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Review Article

Fertility and Pregnancy after Bariatric Surgery: Challenges and Solutions

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Abstract

Introduction Obesity is increasing worldwide, and bariatric surgery (BS) is increasingly employed for weight management in women of reproductive age. An interplay between pregnancy and BS is very likely. A review of the challenges faced and solutions needed is warranted.

Materials and Methods A narrative, nonsystematic review of the international literature from a single online database (PubMed) was performed on July 23, 2023. All articles were included. The retrieved relevant literature is narrated in a concise thematic account.

Results BS carries major metabolic, mechanical, and vascular benefits, possibly accompanied by nutritional, vitamins, minerals, and micronutrient deficiencies, which might be clinical or subclinical. A few of the frequently reported postbariatric nutritional jeopardies could be augmented by the physiological changes of pregnancy, which need a different approach to management. Nutritional deficiencies during pregnancy could carry both maternal and fetal short- and long-term risks. Fetal risks may range from miscarriage to low birth weight, neural tube defects, congenital anomalies, cognitive impairment, and internal organ dysplasia. Postbariatric status is, by default, a high-risk pregnancy category, given the altered biochemical, vasomotor, and mechanical indices of any lady treated with BS. Postgastric bypass hypoglycemia (PGBH) is a relatively common phenomenon during pregnancy, and it usually calls for multidisciplinary action to control. A dedicated monitoring protocol before, during, and after pregnancy has been suggested in several guidelines to guard against the potentially devastating consequences to both mother and fetus.

Conclusions Weight reduction after BS enhances fertility. The optimum timing for ladies treated with BS to get pregnant is not very well established yet. However, various societies have provided multidisciplinary management guidance of management prior to and during pregnancy. Many nutritional supplements that are not routinely prescribed during pregnancy will be essential for those treated with BS. Further studies are still warranted to ensure the safe interim between BS and conception as well as the safety of various doses of medications used for postbariatric individuals, for instance, medications used for PGBH.

Keywords
- Obesity
- Pregnancy
- bariatric surgery
- fetal outcome
- maternal outcome
- malnutrition
- dietary modifications

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Introduction

The proportion of adult women who are overweight and obese increased worldwide from 29.8% in 1980 to 38.0% in 2013. Increased body mass index (BMI) affects fertility and is associated with numerous pregnancy complications, as well as increased maternal, fetal, and neonatal morbidity and mortality.[1]

Depending on the degree of obesity, available management options include lifestyle modification, pharmacological approaches, and bariatric surgery (BS). The most effective, long-lasting treatment for the management of patients with severe obesity is BS.[2]

Although generally safe and effective for weight loss and improvement of metabolic disorders, BS creates a new anatomical and functional environment in the very space that comprises pregnancy. BS leads to the improvement in many obesity-related pregnancy complications, such as gestational diabetes mellitus (GDM), pregnancy-induced hypertension, and fetal macrosomia. However, it can lead to adverse outcomes for mothers and offspring, for example, nutritional deficiencies, anemia, altered maternal glucose metabolism, and small for gestational age children.[3,4]

The effect of BS on pregnancy is a potential management issue in clinical practice because of the increasing number of postbariatric patients; obstetricians, primary care physicians, obesity specialists, dietitians, and nurses need to be aware of and involved in this special condition of monitoring and management of pregnancy. Here, we review the literature on the interplay between pregnancy and postbariatric status. Our objective is to identify the best timing after surgery for a safe conception and the best outcome, recognize potential complications of BS during pregnancy, and identify the best practice from medical, nutritional, and obstetric management.

Materials and Methods

The aim is to provide a reasonably concise but representative narration of the global literature on pregnancy after BS. This is a nonsystematic narrative literature review on the challenges and solutions regarding fertility and pregnancy after BS. A review of the international literature from a single online database (PubMed, NLM, United States) was performed on July 23, 2023. The database was searched with no filters. A manual search was also performed for more relevant literature, such as institutional guidelines from professional societies. Relevant articles were reviewed and narrated thematically. The review gives an overview of all aspects of the subject. We did not perform statistical analysis on the data included in the original articles, and no detailed images and numerical presentations were included.

Emerging Concepts

The themes from the review process included epidemiology, clinical presentations, diagnosis challenges, specific management, and outcomes (►**Table 1**). These will be discussed thematically below.

