Bariatric Surgery

A Double-Edged Sword

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Today, bariatric surgery is the most effective treatment of obesity. Restrictive surgeries are aimed at reducing the volume of the stomach. Such operations have the least adverse effects in terms of the physiology of digestion. However, they are less effective in losing weight. Mixed operations (gastric bypass surgery, biliopancreatic diversion) decrease the volume of the stomach and the length of the small intestine. Mixed operations tend to provide more pronounced results in a short time. However, by seriously disrupting the digestion and absorption of the food, they may result in severe micronutrient deficiencies. The assimilation of lipophilic substances is severely impaired as the biliopancreatic system is almost disconnected from the digestive tract. Furthermore, the assimilations of not only fats and essential fatty acids but also all fat-soluble vitamins are interrupted. In most cases, these patients need to take high-dose micronutrient supplements for their whole life. Usually, deficiencies of vitamins A, D, E, C, and vitamins of group B, especially B_1, B_6, B_{12}, niacin, and folate, as well as iron, calcium, phosphate, magnesium, zinc, copper, and selenium, are found after operations. Restrictive operations, although less traumatic for the digestive system, significantly disrupt the digestion and absorption of nutrients, especially those in which the stomach plays a significant role in its digestion. These are proteins, folate, niacin, vitamin B_{12}, iron, and copper. Bariatric surgical procedures are like a double-edged sword. They can be highly effective in the treatment of obesity and related complications; nevertheless, they are surgeries with serious potential for complications. Nutr Today. 2022;57(3):117–144

Obesity is a condition of a body in which an excessive or abnormal amount of adipose tissue is accumulated such that it may impair health.[1] The number of individuals with obesity has doubled from 1980 to 2014 and has nearly tripled since 1975. In 2016, more than 1.9 billion people in the world were overweight, and 650 million were suffering from obesity.[2] A recent study (2015-2016) in the United States has pointed out that 39.8% of adults and 18.5% of youths (body mass index [BMI] ≥95th percentile of age- and sex-specific growth charts) were suffering from obesity, that is, BMI 30 kg/m^2 or greater.[2,3] Morbid obesity (BMI >40 kg/m^2), which represents at least 50-kg overweight,[4] shortens life expectancy by 5 to 20 years.[5] The prevalence of obesity has risen to a global epidemic in recent decades. Some conservative measures have been tried to treat morbid obesity. However, bariatric surgery is still superior to any medical treatment in terms of results.[6] That is why bariatric operations should be performed in such patients.[7–11] It should also be noted that conservative treatment such as GLP-1 RA (glucagon like peptide-1 receptor agonists)–based therapy after surgery was found to be effective to prevent postbariatric weight regain.[12] Similarly, genomics of obesity also suggest that gene therapies and gene editing may have a future role in the management of some patients,[13,14] but more research must be done before it can be made widely available. There are several medical indications for the surgical treatment of obesity. According to the recommendations of the American Society of Metabolic and Bariatric Surgery, operations are indicated when BMI exceeds 40 kg/m^2 or when an individual with a concomitant disease such as hypertension, obstructive sleep apnea, nonalcoholic fatty liver disease, or bronchial

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asthma has a BMI of more than 35 kg/m^2.[15] Each year, the number of bariatric procedures is increasing exponentially. By 2013, more than 468 000 bariatric surgeries had been performed.[16]

With the implementation of these surgeries, higher rates of diabetes remission and lower risk of cardiovascular and other health outcomes have been found out.[17] Similarly the surgery can also result in substantial weight loss, resolution of comorbid conditions, and improved quality of life.[18] Besides decreasing weight, these surgeries have been found to improve metabolic health and prolong life for patients suffering from obesity.[19]

Russian Experience in the Treatment of Obesity

According to the practice in Russia, if BMI is 30 kg/m^2 or greater or if there are obesity-associated diseases in patients with a BMI of 27 to 29.9 kg/m^2, the prescription of pharmacological agents is recommended.

Currently, there are 5 drugs that are widely used. Orlistat (intestinal lipase inhibitor) is a peripheral drug that has a therapeutic effect within the gastrointestinal tract and does not have systemic effects. As a long-acting inhibitor of gastrointestinal lipases, orlistat prevents the breakdown and subsequent absorption of fats from food, thereby creating an energy deficit, which leads to a decrease in body weight.[20]

Acarbose is the next drug that is commonly used for treating obesity. It is an α-glucosidase inhibitor that treats obesity by inhibiting the digestion of oligosaccharides and disaccharides at the brush border of the small intestine.[21]

Similarly, metformin is also one of the widely used drugs in reducing obesity. It reduces the absorption of carbohydrates,[22] decreases plasma ghrelin,[23] and induces lipolysis and anorexia by activating GLP-1.[24] Moreover, it also reduces insulin and leptin resistance.[25]

Another drug used to treat obesity is liraglutide (an analog of human GLP-1, which is a physiological regulator of appetite and food intake). It is found to have an additional effect on weight loss in diabetic patients and patients with obesity[26] by inhibiting appetite[27,28] and by changing the gut microbiota.[29,30] Liraglutide also stimulates insulin secretion, suppresses glucagon secretion, and improves the function of pancreatic beta cells, which leads to a decreased postprandial glucose concentration. Furthermore, delayed gastric emptying also lowers blood glucose concentration.[31]

And finally, the next drug in use for treating obesity is sibutramine (an inhibitor of the reuptake of serotonin and norepinephrine and, to a lesser extent, dopamine, in the synapses of the central nervous system). This drug has a dual mechanism of action: it accelerates the feeling of fullness and increases the body's energy consumption, which together leads to a negative energy balance.[32]

Diet therapy remains the main method in the treatment of obesity. However, for most patients with morbid obesity, changing the diet over a long period is a dauntingly difficult task. A decrease in caloric intake by 500 to 1000 kcal per day usually leads to a decrease in body weight by 0.5 to 1.0 kg per week. This rate of weight loss persists for 3 to 6 months. But, on the other hand, a decreased body mass inadvertently leads to a decreased basal metabolic rate by 16 kcal/kg per day in men and by 12 kcal/kg per day in women.[33] So, eventually, the body acquires a steady state, and body weight decrease slows. After this, pharmacotherapy is added to diet therapy.

But, unfortunately, a long-term sustained positive effect cannot always be obtained, especially in patients with morbid obesity; therefore, bariatric surgery is recommended for this category of patients. In Russia, surgery is considered to be indicated as per guidelines of the World Association for Surgery of Obesity and Metabolic Disorders, European interdisciplinary guidelines for metabolic and bariatric surgery, and National Clinical Guidelines for the treatment of morbid obesity in adults.[33]

Currently, in Russia, bariatric surgery is widely carried out for morbid obesity (BMI ≥40 kg/m^2) and obesity with BMI ≥35 kg/m^2 or greater in combination with severe concomitant diseases that are poorly controlled by lifestyle changes and drug therapy. The number of bariatric surgeries in Russia is increasing every year. According to the data, 16 980 operations have been performed in Russia since 1999. Half of these interventions were longitudinal gastric resection (49%). Forty-eight percent of all operations were performed in Moscow.[34]

MATERIALS AND METHODS

An electronic search was conducted in PubMed. A MeSH search was done with terms including "Micronutrients" AND "Bariatric Surgery." The details of selection criteria are shown in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram in Figure 1. Eventually, 63 studies were selected as eligible for our review.

