Metabolic/Bariatric Surgery: Nutritional Implications and Outcomes

Sabrena F. Noria MD, PhD

The Obesity Epidemic

Obesity has become a problem of epidemic proportion in the United States (US). According to the Centers for Disease Control and Prevention (CDC), from 1976–1980 approximately 15% of US adults were overweight or obese, and by 2010 that increased to 36%. On average, individuals are 24 pounds heavier than they were in 1960 and if this trend continues, by 2030 50% of Americans will be overweight or obese.[1] Unfortunately the obesity crisis is not isolated to the US, but is a worldwide problem, having doubled since 1980, such that there are 500 million obese adults globally.[2]

To assume obesity is an imbalance between energy consumption and expenditure is too simplistic. It is the product of a complex interplay between evolutionary, biological, psychological, sociological, economic and institutional factors. In fact, the United Kingdom (UK) government Foresight Research on obesity identified more than 100 variables that directly or indirectly affect obesity[3] which, in turn, has serious social and economic implications. For example, the estimated annual global direct economic impact of obesity is 2 trillion US dollars, ranking it third behind smoking; and armed violence, war, and terrorism.[4] This impact is related to both direct medical costs and non-medical costs.

Focusing on direct medical costs, it is estimated that in the US, every point of body mass index (BMI) above 30 kg/m^2 adds ~$300 in per capita annual medical costs with a weighted average annual medical cost of $5,500 for individuals with a BMI over 30 kg/m^2.[4] These direct costs of obesity are related to the medical comorbidities associated with this disease. In particular, there has been extensive research on the relationship between obesity and type 2 diabetes, hypertension, hyperlipidemia, and obstructive sleep apnea.[5] However, obesity affects every body system, and is also correlated with development of cancers including endometrial, esophageal, breast, and colorectal cancer. Finally, obesity has been shown to be an independent risk factor for death,[6] such that as BMI increases above 35 kg/m^2 the estimated years of life lost for a 20-year-old white male in the US increases from 4 years up to 12 years when BMI climbs over 45 kg/m^2.[7]

There are multiple metrics for measuring obesity. However, the most commonly used is BMI, which is derived from weight (kg) divided by height (m^2). While BMI is good for quantifying obesity on a population level, it is not as useful in the clinic as it is unigender and uniracial, fails to reflect the distribution of fat and muscle, and fails to indicate the severity of comorbidities.[8] However, given its adoption by Medicare and US private carriers in 2004, it is the metric used to determine access to surgical care. Therefore, individuals are categorized as overweight (BMI = 25 kg/m^2 – 29.9 kg/m^2); obese (BMI = 30 kg/m^2 – 34.9 kg/m^2 [Class I obesity]); and morbidly obese (BMI = 35 kg/m^2 – 39.9 kg/m^2 [Class II obesity]), 40 kg/m^2 – 49.9 kg/m^2 [Class III obesity]), and super-obese (BMI $\geq$ 50 kg/m^2).[9]

In order to be eligible for surgery, an individual must be considered morbidly obese (also referred to as "clinically severe obesity"), which was defined by the 1991 National Institutes of Health (NIH) Consensus Conference Statement on Gastrointestinal Surgery for Severe Obesity as a BMI ≥ 40 kg/m² or a BMI ≥ 35 kg/m² in the presence of high-risk comorbid conditions.[9] This degree of obesity is considered eligible for surgery because it is at this stage that it becomes "morbid"; significantly increasing the risk of one or more obesity-related health conditions or serious diseases that result either in significant physical disability or even death.