Obesity in Women of Reproductive Age

The globally increased prevalence of obesity (BMI $\geq$ 30 kg/m^2) impacts women's health during their fertile age, affecting the heart, liver, kidneys, joints, and reproductive system. The World Obesity Federation estimates that one in five women will have obesity by 2030.[1]

Obesity in women of childbearing age adds complications like polycystic ovarian syndrome (PCOS) and infertility. Gaining weight increases the frequency of menstrual disorders by reducing insulin sensitivity, increasing the androgen blood levels, and promoting inflammation through the rise of inflammatory factors. These endocrine-metabolic disturbances result in PCOS and anovulatory menstrual cycles that are considered the main infertility cause in overweight and obese women.[2]

BMI is strongly related to diabetes and insulin resistance.[3] In an obese woman, the β-cells may be unable to compensate fully for decreased insulin sensitivity. Contemporary, the amount of nonesterified fatty acids secreted from adipose tissue in obese women, the hormones and cytokines, the proinflammatory substances, and other substances are increased and involved in developing insulin resistance and diabetes, affecting fertility and childbirth outcomes.

Pregnancies of diabetic women or women who develop GDM during pregnancy have a 38% increased risk of first-trimester miscarriage, compared with 13% of uncomplicated pregnancies. There is also an increased risk of fetal malformations such as spina bifida, umbilical hernia, cardiac

Table 1 The literature review revealed the themes of the interplay of pregnancy and bariatric surgery

• Increasing obesity in women of reproductive age.
• Bariatric surgery as a weight loss procedure is effective; it has several types and complex mechanisms to induce weight loss.
• The effect of bariatric surgery needs consideration during the preconception period.
• The advantageous effects of bariatric surgery on obesity comorbidities are recognized during pregnancy by virtue of the positive effects of weight loss.
• Metabolic alterations postbariatric surgery are relevant to pregnancy.
• Bariatric surgery, like visceral surgery, may affect pregnancy through anatomical and metabolic effects.
• Evidence-based and experience-based professional guidelines for managing postbariatric conception and pregnancy are available and are worthy of review and adherence by practicing physicians.

disorders, eye disorders, and cleft lip and palate. In contrast, the risk of fetal macrosomia increases from 15 to 30% compared with 7% of normal pregnancies.

Diabetic retinopathy and neuropathy often affect the pregnancies of women with preexisting or gestational diabetes, while diabetic nephropathy is associated with higher rates of congenital anomalies and preeclampsia.[4] Less common but potentially life-threatening is ischemic heart disease. The risk of premature delivery of pregnancies with diabetes is increased by 150%, while the risk of instrumental delivery or cesarean section is three times greater. Neonatal morbidity including nonsuction syndrome, respiratory distress, Apgar score < 7 (death within 7 days of birth) triples, while postpartum maternal morbidity (anemia due to postpartum hemorrhage, hypertension, urinary tract infection, surgical site infection, thromboembolism episodes) also increases.

High prevalence comorbidity in the obese population is hypertension, which results in cardiovascular disease (CVD) compromise and chronic kidney disease. Obesity is a metabolic process characterized by severe oxidative stress, reduced availability of nitric oxide, and increased markers of inflammation in the circulation that affects the vascular endothelium, leading to hypertension and CVD. In addition, altered gut microbiota affecting intestinal permeability is another mechanism for promoting inflammation in obesity. Obstructive sleep apnea, extremely common in obesity,[5] also increases blood pressure in obese women by stimulating the sympathetic nervous system. In addition, the increased expression of angiotensin type 1 and 2 receptors and the subsequent increased activity of the renin–angiotensin–aldosterone system caused by obesity alters renal hemodynamics by causing the dilation of afferent renal arteries and vasoconstriction of efferent renal arteries, resulting in further development of hypertension.[6]

Several maternal risk factors in pregnant women have been implicated in developing gestational hypertension, including preconception obesity, chronic pre-existing hypertension, family history, and more. The increase in adipose tissue, a rich source of proinflammatory cytokines and complement proteins, causes an exacerbation of the systemic inflammatory response, resulting in angiogenic imbalances in the circulation and placenta and abnormal placental development and preeclampsia.[7] Preeclampsia is characterized by late gestational hypertension and signs such as proteinuria, renal insufficiency, thrombocytopenia, hepatic dysfunction, and pulmonary edema. Cardiometabolic diseases for both mother and offspring later in life include stroke, hypertension, and metabolic syndrome. