"Bariatric Surgery"

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Chapter – Nutritional Outcomes of Bariatric Surgery

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Chapter Outline

Introduction

For the obese, the benefits of weight loss are overwhelming. The comorbidities of obesity improve or are resolved completely, the quality of life improves and there are major psychosocial benefits[1]. However in achieving these benefits we remember the first dictum of health care – Primum non nocere – first do no harm. There may be a nutritional price to be paid for the weight loss. We must be committed to minimizing or deleting this cost. In this chapter we review the range of nutritional problems which have been identified in association with bariatric surgery, characterize the mechanisms for their occurrence and define strategies to minimize the problems

The nutritional problems of bariatric procedures reflect the mechanisms of effect of each procedure. Weight loss is achieved either by reducing the intake or the absorption of nutrients. There are two fundamental mechanisms for reducing the intake. First, it may be reduced by creating a sense of satiety, of reducing the almost constant background sense of hunger, so that food is not sought. It is probable that this is a component of most bariatric procedures but, in general, this mechanism has been poorly studied and documented. We have demonstrated this to be an important effect after Laparoscopic adjustable banding surgery (LAGB). Second, bariatric procedures may create a sense of fullness early after commencing eating thereby inducing early satiety. This is the so-called restrictive effect, most prominent as a mechanism in gastroplasty but also important in LAGB and RYGB. The role of malabsorption of nutrients as a mechanism for current bariatric procedures varies greatly with technique. It is most prominent after BPD and its duodenal switch variant, but is undoubtedly significant after all forms of RYGB. A profile of possible malnutrition can be established for each current bariatric procedure and an awareness of this profile is mandatory if adequate follow up care of the patient can occur.

The following nutritional criteria have been enunciated by Dr Luc Van Gaal for dietary weight loss programs [2]. We believe that these criteria are equally appropriate for bariatric surgical procedures:-

1. The diet should be safe and including adequate vitamins, minerals and protein. It should be low in energy, but not in essential nutrients. The diet should provide adequate dietary fiber.

2. Weight loss programs should be directed to a slow, steady weight loss unless the health condition of the patient requires more rapid weight loss.

3. The diet must be palatable and acceptable to the patient, to achieve high patient compliance.

4. Strategies for weight maintenance should be implemented.

Thus dietary strategies need to be complemented with behavioral change and increased physical activity. In addition to the above there are specific considerations related to each of the surgical techniques used to achieve weight loss. Procedures with a diversionary or malabsorptive component are more likely to produce specific deficiencies or metabolic

risks, and procedures that are too restrictive may lead to maladaptive eating patterns producing significant changes in nutrient intake.

Jejunoileal bypass (JIB), a procedure no longer performed, provided the paradigm of a malabsorptive procedure and produced a plethora of major metabolic problems and nutritional deficiencies. It perhaps provides a model of the potential nutritional problems that may follow less intrusive surgery. The long-term complications of JIB included, arthralgia or arthritis, oxalate urolithiasis, metabolic bone disease[3], multiple vitamin and mineral deficiencies[4-6], and liver failure[7]. The effects not only result from malabsorption, but the additional toxic effects of gastrointestinal bacterial overgrowth.

Macronutrient Deficiency

Protein deficiency or malnutrition has until recently been the only focus of investigation into macronutrient deficiency following bariatric surgery. Deficiency of carbohydrate has not been an issue, but concern regarding essential fatty acids deficiency in association with fat malabsorption has been raised recently.

Protein Malnutrition:

A major reduction in energy intake or absorption following bariatric surgery leads to rapid weight loss. Mobilization of free fatty acids from adipose tissue and amino acids from muscle are needed to provide essential oxidative substrates for metabolic and brain function. As amino acids are diverted to gluconeogenesis, protein synthesis and metabolic rate is reduced, there is a reduction in both fat and lean body mass. Protein intake may be disproportionately reduced as a result of intolerance of high protein foods increasing loss of lean body mass[8]. Mobilization of amino acids from muscle supports some albumin synthesis, with low albumin levels post-operatively reflecting significant protein depletion.