Preoperative Preparation for Metabolic/Bariatric Surgery

Methods of weight loss are broadly divided into medical and surgical. Medically-managed weight loss (ie, diet, exercise, meal replacements, pharmacotherapy) can be successful for individuals categorized as overweight; however, it has been proven ineffective for those with a BMI ≥ 30 kg/m².[9] Only bariatric surgery has been proven effective over the long term for most patients with clinically severe obesity.[9] Additionally, to qualify for surgery, patients cannot have a known endocrine or metabolic cause for their obesity; they cannot have a history of substance abuse, eating disorder, or major psychiatric problem that is untreated and/or unresolved; patients must have attempted medical weight loss treatments without success; they must be able to understand the risks of the operation and be able to give consent; and finally, patients must be prepared to commit to the lifestyle changes that are necessary for success after surgery. Given these requirements, successful and sustained weight loss requires more than just surgery. At a minimum, metabolic/bariatric surgery programs require a comprehensive team that includes nurses, dietitians, psychologists, exercise physiologists, endocrinologists, cardiologists, and pulmonologists.

In preparing patients for surgery, an initial intake evaluation requires a complete medical and dietary history. Focusing on the latter, although obesity is considered a state of "over-nutrition", it is a risk factor for both macro- and micronutrient deficiencies (Table 1).[10-13] Therefore, identifying and rectifying these deficiencies preoperatively, through education and supplementation, aids in preventing postoperative nutritional deficiencies.

Table 1: Obesity is a Risk Factor for Nutrient Deficiencies[10-13]

Nutrients	Prevalence of Deficiency in Obesity
Protein	16%[10]
Iron	44% - 50%[11,12]
Vitamin C	36%[13]
Vitamin D	25% - 80%[11,13]
Vitamin A	12.5%[13]
Vitamin E	23%[13]
Zinc	28%[13]
Thiamin (B_1)	15% - 29%[11-13]
Cobalamin (B_{12})	18%[13]
Folate	6%[13]

Surgical Procedures

Restrictive Procedures

Restrictive procedures limit the luminal diameter of the stomach, but do not re-route food through the gastrointestinal tract. Procedures may utilize some form of foreign material or "band" (ie, laparoscopic adjustable gastric band [LAGB]), and/or surgically resize the stomach with a stapler in order to create a small gastric pouch (ie, sleeve gastrectomy [SG]).

The LAGB was once the second most common bariatric procedure, but recently has been replaced by the SG.[14] The procedure consists of placing an adjustable plastic and silicone ring around the proximal stomach just beneath the gastroesophageal junction. A subcutaneous access port allows the degree of band constriction to be adjusted by the injection or withdrawal of saline. Although the risk of mortality and major morbidity is low, the amount of excess weight loss (EWL) obtained is less than that seen with surgical malabsorptive procedures.[15,16]

The laparoscopic sleeve gastrectomy (LSG) is emerging as one of the most popular surgical procedures for the management of obesity. It has gained popularity because it is considered less technically demanding, the entire stomach and duodenum are still accessible by endoscopy, and there is no risk of internal hernia formation. The procedure involves resection of the greater curvature of the stomach by stapling it over a sizing tube (bougie) ranging from 11 to 20 mm in diameter.[17] Originally developed as part of the biliopancreatic diversion with duodenal switch,[18] it was subsequently used as the initial procedure of staged surgery for the super-obese.[19,20] Currently, LSG is most commonly applied as a stand-alone procedure,[21] and is being used with increasing frequency, comprising 36.3% of primary bariatric operations in 2012.[14] The effectiveness of LSG with respect to weight loss and resolution of comorbidities is positioned between that achieved after Roux-en-Y gastric bypass (RYGB) and LAGB.[22] These results suggest that, at least in the short term, LSG is an efficacious method of weight loss.

Malabsorptive Procedures with Some Restriction

Malabsorptive procedures are designed to reduce the area of intestinal mucosa available for nutrient absorption. The jejunoileal bypass (JIB) involves bypassing most of the small intestine by anastomosing the proximal jejunum, past the ligament of Trietz, to the terminal ileum. While excellent weight loss is achieved, the blind jejunal-ileal limb leads to nutritional complications and hepatic cirrhosis secondary to bacterial overgrowth.[23-25] As such, this procedure was abandoned, and the biliopancreatic diversion (BPD) was devised to improve upon the JIB.