RESULTS AND DISCUSSION

Micronutrient Status in Individuals With Obesity Before Bariatric Intervention

Bariatric surgery implies an artificial disruption of the gastrointestinal tract. However, this intervention not only reduces the amount of ingested food but also disrupts its digestion and reduces the availability of micronutrients. Moreover, many authors agree that some individuals with obesity already have micronutrient deficiencies even before surgery[35–38] due to consumption of a diet low in nutritional quality,[38,39] which may adversely affect nutritional status. For example, hepcidin is a hormone secreted by the liver whose level is regulated by iron overload and by inflammation.[40,41] These conditions trigger the mechanisms that inhibit iron entry into the circulation by the disintegration of iron exporter ferroportin-1,

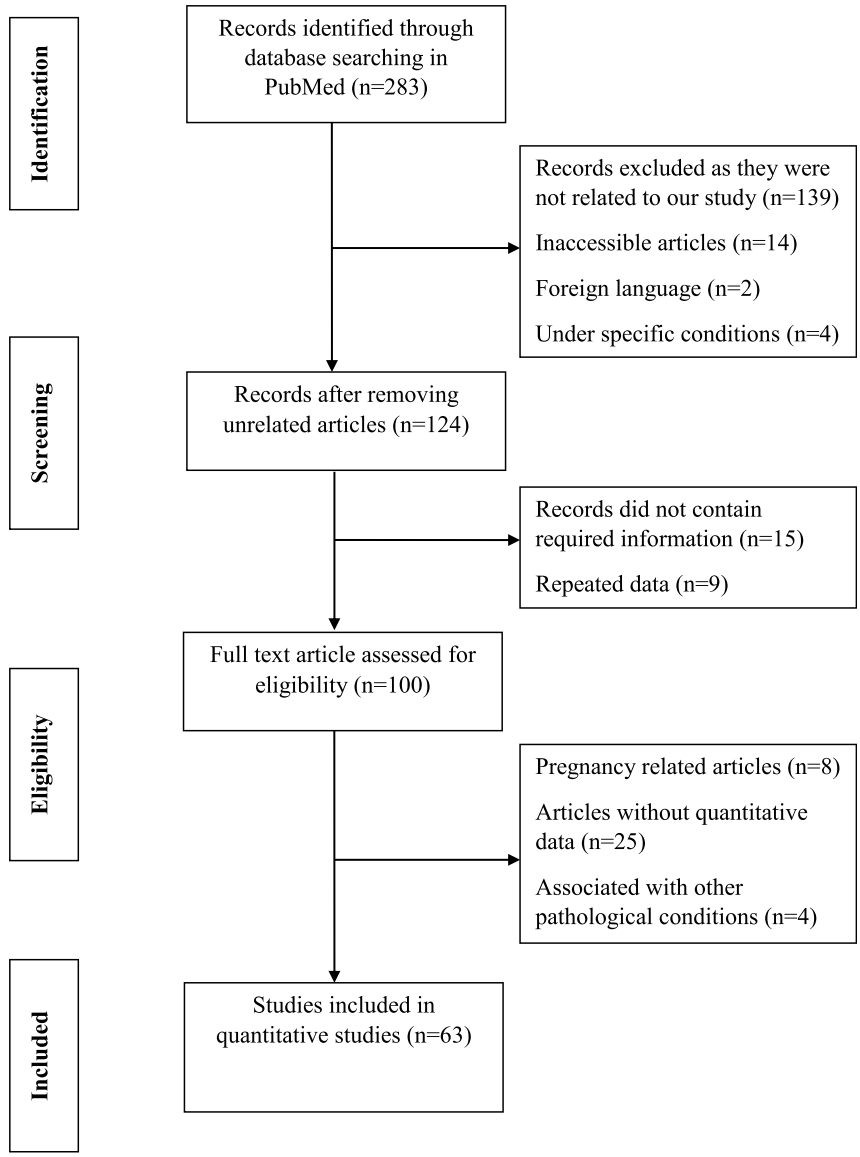

FIGURE 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of study selection process.

thereby blocking its absorption from the gastrointestinal tract, and by locking iron inside hepatocytes.[42,43] As inflammation accompanies severe obesity,[44] a higher amount of hepcidin is produced that inhibits iron absorption and release of iron from the hepatocytes. The effect is more profound in females, who are already at higher risk of being deficient in iron.

Many studies show that patients with morbid obesity, even before undergoing bariatric surgery, already have multiple micronutrient deficiencies. Several studies have found that in patients with morbid obesity, serum concentrations of 25(OH)D, folic acid, and vitamins B_{12} and A were reduced before bariatric intervention.[45–48] A number of studies have found that vitamin D deficiency is a characteristic feature of the majority of the patients before bariatric surgery.[49–51] In a systematic review, Chakhtoura et al[52] have analyzed 51 different studies and have found the mean presurgery calcidiol level in 29 studies to be less than 30 ng/mL and in 17 studies to be less than 20 ng/mL. Before undergoing bariatric intervention, most patients with morbid obesity were simultaneously deficient in 3 or more micronutrients (folate; vitamins B_{12}, B_6, D, and A; sodium; chlorine; calcium; phosphorus; magnesium; and iron).[39,53–61] At the same time, a decrease in serum iron was more frequently observed in women before the surgery than in men.[62] The detailed information is presented in Table 1.

Thus, it is clear that many patients today have serious micronutrient disorders even before surgery; especially deficiencies of folate, vitamins D and B_{12}, iron, and magnesium are observed. In all cases, it is necessary to monitor the

micronutrient status before performing bariatric surgery. If a deficit is identified, it is necessary to replenish it. Uncorrected deficiency of iron, folate or Vitamin B_{12}, particularly in the combined form, can seriously disrupt hematopoiesis in the postoperative period, especially in the case of blood loss. Lack of zinc and vitamin D significantly increases the risk of infectious complications and deficiency of magnesium and potassium—disorders in the cardiovascular system. In addition, numerous delayed consequences are possible.

Bariatric Surgery: Types, Outcomes, and Complications

There are three types of bariatric surgeries: blocking (malabsorption), restrictive, and mixed (Figure 2 and Table 2)[92–96] Blocking procedures restrict the absorption of nutrients by cutting off a part of the intestine from digestion. Restrictive surgery reduces the volume of the stomach and limits the amount of food intake. Mixed surgery includes a combination of restrictive and malabsorptive surgeries.[97] Mixed surgeries (gastric bypass [GBy], biliopancreatic diversion [BPD]) provide a more significant reduction in body weight.[97] However, after such operations, patients require micronutrient supplement therapy, as metabolic disorders are among its' frequent adverse effects.[98]

Blocking Surgery

Today, these procedures are usually not performed because of the numerous complications. For example, jejunoileal bypass (JIB) reduces the length and area of the inner surface of the small intestine, impairing food digestion and absorption of nutrients.[99] **Although the surgery is effective in decreasing body weight, it is rife with complications: a decrease in the levels of sodium, potassium, magnesium, bicarbonate, chloride, calcium, B vitamins and vitamin D leads to osteoporosis, secondary hyperparathyroidism, phosphaturia, and oxaluria; iron deficiency, folic acid, and vitamin B_{12} deficiency may cause anemia; and hypoproteinemia with hypoalbuminemia may be seen due to insufficient protein absorption.**[100] Extensive resection of the small intestine causes malabsorption of carbohydrates and an increase in the osmolarity of the chyme. Because of the malabsorptions of the fats and bile acids, steatorrhea may develop.[101] In addition, the ingress of free bile acids into the large intestine inhibits the absorption of sodium ions and stimulates the secretion of chloride, causing diarrhea. As a result of microbial contamination, disturbances of microcirculation on the wall of the small intestine, and irritation of the wall of the large intestine with bile acids, enteritis develops.[102] These complications arise from the active multiplication of bacteria in the area of intestinal anastomoses. From 1960 to 1970, approximately 100 000 JIB operations were performed in the world.[103] However, because of a large number of complications, these surgical interventions were almost redundant by the beginning of the 1980s. Currently, only some modifications of this operation are used with the formation of various lengths of the ileum, which is determined by the patient's body weight, gender, and age.