The prevalence of protein malnutrition following bariatric surgery is uncertain as diagnostic criteria vary from study to study. However, protein malnutrition is a serious complication and may occur with continued rapid weight loss or excessive weight loss after any form of bariatric surgery. Protein malnutrition is likely to accompanied by a range of nutritional deficiencies. There are several case reports following gastroplasty[9, 10], but the risk appears to be greater with procedures with a significant component of malabsorption such as gastric bypass, especially distal gastric bypass[11, 12] and biliopancreatic diversion[13, 14]. The duodenal switch variant of biliopancreatic diversion may have reduced risk when compared with the original operation[15].

The management of protein malnutrition requires an assessment of the underlying problem, assisted enteral feeding or parenteral nutrition and correction of any associated nutritional deficiency. Revisional surgery may be necessary to improve intestinal absorption. Recovery may be quite slow and needs to be carefully monitored.

Essential fatty acids

Procedures producing significant fat malabsorption will also impair the absorption of fat-soluble vitamins and essential fatty acids. Essential fatty acids, linoleic and alpha-linolenic acid are the precursors for prostaglandin and leukotriene production. Deficiency can lead to alopecia, dermatitis, thrombocytopenia and anemia. Unfortunately there have been very few studies to look at the potential problems associated with essential fatty acids following bariatric surgery. Obese subjects have low levels of essential fatty acids and vitamin E in plasma with dietary restriction and fat malabsorption very likely to be associated with deficiency[16, 17]. One study has reported deficiency of essential fatty acids 1-year following BPDDS[18]. The quality of dietary fat may be very important after bariatric surgery, especially surgery causing fat malabsorption.

Micronutrient Deficiency

Iron

Iron is absorbed as the ferrous form and gastric acid aids conversion from the ferric ion in food to. Iron is best absorbed in the duodenum and upper jejunum. Iron deficiency anemia is a common complication of gastric bypass surgery[19]. This may result from several surgically induced factors: gastric bypass limits exposure of food to gastric acid, the region of optimal iron absorption is bypassed by surgery and meat intake is often reduced after gastric bypass[20]. Brolin et al reported iron deficiency in 32% of patients at a mean follow up of 2-years after bypass and of these 67% developed anemia[21]. By 42 months after surgery 47% were iron deficient and almost one-third had a microcytic anemia[22]. Iron deficiency does not appear to be more common in subjects having long limb gastric bypass (150cm defuctionalized jejenum) when compared with the standard (75cm defunctionalized jejenum)[23]. Low iron levels continue to be a significant problem years after gastric bypass surgery when weight is stable and therefore energy intake and expenditure balanced[20]. Routine micronutrient supplementation did not prevent iron deficiency or anemia, but significant oral iron supplementation of 350 mg twice daily was able to prevent the development iron deficiency in the majority of menstruating women[24]. It is important to have adequate stores before the last trimester of pregnancy as refractory iron deficiency anemia may occur when fetal iron demands are very high[25]. Thus significant iron supplementation, for an indefinite period, is required to prevent iron deficiency especially in menstruating women[21]. It is relevant to note that low iron levels are expected after both partial and total gastrectomy. Late follow-up, 25-30 years after subtotal gastrectomy found iron deficiency and B12 deficiency in 90% of women and 70% of men, indicating the need for indefinite long term biochemical monitoring and supplementation[26]. The gastric bypass should be expected to cause no less a problem.

Iron deficiency may occur after gastroplasty or adjustable gastric banding as a result of reduced dietary intake, principally related to a reduction in meat intake, but is not a common or predictable event[27].

Biliopancreatic diversion (BPD) may also reduce the opportunity for iron absorption within the gut, and iron deficiency anemia has been reported as a common event if careful supplementation is not provided[28, 29]. Limiting gastric resection and retaining the continuity of the antrum, pylorus and cuff of duodenum may help spare the effect. Indeed one study has reported ferritin levels are better maintained after the duodenal switch variant of the operation[15]. The duodenal switch procedure may also reduce the risk iron loss associated with gastrointestinal bleeding associated with stomal ulcers.