The BPD consists of a partial gastrectomy, resulting in a 200–500 mL sized proximal gastric pouch, and creation of a distal roux and proximal biliary limb by division of the small bowel 250 cm proximal to the terminal ileum. The gastric pouch is then anastomosed to the end of the roux limb, and the biliary limb is attached 50 cm proximal to the ileocecal valve, thereby creating a very short common channel.[26] The procedure was later modified, creating the biliopancreatic diversion with a duodenal switch (BPD/DS). This entails fashioning a gastric sleeve with a maximum reservoir of 150–200 mL. The small bowel is then divided 4-5 cm distal to the pylorus, and 250 cm proximal to the terminal ileum. The proximal duodenal end is reconnected to the last 250 cm of small intestine, and the biliary limb is anastomosed 100 cm proximal to the terminal ileum.[15,18,23] This procedure preserves the antrum, pylorus, a short segment of duodenum, and vagal nerve integrity; thereby having a theoretical advantage of preserving a more physiologic digestive behavior, and diminishing the risk of dumping syndrome, ulcerogenicity, and hypocalcaemia.[23]

Restrictive Procedure with Some Malabsorption

The Roux-en-Y gastric bypass (RYGB) is considered the "gold-standard" for bariatric surgery and is still the most commonly performed operation, although there has been a reduction in number of procedures commensurate with the increase in sleeve gastrectomies performed. [14,23,26] Technically, the procedure involves creating a gastric pouch, roux-limb and biliary limb. Using surgical staplers, a small, vertically oriented gastric pouch with a volume < 30 cm^3 is formed. Dividing the small bowel 30-40 cm from the ligament of Trietz creates the roux and biliary limbs. Restoration of continuity occurs by connecting the roux limb to the gastric pouch, creating a gastrojejunostomy, and anastomosing the biliary limb approximately 150 cm distal to the gastrojejunostomy. After a RYGB, the size of the pouch restricts the volume of ingested food, and creation of the Roux-en-Y effectively bypasses approximately 95% of the stomach, the entire duodenum, and a portion of the jejunum.[23]

Risks and Complications of Surgery

As with all surgical procedures, metabolic/bariatric surgical procedures are associated with both early and late complications. Early complications (1–6 weeks postop) include staple/suture line leaks (RYGB [<1%], SG [<2%]), bleeding (<1.5%), infection (<1.5%), pulmonary embolism (<0.5%), pneumonia (<0.4%), cardiac arrest (<0.1%), sepsis (<0.5%) and death (RYGB [0.14%], SG [0.11%], LAGB [0.05%]).[22]

Late complications (> 6 weeks postop) include staple/suture line leaks, gallstone disease, bowel obstruction, malnutrition and/or vitamin deficiencies, persistent nausea and vomiting, and failure to lose weight or weight regain. Late surgery-specific complications of RYGB include gastrojejunal ulceration leading to bleeding (0.6% – 4%) or stenosis (1.42%), internal hernias (0.1% – 5%), and gastrogastric fistulas (<1%).[22] Late complications related to LAGB include port/tube malfunction (0.4%-7%), band slippage/migration (2%-10%), band erosion into the stomach (0%-3%), pouch dilatation (10%), and port infection (<1%).[22]

Nutritional consequences of surgery are primarily related to micronutrients. Specifically, deficiencies in fat-soluble vitamins (A, D, K) and zinc are more common after BPD/DS. Additionally, vitamin B_{12} and iron deficiencies are seen more commonly after RYGB due to exclusion of the majority of the stomach. Macronutrient deficiencies are rare, but can occur after any procedure (3% - 11%), and are related to poor oral intake (Table 2).[12,13,27] In order to mitigate these complications, the American Society for Metabolic and Bariatric Surgery (ASMBS) provides guidelines for the type and timing of micronutrient supplementation (Table 3).[12]

Table 2: ASMBS Guidelines: Biochemical Monitoring for Nutritional Status/ Nutritional Consequences of Metabolic/Bariatric Surgery[12,13,27]