Restrictive Operations

Restrictive operations on the stomach (installation of an intragastric balloon, gastric banding [GBn], sleeve gastrectomy, or longitudinal gastrectomy [LG]) **are physiologically more appropriate. After such surgical interventions, there is a decrease in body weight and a low rate of postoperative complications**. Similarly, there is an absence of unwanted metabolic disorders with a minimum amount of replacement therapy. When carrying out restrictive operations, the volume of the stomach is decreased or its lumen has narrowed, leading to a decrease in the volume of food consumed.

Intragastric balloons are used as a temporary measure for weight loss in patients with a BMI of 35 to 38 kg/m^2.[104] The balloon is placed with the help of a gastroscope for 6 months. Common complications of intragastric balloons include gastric erosion and obstructive intestinal obstruction.

Gastric banding is used in patients with a BMI of 35 to 45 kg/m^2. But, nowadays, it has been applied to people with a BMI of less than 35 kg/m^2 as well. The purpose of the operation is to drastically reduce the amount of food consumed. This goal is achieved by placing a special ring (band) on the upper part of the stomach, below the gastroesophageal junction. After this surgery, complications such as gastric erosion around the band and band displacement may occur.[105,106] As a result of the displacement of the ring, patients may need to repeat the surgical interventions. So, in Europe, the relative number of operations performed with this method has decreased from 63.7% in 2003 to 17.8% in 2011.[107]

In 2006 longitudinal gastrectomy was introduced as an independent method of bariatric surgery.[108] Until that time, gastrectomy had been a part of a more complex operation, BPD, which significantly reduced not only the body fat mass but also normalized carbohydrate metabolism.[109] With LG, 80% to 90% of the stomach is resected, which reduces its volume to 100-150 mL. In this case, the patient's intestines remain unaffected, which eliminates the risk of a number of metabolic complications. As a result of LG, patients lose nearly up to 80% of their excess body weight.[110] However, the long-term consequences of the operation have not yet been sufficiently studied because this surgical method is relatively new. Currently, the results of the LG are being actively studied, and the procedure is constantly being improved. Unlike operations with a blocking component, such surgical techniques are associated with fewer long-term complications.[105] Longitudinal gastrectomy is less complex than GBy, has a lower incidence of postoperative complications,[111] and shows comparable results in terms of losing excess body fat.[112] Initially, kidney transplantation

TABLE 1 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity Before Bariatric Surgery

Micronutrient	Percentage of Deficiency	References
25(OH)D	100%	Bodunova et al[63]
	97.9%	Ben-Porat et al[56]
	97.5%	Krzizek et al[45]
	93%	Peterson et al[49]
	83%–86%	Verger et al[64]
	83%	Malek et al[65]
	83%	Damms-Machado et al; Wang et al[53,66]
	81%	Van Rutte et al[54]
	76.9%	Sun et al[35]
	75.6%	Al-Mutawa et al[59]
	74.35%	Arias et al[67]
	68%	Lefebvre et al[55]
	60%	Grace et al[68]; Al-Mulhim[60]
	58%–65%	Homan et al[69]
	53.6%	Asghari et al[61]
	39.5%	Schiavo et al (2019)[70]
	35.2%	Paredes et al[51]
	35%	Remedios et al[71]
	33%	Ybarra et al[72]
	20.4%	Gillon et al[73]

(continues)

TABLE 1 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity Before Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency	References
Folic acid	63.2%	Krzizek et al[45]
	32.2%	Wang et al[53]
	25% (1 y before LG)	Bodunova et al[63]
	24%	Van Rutte et al[54]
	20% (1 y before GBn)	Bodunova et al[63]
	15.8%	Bloomberg et al[74]
	13%	Madan et al[46]
	8.8%	Gillon et al[73]
	7.4%	Paredes et al[51]
	5.3%	Peterson et al[49]
	5.5%	Damms-Machado et al[66]
	3%–4%	Patel et al[75]
	0%–2%	Homan et al[69]
	0.9%	Al-Mulhim[60]
	0%	Al-Mutawa et al[59]
	0%	Sun et al[35]

(continues)

TABLE 1 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity Before Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency	References
Vitamin B_{12}	56.7%	Remedios et al[71]
	50%	Malek et al[65]
	34.4%	Asghari et al[61]
	16%	Al-Mutawa et al[59]
	13.9%	Antoine et al[76]
	13%	Madan et al[46]
	12.3%	Arias et al[67]
	11.7%	Ben-Porat et al[56]
	10.5%	Schiavo et al (2019)[70]
	10% (before LG)	Ferraz et al[77]
	9.3%	Damms-Machado et al[66]
	9% (before GBy)	Ferraz et al[77]
	8.4%	Lefebvre et al[55]
	7%–8%	Homan et al[69]
	6.4%	Gillon et al[73]
	5.1%	Krzizek et al[45]
	4.7%	Wang et al[53]
	4.6%	Paredes et al[51]
	3.6%	Schweiger et al[47]
	3.5%	Peterson et al[49]
	3%–8%	Patel et al[75]
	3%–5%	Verger et al[64]
	1.8%	Al-Mulhim[60]
	0%	Sun et al[35]
Vitamin B_6	24%	Van Rutte et al[54]
	11%	Damms-Machado et al[66]
	0%	Sun et al[35]

(continues)

TABLE 1 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity Before Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency	References
Vitamin A	70% (1 y before GBy)	Bodunova et al[63]
	52.5% (1 y before LG)	Bodunova et al[63]
	23%	Coupaye et al (2009)[78]
	21%	Pereira et al (2013) group 1[79]
	21%	Pereira et al (2013) group 2[79]
	20%	Pereira et al (2013) group 3[79]
	17%	Lefebvre et al[55]
	16%	Coupaye et al (2014)[80]
	14%	Pereira et al (2009)[81]
	14%	Coupaye et al (2009)[78]
	9%	Donadelli et al[82]
	7%	Madan et al[46]
	7%	Aasheim et al (2009)[83]
	7%	Ledoux et al[84]
	6.2%	Krzizek et al[45]
	1.7%	Peterson et al[49]
	1.61%	Sun et al[35]
	0%	Aasheim et al (2012)[85]
	0%	Schollnberger et al[86]
	0%	Provenzale et al[87]
	0%	Damms-Machado et al[66]
	0%	Van Rutte et al[54]

(continues)

TABLE 1 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity Before Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency	References
Iron	57%	Peterson et al[49]
	51%	Al-Mutawa et al[59]
	43%	Remedios et al[71]
	40.4%	Ben-Porat et al[56]
	38%	Van Rutte et al[54]
	29%	Damms-Machado et al[66]
	26.3%	Bloomberg et al[74]
	29% (before GBy)	Ferraz et al[77]
	24% (before LG)	Ferraz et al[77]
	18.%	Paredes et al[51]
	17.3%	Lefebvre et al[55]
	11.6%	Al-Mulhim[60]
	10.2%	Asghari et al[61]
	9.6%	Krzizek et al[45]
	9%	Wang et al[53]
	7%–37%	Patel et al[75]
	7%–18%	Verger et al[64]
	4%–8%	Homan et al[69]
	3.16%	Sun et al[35]
	2.77%	Gobato et al[88]
Calcium	13.7%	Wang et al[53]
	11%	Remedios et al[71]
	4.05%	Sun et al[35]
	4%	Paredes et al[51]
	1.3%	Lefebvre et al[55]
	0.5%	Van Rutte et al[54]
Magnesium	35.4%	Lefebvre et al[55]
	13.1%	Paredes et al[51]
	0%	Sun et al[35]

(continues)