Regular adequate iron supplementation is needed to prevent iron deficiency after any surgery with a diversionary component. Hemoglobin, serum iron status and ferritin should be monitored after all bariatric surgery. Iron deficiency should be treated with oral iron. Ferrous sulfate 200mg three times a day is a simple and cheap choice[30]. Iron tablets can cause local irritation and erosion to the gastric mucosa. Consequently, if significant gastric restriction or delayed emptying is suspected, a liquid preparation may be more appropriate[31]. Iron tablets are often coated and gastric acid is required to allow full bioavailability. Thus a liquid preparation may also be appropriate after gastric bypass. The addition of ascorbic acid may enhance absorption. Once iron stores have been replenished, the daily iron dose can usually be reduced to improve compliance as lower doses reduce the incidence of the common gastrointestinal side effects. Compliance is important. If supplementation is inadequate iron deficiency anemia returns[32]. Parenteral iron should only be used if there is intolerance to at least two iron preparations or non-compliance[30].

Vitamin B12

The only dietary sources of vitamin B12 are animal products: meat and dairy. Vitamin B12 deficiency leads to megaloblastic anemia and, via demyelination, to potentially irreversible neurological changes including peripheral neuropathy, subacute combined degeneration of the spinal chord, optic atrophy and dementia. Inadequacy or deficiency of vitamin B12 raises homocysteine concentrations leading to increased endothelial dysfunction, increasing the risk of both arteriosclerotic and venous thromboembolic diseases. It is also likely to increase the risk of birth defects, including neural tube defects.

Gastric acid facilitates vitamin B12 release from food and its attachment to gastric R binder. Digestion of this complex in the duodenum allows release of vitamin B12, which then binds to intrinsic factor (IF), a product of the gastric parietal cells. The vitamin B12-IF complex is then absorbed with the assistance of specific receptors in the distal ileum. Body stores of vitamin B12 are usually considerable and if absorption were to cease abruptly it may take more than a year for deficiency to present. Vitamin B12 absorption is not likely to be an issue with gastric restrictive procedures.

Vitamin B12 deficiency is common following gastric bypass[33, 34] and the deficiency may not be prevented by a standard multivitamin preparation[22, 35]. The Schillings test may be normal or abnormal. An abnormal Schillings test is generally associated with reduced or absent IF in the gastric juice[36, 37]. Deficiency in the presence of a normal Schillings test

possibly results from reduced acid-pepsin activity which may fail to release protein bound vitamin B12 or inadequate intestinal vitamin B12-IF mixing which may not allow theraputic reliability[38]. Vitamin B12 deficiency is seen in up to 30% of patients who receive the recommended daily intake of vitamin B12 indicating that routine supplementation is often inadequate[35]. Specific vitamin B12 supplementation following gastric bypass is required and 350mcg of oral crystalline B12 has been shown to adequately replace vitamin B12 in 95% of patients[38]. Low vitamin B12 is seen in a high percentage of patients (36%) 22 months following gastric bypass surgery. Vitamin B12 deficiency in nursing mothers is associated with low breast milk vitamin B12 and deficiency has been reported in breast fed infants[39, 40]. Vitamin B12 deficiency does not appear to be more common in subjects having long limb gastric bypass when compared with the standard technique[23].

Reports of significant vitamin B12 deficiency following biliopancreatic diversion are few but are similar to those seen following gastric bypass[41]. Theoretically the duodenal switch variant of this operation should provide less risk of vitamin B12 deficiency. No data on this comparison are available.

Folate

Folate is a water-soluble vitamin that functions as a one-carbon unit transfer coenzyme for synthesis of purines and pyramidines, and for amino acid conversions. Folate is principally absorbed in the proximal third of the small intestine and is partly pH dependent. Gastric atrophy, achlorhydria and gastrectomy have all been associated with some malabsorption of folate[42]. However increased bacterial presence in the small bowel may allow increased bacterial folate production countering this effect[43]. Low folate levels were found in 30% of patients following total or subtotal gastrectomy. Deficiency can be attributed to inadequate intake, increased demand, for example during pregnancy, or malabsorption. Stores last no more than a few months after intake ceases.