Nutrient	Screening	Normal Range	Post-op Deficiency	Notes
B_1 Thiamin	Serum thiamin	10–64 ng/mL	Rare unless high N/V	More common after RYGB (<18%) (↓ acid ↓ absorption)
B_{12}	Serum B_{12}	200–1000 pg/mL	12%–33%	More common after RYGB (↓ parietal cells ↓ IF)
Folate	RBC folate	280–791 ng/mL	Uncommon	More common after RYGB (< 45%) (due to bypass of proximal small bowel)
Iron	Ferritin	♂15–200 ng/mL ♀12–150 ng/mL	Avg: 20%–49% RYGB 15% BPD/DS 26%	More common after RYGB in menstruating women (51%), and patients with super obesity (49%–52%)
Vitamin A	Plasma retinol	20–80 µg/dL	Common with BPD/DS	Common (50%) with BPD/DS after 1 yr., up to 70% at 4 yr.; may occur with RYGB, AGB
Vitamin D	25(OH)D, Ca, PO4, PTH	25–40 ng/mL	> 50%	Common with BPD/DS after 1 yr.; may occur with RYGB; prevalence unknown
Vitamin K	PT	10–13 seconds	51%	Common with BPD/DS after 1 yr.
Zinc	Plasma zinc	60–130 µg/dL	36% - 51%	Common with BPD/ DS after 1 yr.; may occur with RYGB
Protein	Albumin Total Protein	4–6 g/dL 6–8 g/dL	3% - 11%	Rare, but can occur with RYGB, AGB, and BPD/DS if protein intake is low

ASMBS=American Society for Metabolic and Bariatric Surgery, N/V=Nausea/Vomiting, RYGB=Roux-en-Y gastric bypass, IF=intrinsic factor, BPD/DS=biliopancreatic diversion with a duodenal switch, AGB=adjustable gastric band

Table 3: ASMBS Guidelines: Postoperative Vitamin-Mineral Supplementation[12]

Supplement	RYGB	BPD/DS	LAGB	Comment
Multivitamin-Mineral Supplement. • A high-potency vitamin containing 100% of daily value for at least 2/3 of nutrients • Choose a complete formula with at least 18 mg iron, 400 µg folic acid, and containing selenium and zinc in each serving	200% of daily value	200% of daily value	100% of daily value	Begin on day 1 after hospital discharge
Additional Elemental Calcium • Choose a brand that contains calcium citrate and vitamin D_3	1500–2000 mg/d	1800– 2400 mg/d	1500 mg/d	May begin on day 1 after hospital discharge or within 1 mo. after surgery
Additional Cobalamin (vitamin B_{12})	1000 µg/ mo.			Begin 0–3 mo. after surgery
Fat-Soluble Vitamins		Vit A 10,000 IU Vit D 2,000 IU Vit K 300 µg		May begin 2–4 weeks after surgery

ASMBS=American Society for Metabolic and Bariatric Surgery, RYGB=Roux-en-Y gastric bypass, BPD/DS=biliopancreatic diversion with a duodenal switch, LAGB=laparoscopic adjustable gastric band

Outcomes of Surgery

Several studies have demonstrated that on average, both the RYGB and SG achieve 60% - 80% EWL within 2 years, and LAGB achieves 50% EWL within the same time frame.[28-30] More importantly, bariatric surgery results in the improvement and/or resolution of diabetes, hypertension, hyperlipidemia and obstructive sleep apnea.[28,30] Finally, in terms of mortality, a study by Arterburn et al[31] demonstrated that bariatric surgery was associated with a lower mortality when compared to matched controls at 1–5 years postoperatively (adjusted hazard ratio (HR): 0.45 [0.36-0.56]; P<0.001), and >5–14 years (HR: 0.47 [0.39-0.58]; P<0.001).