TABLE 1 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity Before Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency	References
Phosphorous	21.6%	Lefebvre et al[55]
	10.4%	Wang et al[53]
	0%	Sun et al[35]
Sodium	11.02%	Sun et al[35]
	7.6%	Wang et al[53]
Chlorine	15.6%	Wang et al[53]
	10.48%	Sun et al[35]
Zinc	55.5%	Gobato et al[88]
	40% (before LG)	Ferraz et al[77]
	34% (before GBy)	Ferraz et al[77]
	14–50	Patel et al[75]
	10.16%	Sun et al[35]
	7.9%	Schiavo et al (2019)[70]

Abbreviations: GBn, gastric banding; GBy, gastric bypass; LG, longitudinal gastrectomy.

was contraindicated in patients with obesity, but after the LG was performed in them, it was possible to perform kidney transplantation.[113] Since the LG came into use, transplantation is no longer contraindicated in patients suffering from obesity. This type of bariatric intervention eliminates the contraindication for kidney transplantation due to obesity, in most patients within less than 1 year of postoperative follow-up.[113]

After bariatric surgery, the most severe complication is the appearance of a fistula,[89] the frequency of which continues to decrease, which may be associated with the advancements of surgical procedures and postoperative care. Currently, fistula formation occurs in 0.6% to 5% of cases after shunting[114,115] and in approximately 1% of patients after LG.[116,117]

Gehrer et al[118] found that after the LG operation, fewer micronutrient deficiencies were observed in comparison with GBy. Before the surgery, it is recommended to assess the micronutrient status[119–121] because many studies show that micronutrient deficiencies identified preoperatively highly correlate with the risk of deficiency of the same nutrients postoperatively (Table 3).

Mixed Restrictive and Malabsorptive Procedures

Currently, GBy is the criterion standard of bariatric surgery.[5,70] As a result of GBy, patients can lose from 66% to 75% of their excess body weight in the first 24 months after surgery.[145,146] After GBy, patients not only successfully lose weight, but also decrease activity of serum transaminases[147] and improve glycemic control.[148,149] There are several modifications of the GBy, but their essence boils down to the fact that by crossing the stomach in the upper part of it, a "small stomach" with a volume of 20 to 30 mL is formed, to which a loop of the small intestine is sutured. By reducing the amount of food consumed and the absorption of nutrients, a decrease in body weight is obtained.[150] The frequent surgical complications after GBy are stenosis of the anastomosis between the stomach and duodenum, ulcers between the stomach and small intestine, hernia of the abdominal wall,[151,152] insufficient protein absorption,[153] and micronutrient deficiencies.[71]

Vitamin B_{12} deficiency is usually observed several years after bariatric surgery because it has a large reserve in the liver. The reserves of vitamin B_{12} in the liver are sufficient to fulfill the physiological needs of the body for 3 to 5 years after the disappearance of Castle's gastric intrinsic factor. But, in the absence of enterohepatic circulation, this period is reduced from 3-5 years to a few months (sometimes up to a year). Deficiency of vitamin B_{12} is observed in all types of mixed operations because of a decrease in or lack of production of hydrochloric acid, a decrease in the production of Castle's intrinsic factor by parietal cells, and

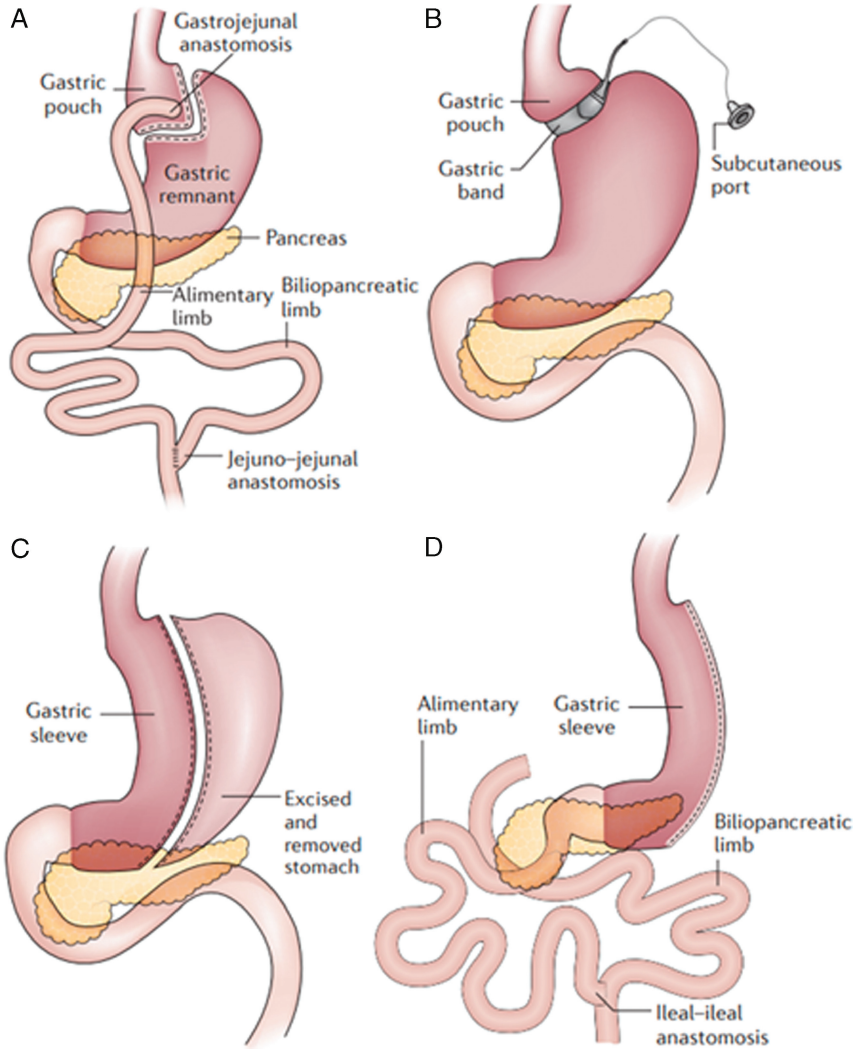

FIGURE 2. Schemes of different types of bariatric surgeries.[90]

a decrease in the number of cells with receptors for the complex "vitamin B_{12}—intrinsic factor." Moreover, vitamin B_{12} deficiency develops with pancreatic insufficiency because there is an insufficient amount of the enzyme that releases B_{12} from the carrier protein and a calcium deficiency, which is necessary for the combination of the vitamin B_{12} complex (intrinsic factor) with a receptor. After bariatric surgery, thiamine deficiency develops in the postoperative period from 6 to 15 weeks.[154] Vitamin E deficiency may occur in 6 to 12 months after surgery (mixed and blocking), but it can develop even after several years.[154] Vitamin E is absorbed in the upper parts of the small intestine; bile acids and fatty acids are needed for its absorption. Usually, vitamin E deficiency develops in patients with malabsorption.

In a Russian study, the change in the vitamin nutritional status in patients with obesity after GBy, GBn, and LG was studied.[63] Gastric bypass was performed in patients with the most severe forms of obesity. After surgery, a significant decrease in body weight was observed in patients who underwent GBy and LG. When examining a group of patients who underwent GBn, it was found that even before the operation, more than 50% of patients had a deficiency of vitamins C (95%), B_6 (95%), D (80%), and Folate (50%) in blood.[63] In the postoperative period, the number of patients with a deficiency of folic acid and niacin also increased. In the group of patients who underwent LG, vitamins C, D, B_6, and folate; retinol and niacin were significantly reduced before the operation (in 87.5%, 100%, 92.5%, 87.5%, 52.5%, and 70% of patients, respectively). A year after the operation, the number of patients with deficiencies of these vitamins remained the same or increased (the number of patients with niacin deficiency increased to 100%). The concentrations of other vitamins did not significantly decrease after 1 year of the operation. In the group of patients who underwent GBy, there was a significant decrease in vitamins C, D, B_6, and folate and retinol

TABLE 2 Different Types of Bariatric Surgeries and Their Brief Procedures[63,91]

Types of Bariatric Surgeries		Procedure	
Restrictive	LG	The main essence of these types of operations is to either shrink down the size of the stomach or occupy space inside the stomach, such that the patient would feel more full when they eat less.	In LG, a large portion of the stomach, following the major curve is surgically removed. After the surgery, the stomach acquires a tube-like structure, which is like a banana in shape, and the size of the stomach is reduced to 60-150 mL. It is to be noted that the change is irreversible.
	GBn		In this procedure, an inflatable silicone device is installed around the top of the stomach such that a smaller stomach pouch is formed. The smaller pouch gets filled quickly and a false message is sent to the brain that the entire stomach is full, which gives the sensation of satiety. Thus, it down-regulates the intake of food by slowing down the amount of food consumed at each meal. As the patient loses weight, the size of the gastric band is changed by introducing saline solution through the port placed under the skin.
	IGB		IGB involves introducing a deflated balloon into the stomach. The balloon is then filled with saline or radioactive marker, which subsequently reduces the gastric space for the food consumed by the patient. This method treats obesity by increasing satiety, delaying gastric emptying, and reducing the amount of food eaten at one time.
Blocking (JIB)		The essence of the different blocking surgeries is related to the shunting of the various parts of the small intestine, which reduces the absorption of food. This type of surgical intervention is no longer performed.	
Mixed	GBy	In mixed surgeries, both restrictive and blocking methods are applied at the same time in the same patient.	It includes 2 different components: restrictive and blocking surgeries. Initially, the stomach is surgically divided into 2 parts—the upper smaller pouch and the lower much larger pouch. Then, the intestine is rearranged such that it gets connected with both of these. There are different ways to connect the intestine, thus there exist different variations of this procedure. The Roux-en-Y gastric bypass is the most common variant of this type of surgery. In this operation, the small intestine is cut approximately 45 cm below the lower stomach, and the distal outlet is connected with the smaller upper stomach pouch. The other proximal end of the intestine is also connected with the intestine forming Y-intersection.
	BPD		In this procedure, longitudinal resection of the stomach is performed along its greater curve. The stomach is then disconnected from the duodenum and reconnected to the distal small intestine, nearly at approximately 75-100 cm from the colon.

Abbreviations: BPD, biliopancreatic diversion; GBn, gastric banding; GBy, gastric bypass; IGB, intragastric balloon; JIB, jejunoileal bypass; LG, longitudinal gastrectomy.

both before and after surgery.[63] The authors surmise the niacin deficiency revealed in most patients to be associated with the fact that when performing the above operations that the anatomy of the stomach and the proximal small intestine gets changed, where this vitamin is absorbed. The authors associate the folate deficiency in patients who have undergone GBn and LG with the "termination" of the stomach from the process of folic acid assimilation. In addition, gastric absorption is critical for the metabolism of copper, the bulk of which is absorbed in the stomach.[155]

With JIB, there is protein malabsorption in the shortened small intestine. Similarly, with GBy, the protein absorption in the shortened small intestine is disrupted, and its denaturation by gastric hydrochloric acid and initial breakdown by pepsin are impaired. In addition, many patients who have undergone GBy develop an aversion to protein foods. After GBy, there is a high risk of developing B_{12}-deficiency anemia due to a decrease in the production of Castle's intrinsic factor by the stomach. The risk of folate-deficiency anemia also increases.[153] In this regard, patients after GBy are prescribed to take high oral doses of cobalamin—at least 350 μg/day—as a result of its extremely low bioavailability. The daily dosage of folic acid in the postoperative period is usually at least 800 μg/day.

Also, after GBy, iron-deficiency anemia is observed (the incidence ranges from 15% to 60%).[153] Usually, in the acidic environment of the stomach, iron complexes are formed with ascorbic acid, bile acids, amino acids, monosaccharides, and disaccharides, which are then absorbed in the duodenum and jejunum. When most of the stomach and especially the duodenum do not take part in the digestion of the food, the iron content of the food could not be utilized properly. Thus, patients constantly need to take iron supplements. Moreover, metabolism of iron, vitamin B_{12}, and

TABLE 3 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity After Bariatric Surgery

Micronutrient	Percentage of Deficiency Before the Operation	Percentage of Deficiency After the Operation	References
Vitamin A	70%	92.5% (1 y after GBy)	Bodunova et al[63]
	71.6%	55.2% (1 y after LG)	van Rutte et al[54]
	52.5%	52.5% (1 y after LG)	Bodunova et al[63]
	N/D[a]	52% (1 y after BPD)	Patel et al[75]
	14%	39% (6 mo after GBy)	Pereira et al (2009)[81]
	N/D[a]	36% (≤1 y after GBy)	Ledoux et al[84]
	N/D[a]	33.2% (≤1 y after LG)	Ledoux et al[84]
	9%	28% (1 y after GBy)	Donadelli et al[82]
	16%	23% (1 y after GBy)	Coupaye et al (2014)[80]
	21%	21% (6 mo after GBy)	Pereira et al (2013) group 1[79]
	N/D[a]	21% (1 y after GBy)	Gong et al[122]
	16%	20% (1 y after LG)	Coupaye et al (2014)[80]
	20%	20% (6 mo after GBy)	Pereira et al (2013) group 3[79]
	7%	17% (after 1 y of GBy)	Madan et al[46]
	7.9%	15.3% (1 y after LG)	Caron et al[123]
	7%	13% (after 1 y of GBy)	Ledoux et al[84]
	N/D[a]	11% (after 1 y of GBy)	Lovette et al[124]
	23%	10% (1 y after GBn)	Coupaye et al (2009)[78]
	14%	10% (1 y after GBy)	Coupaye et al (2009)[78]
	0%	9.4% (1 y after LG)	Schollnberger et al[86]
	21%	8.7% (6 mo after GBy)	Pereira et al (2013) group 2[79]
	1.7%	7.7% 1 y after GBy)	Johnson et al[125]
	7%	7% (1 y after GBy)	Aasheim et al (2009)[83]
	N/D[a]	5.5% (1 y after GBy)	Boyce et al[126]
	2.7%	5.2% (1 y after LG)	Johnson et al[125]
	N/D[a]	4.9% (1 y after GBy)	James et al[127]
	0%	4% (1 y after GBy)	Aasheim et al (2012)[85]
	1.9%	3.7% (1 y after GBy)	Voglino et al[128]
	0%	2% (1 y after GBy)	Provenzale et al[87]
	0%	0% (1 y after LG)	Van Rutte et al[54]
	0%	0% (1 y after LG)	Damms-Machado et al[66]
	17%	0% (2 y after GBy)	Billeter et al[129]
	N/D[a]	0% (1 y after GBy)	Arias et al[67]

(continues)