It is established that folic acid supplements can prevent neural tube defects [44]. Mills et al [45, 46] have shown increased homocysteine levels in women carrying a foetus with a neural tube defect. They hypothesize that the folate and vitamin B12 dependent enzyme methionine synthetase is likely to be the critical pathway, with adequate methionine needed for neural tube closure. Cuskelly [47] showed that increasing dietary folic acid in food was inadequate and folate supplementation of 400 mcg/day is recommended for women who could become pregnant to prevent neural tube defects [44, 48]. Folate deficiency is also associated with megaloblastic anemia and increased cardiovascular risk

Folate deficiency has been has been reported as common after gastric bypass surgery[9, 49]. However the incidence varies greatly and with adequate oral intake with supplements, deficiency is readily prevented[50, 51]. A folate supplement of 400 mcg per day will minimize homocysteine levels in most people [52] and this is the minimum recommended dose for all patients following bariatric surgery. We have demonstrated that this dose is adequate to maintain both adequate folate and optimal low homocysteine concentrations

following LAGB surgery. There are no data to indicate an appropriate dose of folate to maintain optimal homocysteine levels following RYGB or BPD.

Vitamin B6

The coenzyme form of vitamin B6 is pyridoxial phosphate, an essential cofactor and stabilizer for many enzymes involved in amino acid metabolism. Vitamin B6 is available in many foods, readily absorbed and deficiency is rare. Requirements are increased by pregnancy and by estrogens. Deficiency may be seen in those taking drugs that have a pyridoxial antagonist effect, for example isoniazid and penicillamine. Supplementation may be required in pregnancy and for those taking oral contraceptives. Specific deficiencies have not been reported following bariatric surgery.

Homocysteine - Weight loss and raised plasma homocysteine levels

There is now consistent evidence that fasting plasma homocysteine levels rise with weight loss[53-55]. A raised level of homocysteine, an amino acid, is associated with a broad range of cardiovascular events including myocardial infarction, stroke and thromboembolic disease[56] and is a recognized independent risk factor for cardiovascular disease[57] along with weight, smoking, blood pressure, hypercholesterolemia and Type 2 diabetes. It has a direct toxic effect on vascular endothelium leading to dysfunction a key early step in the atherogenic process[58]. Three micronutrients are important cofactors in homocysteine metabolism. Folate and vitamin B12 are cofactors for the methylation of homocysteine to the essential amino acid methionine and vitamin B6 is involved in its catabolism. The rise in homocysteine levels with weight loss occurs independently of the plasma levels of folate and vitamin B12, but responds to supplementary folate and vitamin B12. With weight loss, higher levels of plasma micronutrients are required to maintain optimal low homocysteine levels[55]. It is therefore recommended that all bariatric surgical patients take adequate supplements of folate, vitamin B12 and vitamin B6 and that fasting plasma homocysteine levels should be monitored[59]. Homocysteine levels greater than 15 umol/l are abnormally high. The American Heart Association recommends that levels of homocysteine should be maintained below 10 umol/l. Supplementation should be provided preferably to achieve levels below 10 umol/l.

Thiamine (Vitamin B1)

Thiamine pyrophosphate is required for branched amino acid and carbohydrate metabolism. It is readily absorbed by both passive and active mechanisms with most deficiency resulting from poor dietary intake. Total body storage is approximately 30mg and biological half-life ranges from 9-18 days.

Deficiency induces anorexia, irritability, apathy and generalized weakness. More prolonged deficiency produces wet or dry beriberi syndromes. In both forms patients

complain of pain and paraesthesia. Wet beriberi presents with high output congestive cardiac failure and peripheral neuritis. Dry beriberi presents with a symmetrical mixed motor and sensory peripheral neuropathy. The central nervous system can also be affected by Wernicke's encephalophathy characterized by nystagmus, opthalmoplegia, cerebellar ataxia and mental impairment. The addition of loss of memory and confabulation is known as Wernicke-Korsacoff syndrome a condition usually described in alcoholics.

Wernicke-Korsacoff syndrome is a serious nutritional complication that can follow rapid weight loss after bariatric surgery. Most case reports cite persistent or severe vomiting in conjunction with rapid weight loss soon after the surgery as the usual precipitating conditions. Thiamine-related neurological disorders should be prevented by appropriately managing any complication leading to vomiting and instituting parenteral vitamin B1 supplementation early should persistent vomiting occur[60-64]. Neurological conditions occurring soon after surgery need to be viewed with a high degree of suspicion and urgent appropriate vitamin B1 therapy commenced[65]. Routine multivitamin supplementation after all forms of bariatric surgery should include vitamin B1.

Of interest, is a recent report describing a fall in vitamin B1 levels following distal or total gastrectomy for cancer. The problem usually occurred in the first 6 months following surgery[66], and this further emphasizes the need for early supplementation .

The laboratory diagnosis of thiamine deficiency is usually made by measuring transketolase activity. Thiamine is a coenzyme for the transketolase reaction. Acute deficiency should be treated with 100mg/day of thiamine parentrally for seven days followed by adequate oral supplementation.

Calcium – Vitamin D – Metabolic Bone Disease

Vitamin D is functionally a hormone rather than a vitamin and, with adequate sunlight exposure, no dietary intake is necessary. Production of the active form (1,25(OH)2 vitamin D) appears to be regulated physiologically by extracellular calcium and parathyroid hormone concentrations. Oral vitamin D absorption occurs via chylomicrons and is impaired by conditions causing steatorrhea. Skin production of vitamin D may be inadequate if ultra-violet exposure is poor as occurs in limited sun exposure, higher latitudes in winter, increased melanin pigmentation and atmospheric factors such as smog. Calcium is principally absorbed by active transport in the duodenum and upper jejunum, a process closely linked to the active form of vitamin D.

Metabolic bone disease is a well-documented long-term complication of bariatric surgery. Symptoms of metabolic bone disease, when they occur, in adults are often non-specific and the diagnosis often delayed. Generalized skeletal pain, muscle weakness and bony tenderness are usual symptoms and pathological fractures may occur. The diagnosis of metabolic bone disease is often difficult as symptoms can often mimic other diseases. Those who care for patients following bariatric surgery should have a low threshold to exclude metabolic bone disease when vague but suspicious symptoms occur.

Gastric restrictive procedures do not impair calcium or vitamin D absorption and, if intake remains adequate, metabolic bone disease is unlikely. A study of 18 patients followed for up to 2-years after VBG found a small but significant fall in upper femoral but not lumbar bone density. There was an increase in urinary hydroxyproline excretion but no evidence of hyperparathyroidism or vitamin D deficiency[67]. These findings have been confirmed following LAGB surgery[68]. In a small study of 17 patients following LAGB, we found no reduction in total body bone mineral density at a median of 30 months after surgery[69].

Gastric bypass with duodenal exclusion is likely to reduce calcium absorption as it is principally absorbed in the duodenum and upper jejunum and, if intake of calcium or vitamin D is insufficient, will lead to secondary hyperparathyroidism and metabolic bone disease[70, 71]. There is detailed knowledge of the bone changes following gastrectomy for ulcer or cancer[72, 73], but less is known of the effects of gastric and duodenal exclusion following bariatric surgery[74]. Metabolic bone disease following gastrectomy may not present for many years and is characterized by low urinary calcium, raised alkaline phosphatase, high parathyroid hormone and in some cases low 25-hydroxy vitamin D. Bone histology may show a mixed picture of osteoporosis and osteomalacia[75]. Metabolic bone disease has been reported following gastric bypass. Shaker et al, describe 2 women with metabolic bone disease associated with secondary hyperparathyroidism. Another six were also examined. Seven of the eight had raised parathyroid hormone, six had low urinary calcium excretion and both mean lumbar spine and hip mineral density were below predicted for the group. It is of concern that Crowley et al found 90% of patients after gastric bypass surgery were taking inadequate vitamin D and 54% inadequate calcium at follow up[70]. A case report of severe metabolic bone disease 17 years after gastric bypass has been published[76]. Hypocalcaemia has been reported to occurr in 13% and low vitamin A and D in 23% of patients after distal gastric bypass[12].

A US study of 17 consecutive adults with vitamin D deficient osteomalacia indicated that all had gastrointestinal disorders. Twelve had previous history of gastrointestinal surgery producing malabsorbtion. Surgeries were bariatric surgery (n=6), gastrectomy (n=4), intestinal resection for Crohn's disease (n=1) and a Whipple's procedure (n=1). Patient almost always had significant symptoms of osteomalacia but in the minority was the diagnosis considered prior to referral. There was a long period between the gastrointestinal surgery that lead to osteomalacia and a long delay between the development of symptoms and a diagnosis. The best non-invasive clues to a diagnosis were the patient's history, raised serum alkaline phosphatase and parathyroid hormone. If a person has a condition where vitamin D deficiency is a possibility then yearly 25OH-vitanmin D and parathyroid hormone levels are recommended[77].