Given the effect of bariatric surgery on resolution of diabetes, hypertension, sleep apnea, and hyperlipidemia, these procedures are now more appropriately considered metabolic surgery. Although the mechanisms through which these effects are realized have not been completely elucidated, three hypotheses exist to explain the effect of surgery on type 2 diabetes.[32] The foregut hypothesis postulates that exclusion of nutrients from the proximal bowel blocks “anti”-incretins, which causes increased incretin levels (glucagon-like peptide-1/peptide YY [GLP-1/PYY]) and improved glucose control. The mid-gut hypothesis suggests that rapid delivery of nutrients to the distal small bowel enhances intestinal gluconeogenesis, leads to activation of the hepato-portal glucose signaling system, decreases hepatic glucose production, and decreases appetite. Finally, the hindgut hypothesis proposes that rapid delivery of nutrients to the distal small bowel leads to increased levels of GLP-1 and PYY. Certainly increases in both GLP-1 and PYY are seen after procedures that involve intestinal bypass (RYGB, BPD/DS) and reduction of stomach size (SG), both of which cause rapid delivery of nutrients to the L-cells of the distal small bowel, and increased production of these incretins.[32,33]

Summary

Metabolic/bariatric surgery is an effective tool for weight loss and resolution of obesity-related comorbidities. However, surgical manipulation of intestinal anatomy can result in malabsorption of key vitamins and minerals. In order to mitigate these problems, patients must undergo an extensive medical and dietary work-up prior to surgery, and close follow-up after surgery in order to identify and rectify nutrient deficiencies with both comprehensive education and nutritional supplementation.

References

1. Levi J, Segal LM, Thomas K, St Laurent R, Lang A, Rayburn J. F as in Fat: How Obesity Threatens America's Future. Project of the Trust for America's Health and the Robert Wood Johnson Foundation. 2013 Report. Available at http://www.rwjf.org/content/dam/farm/reports/reports/2013/rwjf407528. Accessed November 24, 2015.
2. Finucane MM, Stevens GA, Cowan M, et al. National, regional, and global trends in body mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. *Lancet*. 2011;377(9765):557-567.
3. Butland B, Jebb S, Kopelman P, et al. Foresight: Tracking Obesities: Future Choices – Project Report. UK Government Office for Science. 2nd Ed. October 2007.
4. Dobbs R, Sawers C, Thompson F, et al. Discussion Paper. Overcoming Obesity: An Initial Economic Analysis. McKinsey Global Institute. November 2014.
5. Willett WC, Dietz WH, Colditz GA. Guidelines for healthy weight. *N Engl J Med*. 1999;341(6):427-434.
6. Adams KF, Schatzkin A, Harris TB, et al. Overweight, obesity, and mortality in a large prospective cohort of persons 50 to 71 years old. *N Engl J Med.* 2006;355(8):763-778.
7. Fontaine KR, Redden DT, Wang C, Westfall AO, Allison DB. Years of life lost due to obesity. *JAMA*. 2003;289(2):187-193.
8. Chiu M, Austin PC, Manuel DG, Shah BR, Tu JV. Deriving ethnic-specific BMI cutoff points for assessing diabetes risk. *Diabetes Care*. 2011;34:1741-1748.
9. Buchwald H. Consensus Conference Statement: Bariatric surgery for morbid obesity: health implications for patients, health professionals, and third-party payers. *J Am Coll Surg.* 2005;200:593-604. Available at https://asmbs.org/resources/consensus-statement. Accessed on January 6, 2016.
10. Bavaresco M, Paganini S, Lima TP, et al. Nutritional course of patients submitted to bariatric surgery. *Obes Surg.* 2010; 20(6):716-721.
11. Flancbaum L, Belsley S, Drake V, Colarusso T, Tayler E. Pre-operative nutritional status of patients undergoing Roux-en-Y gastric bypass for morbid obesity. *J Gastrointest Surg*. 2006;10(7):1033-1037.
12. Aills L, Blankenship J, Buffington C, Furtado M, Parrott J. ASMBS Allied Health Nutritional Guidelines for the surgical weight loss patient. *Surg Obes Relat Dis.* 2008;4:S73–S108.
13. Xanthakos SA. Nutritional deficiencies in obesity and after bariatric surgery. *Pediatr Clin North Am*. 2009;56(5):1105-1121.