TABLE 3 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity After Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency Before the Operation	Percentage of Deficiency After the Operation	References
Vitamin C	100%	100% (1 y after GBy)	Bodunova et al[63]
	87.5%	87.5% (1 y after LG)	Bodunova et al[63]
	43%	48% (1 y after GBn)	Coupaye et al (2009)[78]
	N/D[a]	34.6% (after 1 y of GBy)	Lovette et al[124]
	9%	29% (1 y after GBy)	Donadelli et al[82]
	63%	23% (1 y after GBy)	Aasheim et al (2009)[83]
	40%	20% (1 y after LG)	Coupaye et al (2014)[80]
	N/D[a]	11.1% (≤1 y after LG)	Ledoux et al[84]
	15%	11% (1 y after GBy)	Aasheim et al (2012)[85]
	43%	10%–50% (after GBy)	Patel et al[75]
	47%	10% (1 y after GBy)	Coupaye et al (2009)[78]
	47%	10% (1 y after GBy)	Coupaye et al (2014)[80]
	23%	9.7% (1 y after GBy)	Ledoux et al[84]
	N/D[a]	4.7% (≤1 y after GBy)	Ledoux et al[84]
Vitamin D	100%	100% (1 y after GBy)	Bodunova et al[63]
	100%	100% (1 y after LG)	Bodunova et al[63]
	97.9%	93.6% (1 y after LG)	Ben-Porat et al[56]
	86%	71% (1 y after GBy)	Verger et al[64]
	83%	70.4% (1 y after LG)	Damms-Machado et al[66]
	83%	68% (1 y after LG)	Verger et al[64]
	N/D[a]	61.1% (≤1 y after GBy)	Ledoux et al[84]
	N/D[a]	57% (1 y after BPD)	Patel et al[75]
	N/D[a]	54.6% (≤1 y after LG)	Ledoux et al[84]
	74.35%	50% (1 y after GBy)	Arias et al[67]
	49%	49% (1 y after GBy)	Henfridsson et al[130]
	84.62%	48% (1 y after LG)	Vix et al[131]
	92%	43% (1 y after LG)	Toh et al[132]
	74.5%	42.6% (1 y after GBy)	Voglino et al[128]
	90%	37% (1 y after LG)	Moize et al[133]

(continues)

TABLE 3 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity After Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency Before the Operation	Percentage of Deficiency After the Operation	References
	81%	36% (1 y after LG)	Van Rutte et al[54]
	N/D[a]	34.2% (1 y after GBy)	Boyce et al[126]
	60.6%	32.5% (1 y after GBy)	Moize et al[133]
	N/D[a]	30.8% (5 y after LG)	Boyle et al[134]
	46%	30% (1 y after GBy)	Toh et al[132]
	N/D[a]	27% (after bariatric surgery)	Calderón et al[135]
	N/D[a]	22.7% (1 y after GBy)	Leeman et al[136]
	N/D[a]	21% (1 y after LG)	Lovette et al[124]
	26.9%	20.3% (1 y after GBy)	Johnson et al[125]
	40%	19% (1 y after GBy)	Madan et al[46]
	N/D[a]	15.4% (1 y after GBy)	James et al[127]
	26.8%	13.4% (1 y after LG)	Johnson et al[125]
	N/D[a]	12% (1 y after GBy and LG)	Antoine et al[76]
	N/D[a]	7% (after 1 y of GBy)	Lovette et al[124]
	35%	7.5% (1 y after bariatric/metabolic surgery)	Remedios et al[71]
	35%	6.7% (6 mo after bariatric/metabolic surgery)	Remedios et al[71]
	37.2%	5.5% (1 y after LG)	Caron et al[123]
	20.4%	4.9% (after a year of LG)	Gillon et al[73]
	26.4%	4.8% (1 y after LG)	Vage et al[137]
	65%	4% (1 y after GBy)	Schijns et al[138]
Vitamin E	N/D[a]	20% (≤1 y after GBy)	Ledoux et al[84]
	20%	16% (1 y after GBy)	Coupaye et al (2014)[80]
	10%	16% (1 y after GBy)	Ledoux et al[84]
	0%	15% (1 y after GBy)	Aasheim et al (2012)[85]
	12%	3% (1 y after LG)	Coupaye et al (2014)[80]
	3%	3% (1 y after GBy)	Aasheim et al (2009)[83]
	0%	1.8% (1 y after GBy)	Voglino et al[128]
	N/D[a]	1.8% (≤1 y after LG)	Ledoux et al[84]
	N/D[a]	0% (1 y after GBy)	James et al[127]
	0%	0% (1 y after LG)	Damms-Machado et al[66]
	0%	0% (1 y after GBy)	Coupaye et al (2009)[78]
	0%	0% (1 y after GBn)	Coupaye et al (2009)[78]
	0%	0% (2 y after GBy)	Billeter et al[129]

(continues)

TABLE 3 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity After Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency Before the Operation	Percentage of Deficiency After the Operation	References
Folic acid	20%	50% (1 y after GBn)	Bodunova et al[63]
	25%	42,7% (1 y after LG)	Bodunova et al[63]
	3%–4%	22% (after LG)	Patel et al[75]
	40,5%	21.4% (1 y after LG)	Ben-Porat et al[56]
	5.5%	13.8% (1 y after LG)	Damms-Machado et al[66]
	0%	13.7% (1 y after LG)	Antoniewicz et al[139]
	N/D[a]	12.7% (1 y after GBy and LG)	Antoine et al[76]
	24%	12.5% (1 y after LG)	Van Rutte et al[54]
	8.8%	12.3% (1 y after LG)	Gillon et al[73]
	3%–4%	10% (after GBn)	Patel et al[75]
	7.5%	8% (1 y after LG)	Vage et al[137]
	2%	8% (1 y after GBy)	Madan et al[46]
	12.8%	6.4% (6 mo after GBy)	Antoniewicz et al[139]
	3%–4%	5% (after BPD)	Patel et al[75]
	N/D[a]	3.9% (≤1 y after LG)	Ledoux et al[84]
	7%	3.4% (1 y after GBy)	Donadelli et al[82]
	0%	2.77% (6 mo after GBy)	Gobato et al[88]
	6.5%	1.2% (1 y after GBy)	Blume et al[140]
	3%–4%	0-12 (after GBy)	Patel et al[75]
	0%	0.5% (1 y after LG)	Caron et al[123]
	N/D[a]	0.4% (≤1 y after GBy)	Ledoux et al[84]
	N/D[a]	0% (1 y after GBy)	Arias et al[67]
	0%	0% (1 y after GBy)	Voglino et al[128]
	0%	0% (1 y after GBy and LG)	Toh et al[132]
	0%	0% (1 y after GBy)	Schijns et al[138]
	0%	0% (1 y after GBy)	Henfridsson et al[130]
	0%	0% (2 y after GBy)	Billeter et al[129]
	N/D[a]	0% (1 y after GBy)	Arias et al[67]

(continues)

TABLE 3 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity After Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency Before the Operation	Percentage of Deficiency After the Operation	References
Vitamin B_1	38%	57% (1 y after GBn)	Coupaye et al (2009)[78]
	N/D[a]	49% (1 y after GBy)	Kaidar-Person and Rosenthal.[141]
	37%	23% (1 y after LG)	Coupaye et al (2014)[80]
	35%	23% (1 y after GBy)	Coupaye et al (2014)[80]
	N/D[a]	18.3% (1 y after GBy)	Lovette et al[124]
	0%	17.7% (6 mo after LG)	Belfiore et al[142]
	N/D[a]	15% (≤1 y after LG)	Ledoux et al[84]
	0%–29%	12%–18% (after GBy)	Patel et al[75]
	25%	12% (1 y after GBy)	Coupaye et al (2009)[78]
	N/D[a]	11.3% (≤1 y after GBy)	Ledoux et al[84]
	15%	11% (1 y after GBy)	Ledoux et al[84]
	0%	10% (1 y after GBy)	Aasheim et al (2009)[83]
	0%	9.1% (1 y after LG)	Moize et al[133]
	0%	9% (1 y after LG)	Moize et al[133]
	5.5%	9% (1 y after LG)	Van Rutte et al[54]
	8.1%	7.2% (1 y after LG)	Johnson et al[125]
	5.5%	6.1% (1 y after GBy)	Moize et al[133]
	6%	6% (1 y after GBy)	Moize et al[133]
	1.7%	5.9% (1 y after GBy)	Johnson et al[125]
	N/D[a]	3.3% (1 y after GBy)	Boyce et al[126]
	N/D[a]	1% (1 y after GBy)	Arias et al[67]
	17%	0% (1 y after LG)	Verger et al[64]
	9%	0% (1 y after LG)	Saif et al[141]
	9%	0% (1 y after GBy)	Verger et al[64]
	0%	0% (2 y after GBy)	Billeter et al[129]
Vitamin B_2	N/D[a]	13.6% (after 1 y of GBy)	Lovette et al[124]
Vitamin B_3	70%	100% (1 y after LG)	Bodunova et al[63]
	32.5%	82.5% (1 y after GBy)	Bodunova et al[63]
	N/D[a]	13.1% (≤1 y after GBy)	Ledoux et al[84]
	N/D[a]	10.7% (≤1 y after LG)	Ledoux et al[84]
Vitamin B_5	87.5%	87.5% (1 y after LG)	Bodunova et al[63]
	67.5%	82.5% (1 y after GBy)	Bodunova et al[63]

