuals at high risk for hypoglycemia, this approach is unlikely to uncover all high-risk individuals.

Summary and conclusion

Dietary modification is an essential first step in management of post-bariatric hypoglycemia. Guided by data from both available studies as well as long-term clinical experience, our recommendations focus on intake of controlled portions of low glycemic index carbohydrates, avoidance of rapidly-absorbed carbohydrates, choice of heart-healthy fats and ample protein, avoidance of alcohol and liquids with meals, and adjustment of meals and snack timing. It is important to recognize that this approach may not be sufficient in isolation, and individualization is usually required after assessment of initial response to dietary modification. Moreover, even with strict compliance, additional medical treatment aimed at reducing glucose spikes and stimulus for insulin secretion may be required. Additional studies of components of medical nutrition therapy will be helpful to further refine our management of this often-challenging clinical syndrome.

Conflicts of interest

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Editorial comment

How can we treat postbariatric hypoglycemia by medical nutrition therapy?

Gastric bypass surgery has been proven to be effective, not only in achieving substantial and sustained weight loss, but also in preventing and reversing obesity-related morbidity [1], increasing quality of life [2], and decreasing mortality [3]. Unfortunately, gastric bypass surgery comes with a risk of some serious side effects, including postbariatric hypoglycemia (PBH), which can be very disabling. Prevalence of PBH varies depending on how it is defined [4], but there is a marked lack of understanding and knowledge of the condition within the healthcare profession and even among obesity professionals.

The exact mechanisms causing PBH remain incompletely understood, despite extensive debate. It is possible that the symptoms are a physiologic result of the Roux-en-Y