14. Nguyen NT, Nguyen B, Gebhart A, Hohmann S. Changes in the makeup of bariatric surgery: a national increase in use of laparoscopic sleeve gastrectomy. *J Am Coll Surg.* 2013;216(2):252–257.
15. Herron DM, Tong W. Role of surgery in management of type 2 diabetes mellitus. *Mt Sinai J Med.* 2009;76(3):281-293.
16. Parikh MS, Fielding GA, Ren CJ. U.S. experience with 749 laparoscopic adjustable gastric bands: intermediate outcomes. *Surg Endosc.* 2005;19(12):1631-1635.
17. Gagner M, Deitel M, Kalberer TL, Erickson AL, Crosby RD. The Second International Consensus Summit for Sleeve Gastrectomy, March 19-21, 2009. *Surg Obes Relat Dis.* 2009;5(4):476-485.
18. Hess DS, Hess DW. Biliopancreatic diversion with a duodenal switch. *Obes Surg.* 1998;8(3):267-282.
19. Regan JP, Inabnet WB, Gagner M, Pomp A. Early experience with two-stage laparoscopic Roux-en-Y gastric bypass as an alternative in the super-super obese patient. *Obes Surg.* 2003;13(6):861-864.
20. Almogy G, Crookes PF, Anthone GJ. Longitudinal gastrectomy as a treatment for the high-risk super-obese patient. *Obes Surg.* 2004;14(4):492-497.
21. Lee CM, Cirangle PT, Jossart GH. Vertical gastrectomy for morbid obesity in 216 patients: report of 2-year results. *Surg Endosc.* 2007;21(10):1810-1816.
22. Hutter MM, Schirmer BD, Jones DB, et al. First Report from the American College of Surgeons Bariatric Surgery Center Network: Laparoscopic Sleeve Gastrectomy has Morbidity and Effectiveness Positioned Between the Band and the Bypass. *Ann Surg*. 2011;254(3):410–422.
23. Rubino F. Bariatric surgery: effects on glucose homeostasis. *Curr Opin Clin Nutr Metab Care.* 2006;9(4): 497-507.
24. McFarland RJ, Gazet JC, Pilkington TR. A 13-year review of jejunoileal bypass. *Br J Surg.* 1985;72(2):81-87.
25. Baddeley RM. The management of gross refractory obesity by jejuno-ileal bypass. *Br J Surg.* 1979;66(8): 525-532.
26. Colquitt JL, Picot J, Loveman E, Clegg AJ. Surgery for obesity. *Cochrane Database Syst Rev.* 2009;(2):CD003641.
27. Sawaya RA, Jaffe J, Friedenberg L, Friedenberg FK. Vitamin, mineral, and drug absorption following bariatric surgery. *Curr Drug Metab.* 2012;13(9):1345-1355.
28. Buchwald H, Avidor Y, Braunwald E, et al. Bariatric surgery: a systematic review and meta-analysis. *JAMA.* 2004:292(14):1724-1737.
29. Sjostrom L, Lindroos AK, Peltonen M, et al. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *N Engl J Med.* 2004;351(26):2683–2693.
30. Chang SH, Stoll CRT, Song J, Varela E, Eagon CJ, Colditz GA. The effectiveness and risks of bariatric surgery: an updated systematic review and meta-analysis, 2003–2012. *JAMA Surg.* 2014;149(3):275-287.
31. Arterburn DE, Olsen MK, Smith VA, et al. Association between bariatric surgery and long-term survival. *JAMA.* 2015;313(1):62-70.
32. Quercia I, Dutia R, Kotler DP, Belsley S, Laferrere B. Gastrointestinal changes after bariatric surgery. *Diabetes Metab.* 2014;40(2):87-94.
33. Park CW, Torquati A. Physiology of weight loss surgery. *Surg Clin North Am.* 2011;91(6):1149-1161.