(continues)

TABLE 3 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity After Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency Before the Operation	Percentage of Deficiency After the Operation	References
Vitamin B_6	92.5%	92.5% (1 y after LG)	Bodunova et al[63]
	90%	90% (1 y after GBy)	Bodunova et al[63]
	20.9%	47.3%	van Rutte et al[54]
	N/D[a]	17.6% (1 y after GBy)	Lovette et al[124]
	75%	11.1% (1 y after LG)	Moize et al[133]
	N/D[a]	6.4% (≤1 y after LG)	Ledoux et al[84]
	N/D[a]	5.4% (≤1 y after GBy)	Ledoux et al[84]
	3%	4% (1 y after LG)	Van Rutte et al[54]
	11.3%	2.8% (1 y after GBy)	Moize et al[133]
	11%	0% (2 y after GBy)	Billeter et al[129]
	N/D[a]	0% (1 y after GBy)	Arias et al[67]
Vitamin B_{12}	56.7%	44.5% (after 1 y of bariatric/metabolic surgery)	Remedios et al[71]
	56.7%	37% (after 6 mo of bariatric/metabolic surgery)	Remedios et al[71]
	3%–8%	33%–58 (after GBy)	Patel et al[75]
	30.3%	25.8% (1 y after LG)	Caron et al[123]
	6.4%	25.5% (1 y after GBy)	Antoniewicz et al[139]
	19%	23% (1 y after GBy)	Schijns et al[138]
	3%–8%	22% (after BPD)	Patel et al[75]
	12.3%	19% (1 y after GBy)	Arias et al[67]
	6.4%	19% (1 y after LG)	Gillon et al[73]
	3%–4%	18% (after LG)	Patel et al[75]
	11.7%	16.7% (1 y after LG)	Ben-Porat et al[56]
	1%	13% (1 y after GBy)	Henfridsson et al[130]
	N/D[a]	12.7% (≤1 y after GBy)	Ledoux et al[84]
	11.5%	11.5% (1 y after LG)	Van Rutte et al[54]
	1%	11% (1 y after GBy)	Toh et al[132]
	0%	10% (1 y after GBy)	Vargas-Ruiz et al[144]
	10%	9% (1 y after LG)	Ferraz et al[77]
	N/D[a]	9% (1 y after GBy)	Leeman et al[136]
	9%	8% (1 y after GBy)	Ferraz et al[77]
	5.9%	7.8% (1 y after LG)	Antoniewicz et al[139]

(continues)

TABLE 3 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity After Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency Before the Operation	Percentage of Deficiency After the Operation	References
	N/D[a]	7.7% (5 y after LG)	Boyle et al[134]
	N/D[a]	7.5% (≤1 y after LG)	Ledoux et al[84]
	13.9%	7% (1 y after GBy and LG)	Antoine et al [76]
	N/D[a]	7% (after bariatric surgery)	Calderón et al[135]
	5.2%	6.9% (1 y after GBy)	Donadelli et al[82]
	3.6%	6.5% (1 y after LG)	Vage et al[137]
	3%–8%	0%-19% (after GBn)	Patel et al[75]
	1.8%	6.2% (1 y after GBy)	Moize et al[133]
	6.8%	5.6% (1 y after GBy)	Voglino et al[128]
	0%	5% (1 y after GBy)	Madan et al[46]
	N/D[a]	4.8% (1 y after GBy)	Boyce et al[126]
	N/D[a]	3.6% (1 y after GBy)	Lovette et al[124]
	2.9%	3.5% (1 y after GBy)	Blume et al[140]
	2.7%	3.2% (1 y after LG)	Moize et al[133]
	1.6%	1.4% (1 y after GBy)	Johnson et al[125]
	5%	0% (1 y after GBy)	Verger et al[64]
	4%	0% (1 y after LG)	Toh et al[132]
	3%	0% (1 y after LG)	Verger et al[64]
	1.3%	0% (1 y after LG)	Johnson et al[125]
	N/D[a]	0% (1 y after GBy)	James et al[127]
	0%	0% (2 y after GBy)	Billeter et al[129]
Iron	43%	31% (after 6 mo of bariatric/metabolic surgery)	Remedios et al[71]
	34.5%	29.6% (1 y after GBy)	Voglino et al[128]
	40,4%	27.7% (1 y after LG)	Ben-Porat et al[56]
	N/D[a]	23.4% (1 y after GBy)	Leeman et al[136]
	15%	21% (1 y after GBy)	Toh et al[132]
	43%	21.9% (after 1 y of bariatric/metabolic surgery)	Remedios et al[71]
	7%–37%	21%–100% (after BPD)	Patel et al[75]
	16.6%	20% (1 y after GBy)	Vargas-Ruiz et al[144]
	N/D[a]	16.9% (1 y after GBy)	Boyce et al[126]
	N/D[a]	20% (after bariatric surgery)	Calderón et al[135]

(continues)

TABLE 3 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity After Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency Before the Operation	Percentage of Deficiency After the Operation	References
	26.5%	15.9% (1 y after GBy)	Moize et al[133]
	30.8%	10.3% (1 y after LG)	Moize et al[133]
	14%	6% (1 y after GBy)	Madan et al[46]
	5.3%	4.1% (1 y after GBy)	Blume et al[140]
	5.9%	2% (1 y after LG)	Antoniewicz et al[139]
	38%	18.5% (1 y after LG)	Van Rutte et al[54]
	29%	19% (1 y after GBy)	Ferraz et al[77]
	N/D[a]	15.8% (1 y after GBy and LG)	Antoine et al[76]
	7%-37%	14% (after LG)	Patel et al[75]
	18%	11% (1 y after LG)	Toh et al[132]
	N/D[a]	10.3% (5 y after LG)	Boyle et al[134]
	24%	10% (1 y after LG)	Ferraz et al[77]
	20%	8.9% (1 y after LG)	Caron et al[123]
	4.3%	8.5% (1 y after GBy)	Antoniewicz et al[139]
	7%	5% (1 y after LG)	Verger et al[64]
	7%-37%	5%-42% (after GBy)	Patel et al[75]
	7%-37%	0-32 (after GBn)	Patel et al[75]
	5%	3% (1 y after GBy)	Arias et al[67]
	2.77%	0% (6 mo after GBy)	Gobato et al[88]
	18%	0% (1 y after GBy)	Verger et al[64]
Calcium	0%	13.3% (1 y after GBy)	Johnson et al[125]
	11%	9.1% (after 6 mo of bariatric/metabolic surgery)	Remedios et al[71]
	11%	6.9% (after 1 y of bariatric/metabolic surgery)	Remedios et al[71]
	6.4%	4.3% (1 y after GBy)	Antoniewicz et al[139]
	0%	4.3% (1 y after LG)	Damms-Machado et al[66]
	5%	4% (1 y after GBy)	Henfridsson et al[130]
	7.8%	3.9% (1 y after LG)	Antoniewicz et al[139]
	2.9%	3.6% (1 y after LG)	Moize et al[133]
	9.6%	3.5% (1 y after GBy)	Moize et al[133]
	N/D[a]	3% (1 y after GBy)	Arias et al[67]
	13.88%	2.77% (6 mo after Gby)	Gobato et al[88]
	1.9%	2.6% (1 y after LG)	Caron et al[123]