Metabolic bone disease commonly follows BPD surgery. Compston et al, described metabolic bone disease, characterized by defective mineralization, decreased bone formation rate and increased bone resorption in the majority of patients. Twenty-two percent were hypocalcemic, but serum 25-hydroxyvitamin D concentrations were normal in all patients[78]. A high oral intake of calcium and supplementary vitamin D is advised in order to prevent the problem[28]. The duodenal switch variant may provide an advantage with higher mean calcium concentrations, lower parathyroid levels and significantly

smaller proportion of patients complaining of bone pain than following the BPD with distil gastrectomy procedure[15]. A recent report of nutritional markers following the duodenal switch procedure found mean parathyroid hormone levels to be abnormal at 2-years following surgery indicating a high risk of metabolic bone diesase in the majority of patients[79]. It is of interest that peak bone demineralization appears to occur at around 4 years after surgery and has not been found to be an increasing problem thereafter[13, 28]. Some late spontaneous improvement in metabolic bone disease has also been reported following JIB suggesting long term adaptation[80].

Vitamin D and calcium intake should be assessed in all patients following bariatric surgery and all patients should receive 1200 – 1500 mg of calcium and 800 IU of vitamin D per day. After procedures where malabsorbtion of calcium or vitamin D are likely then yearly screening of calcium, alkaline phosphatase, 25-hydroxy vitamin D and parathyroid hormone are recommended[76]. A rise in alkaline phosphatase or parathyroid hormone would be the first biochemical sign of metabolic bone disease and indicate the need to increase calcium and vitamin D therapy. Metabolic bone disease is treated with calcium and vitamin D supplementation, often high doses are required and the adequacy of treatment monitored with biochemical assessment.

Other Micronutrients

Zinc

Low zinc intake has been reported in obese subjects and intake falls with reduced caloric intake[81]. It has been proposed that hair loss following VBG may be caused be zinc deficiency as zinc supplementation arrested hair loss and promoted hair growth[82]. Malabsorptive procedures are also likely to reduce zinc levels with a recent report indicating that 69% of patients had a low zinc level 1-year after BPD-DS surgery[18]. Zinc supplementation should be included in multivitamin supplementation after all forms of bariatric surgery.

Vitamins A, E and K

Procedures producing significant fat malabsorption will also impair the absorption of fat-soluble vitamins and essential fatty acids. Symptomatic deficiency has been reported with night blindness and a prolonged prothombin time responding to vitamin A and D supplementation following jejunoileal bypass. A case report of maternal night blindness and fetal retinal damage has been reported following BPD[83]. There have been very few studies to look at the potential problems associated with fat-soluble vitamins and essential fatty acids following bariatric surgery. Obese subjects have low levels of essential fatty acids and vitamin E in plasma with dietary restriction and fat malabsorption very likely to be associated with deficiency[16, 17]. A single study has reported deficiency of essential fatty acids 1-year following BPDDS and the same study found one third of subjects had low vitamin A levels[18]. The quality of dietary fat may be very important after bariatric surgery, especially surgery causing fat malabsorption.

Magnesium

Very low magnesium levels have been reported after JIB and normal levels reported following gastric restrictive procedures, but the effect on magnesium levels following the currently used malabsorptive procedures such as BPD is unknown.

Summary of nutritional consequences of current bariatric procedures

This summary of nutritional consequences needs to be considered in the following sequence - LAGB, gastroplasty, RYBG and finally BPD as the concerns with the less intrusive procedures are added to by the more intrusive, diversionary or malabsorptive procedures.

Laparoscopic Adjustable Gastric Band

Weight loss following LAGB is usually well controlled and the risk of persistent vomiting and maladaptive eating behavior is very low as a result of adjustability. This reduces the risk of nutritional deficit. However adequate folate, vitamin B12, and vitamin B6 are needed to maintain low homocysteine levels. Foods of high iron content such as red meats are often avoided, putting premenopausal women at risk of iron deficiency. Appropriate dietary advice and monitoring of iron status should be performed and supplements provided if necessary. Optimal maternal weight gain and fetal nutrition during pregnancy can be achieved by judicious band adjustment, a facility that should be used[84]. Complication of the band should be recognized early and, if compromising nutritional status, should be treated promptly. Parenteral thiamin should be administered if there are any persistent obstructive symptoms or vomiting.

A simple daily multivitamin preparation containing vitamin B12, vitamin B6 and at least 400mcg of folic acid is recommended for all patients. These can readily be obtained in preparations containing a range other vitamins and minerals including vitamin B1 and zinc. The addition of a small quantity of iron within this preparation is appropriate for pre-menopausal women.

Gastroplasty

Nutritional issues are similar to that of the LAGB. However the inability to readily adjust the gastric stoma is likely to lead to an increased risk of food intolerance, maladaptive eating and therefore nutritional imbalance. Multivitamin supplementation is recommended and additional nutritional support may be required during pregnancy. Persistent food intolerance may occur and additional thiamin may be necessary.

Roux-en-Y Gastric Bypass

In addition to the nutritional considerations for gastroplasty, which forms an essential element of RYGB, partial gastric and duodenal exclusion provide a major risk of iron and vitamin B12 deficiency, and significant risk of inadequate folate and calcium intake. Careful permanent nutritional follow up is essential. Vitamin B12, folate, fasting homocysteine and iron studies must be performed annually to assess the adequacy of supplementation. Metabolic bone disease is a possibility and should be monitored by measuring alkaline phosphatase and parathyroid hormone levels. Osteoporosis should be assessed with bone density measurement. The risk of nutritional deficiency presenting after many years is high.

Biliopancreatic Diversion

BPD has been proven to provide excellent weight loss over a prolonged period of time[13]. Biliopancreatic diversion is the only commonly used bariatric surgical procedure that provides a major change in energy balance through malabsorption of macronutrients. The balance of malabsorption and reduced caloric intake with BDP is problematic and needs to be very finely balanced. If this procedure allowed sufficient macronutrient malabsorption for the patient to continue to consume all foods at pre-surgery rate is likely to lead to frequent bulky stools and significant diarrhea. The risk of broad range nutritional problems is very high. As currently used, this procedure provides the only truly significant malabsorptive-restrictive procedure. Slight variations in both the malabsorptive and restrictive components may explain some of the variance in nutritional problems described in the literature. Nevertheless this procedure carries with it considerable nutritional risk and responsibility. In addition to all the concerns described previously for gastroplasty and RYGB there is a greater likelihood of calcium and vitamin D deficiency increasing the risk of metabolic bone disease. Alkaline phosphatase, 25-hydroxy-vitamin D and parathyroid hormone levels need to be regularly monitored and there needs to be a low threshold for investigating any symptoms that may indicate bone pain. The risk of other fat-soluble vitamin or essential fatty acid deficiencies needs to be further investigated. Protein levels need to be monitored closely especially during the phase of rapid weight loss. Patients electing to have this form of bariatric surgical procedure need to be counselled that they will need a broad range of vitamin, mineral and possibly macronutrient supplementation regularly, along with careful nutritional monitoring indefinitely.

Biliopancreatic Diversion with duodenal switch

There are theoretical reasons and some limited data to suggest that with the DS variant of BPD there is a lower risk of nutritional deficiency[15]. At the present time there is insufficient evidence to argue for a less intense or varied program of supplementation and monitoring.

Table 1: Estimated risk of specific deficiencies or increased requirements based on the type of surgery performed.

	LAGB	Gastroplasty	RYGB	BPD	BPD -DS
Iron	+	+	+++	+++	++
Thiamine	+	++	+	+	+
Vitamin B12	+	+	+++	++	++
Folate	++	++	++	++	++
Calcium	+	+	++	+++	+++
Vitamin D	+	+	+	+++	+++
Protein	+	+	+	++	++
Fat Soluable Vitamins and Essential Fatty Acids	+	+	+	+++	+++

\+ RDI or standard multivitamin preparation likely to be sufficient.
++ Significant risk of deficiency or increased requirements. Specific supplementation is appropriate especially in higher risk groups.
+++ High risk of deficiency. Additional specific supplementation is necessary to prevent deficiency. Careful monitoring is recommended. Supplementation well in excess of daily requirements may be necessary.

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