(continues)

TABLE 3 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity After Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency Before the Operation	Percentage of Deficiency After the Operation	References
	0.5%	2% (1 y after LG)	Van Rutte et al[54]
	N/D[a]	1.8% (≤1 y after LG or Gby)	Ledoux et alet al[84]
	5.1%	0.9% (1 y after LG)	Vage et al[137]
	21%	0% (2 y after Gby)	Billeter et al[129]
	0.9%	0% (1 y after LG)	Johnson et al[125]
	0%	0% (1 y after GBn and GBy)	Coupaye et al (2009)[78]
Potassium	6.5%	0% (1 y after LG)	Damms-Machado et al[66]
Phosphate	24%	15% (2 y after GBy)	Billeter et al[129]
	21.8%	3.9% (1 y after LG)	Caron et al[123]
	N/D[a]	3.5% (1 y after LG)	Van Rutte et al[54]
Magnesium	N/D[a]	19% (1 y after GBy)	Arias et al[67]
	29.4%	14.1% (1 y after GBy)	Moize et al[133]
	N/D[a]	12.7% (≤1 y after GBy)	Ledoux et al[84]
	N/D[a]	11.1% (≤1 y after LG)	Ledoux et al[84]
	37.8%	10.3% (1 y after LG)	Moize et al[133]
	12%	8% (2 y after GBy)	Billeter et al[129]
	4.3%	4.3% (1 y after GBy)	Antoniewicz et al[139]
	N/D[a]	3% (1 y after LG)	Van Rutte et al[54]
	7.8%	2% (1 y after LG)	Antoniewicz et al[139]
	2.77%	0% (6 mo after GBy)	Gobato et al[88]
Zinc	N/D[a]	64% (≤1 y after GBy)	Ledoux et al[84]
	55.55%	61.11% (6 mo after GBy)	Gobato et al[88]
	8.1%	39.3% (1 y after LG)	Moize et al[133]
	28%	36% (1 y after GBy)	Madan et al[46]
	34%	34% (1 y after GBy)	Ferraz et al[77]
	N/D[a]	33% (after bariatric surgery)	Calderón et al[135]
	N/D[a]	32.2% (≤1 y after LG)	Ledoux et al[84]
	N/D[a]	29% (1 y after GBy)	Gong et al[122]
	11.5%	27.5% (1 y after GBy)	Moize et al[133]
	40%	20% (1 y after LG)	Ferraz et al[77]
	0%	15% (2 y after GBy)	Billeter et al[129]
	N/D[a]	12% (1 y after GBy)	Arias et al[67]
	N/D[a]	5% (1 y after LG)	Van Rutte et al[54]

(continues)

TABLE 3 Deficiency of Vitamins and Chemical Elements in Patients With Morbid Obesity After Bariatric Surgery, Continued

Micronutrient	Percentage of Deficiency Before the Operation	Percentage of Deficiency After the Operation	References
Copper	N/D[a]	27% (after bariatric surgery)	Calderón et al[135]
	10%	15% (2 y after GBy)	Billeter et al[129]
	0%	8.33% (6 mo after GBy)	Gobato et al[88]
Selenium	11%	46% (2 y after GBy)	Billeter et al[129]
	N/D[a]	41.8% (≤1 y after GBy)	Ledoux et al[84]
	N/D[a]	20.4% (≤1 y after LG)	Ledoux et al[84]
	N/D[a]	11% (1 y after GBy)	Gong et al[122]
	58%	3% (1 y after GBy)	Madan et al[46]

Abbreviations: BPD, biliopancreatic diversion; GBn, gastric banding; GBy, gastric bypass; LG, longitudinal gastrectomy.
[a]The concentrations of micronutrients were not assessed before the operation.

folic acid must be assessed after 3 to 6 months of surgery and then annually.[153]

After GBy, most patients also develop deficiencies of vitamin D, calcium, zinc, copper, magnesium, and selenium.[156–163] For the prevention of calcium metabolism disorders in patients, on the 7th to 10th day after GBy, 1500 to 1800 mg of alimentary calcium and 800 to 1000 IU of vitamin D per day are prescribed. Calcium metabolism as well as 25(OH)D levels should be measured after 6 months of having surgery and appropriate therapy should be selected to correct the abnormality. Osteodensitometry is required 2 years after GBy. After performing GBy, the absorption of lipids and lipophilic substances, including fat-soluble vitamins, is sharply reduced.[156]

Among the mixed operations, the BPD was first carried out in 1976 by Scopinaro et al[109] and was based on the achievement of restriction and malabsorption. In this operation, gastric resection is performed with the formation of a proximal gastric pocket with a volume of 500 mL (in patients with a BMI <50 kg/m^2) or 200 mL (in patients with a BMI ≥50 kg/m^2). A 250-cm portion of the intestine is cut off from the ileocecal flap, the distal end is connected to the gastric pocket, and the proximal end is finally connected to the ileum at a distance of 50 cm from the ileocecal flap. The formation of these anastomoses creates a "digestive tract" 200 to 300 cm long, a "biliary tract" 300 to 500 cm long, and a "common tract" 50 to 100 cm long, in which food is digested and nutrients are absorbed. This operation helps to reduce the body weight up to 75%.[103] However, despite the good results, metabolic complications typical for GBy are possible after BPD; especially iron-deficiency anemia and osteoporosis are prevalent because of impaired absorption of lipophilic substances, including vitamin D.[83,164] The detailed information about deficiencies of micronutrients after different bariatric surgeries is illustrated in Table 3.

CONCLUSION

Today, bariatric surgery is the most effective treatment for morbid obesity and metabolic complications associated with it. Often, obesity is not a sole indication for bariatric surgery. The operation is performed when other pathologies are associated, such as progressive diabetes mellitus, obstructive sleep apnea, severe hypertension, and other life-threatening conditions. After analyzing the results of the bariatric surgeries in patients with obesity, many researchers have shown that mixed surgeries (GBy, BPD) have higher efficacy in reducing the body weight as compared with restrictive surgeries (GBn, LG).[165,166] Gastric bypass and BPD, which combine restrictive and blocking components, are characterized by greater complexity and risk of complications. On the other hand, they also provide a more pronounced long-term result, positively affecting the course of metabolic disorders that occur with obesity. Longitudinal gastrectomy is less complex than GBy, has a lower incidence of postoperative complications,[111] and shows similar results in terms of excess body fat loss.[112] Currently, the results of the LG are being actively studied, and the method is being improved. Blocking surgery is practically not used because of the numerous serious complications associated with it.

It must be noted that any type of bariatric surgery ultimately leads to a direct and irreversible digestive disorder. This is, after all, surgical manipulation. Even restrictive surgeries significantly increase the risk of micronutrient deficiencies. Most postbariatric patients have to receive micronutrient replacement therapy for their whole life. In addition, a significant proportion of patients have a number of deficiencies

even before surgery. Bariatrics is a radical and extreme treatment for obesity. It significantly reduces the quality of life despite effective weight loss. Therefore, obesity treatment should begin with dietary and, in extreme cases, with pharmacotherapy. Psychotherapists and psychotropic drugs may also be used.

Furthermore, morbid obesity is not a monolithic disease, but a large set of varied pathologies, not all of which by any stretch are targets for elective surgical intervention. For example, hypothyroidism can also lead to obesity, which, by no means, should be treated by bariatric surgery. The main point here is the patient's attitude on the treatment of his/her disease. Bariatric surgeries are not only the most effective but also the most dangerous method of treating obesity; so, it should only be resorted to as a final option to those patients who do not get persistent effective results from the complex of conservative therapy or to those who have urgent medical indications.

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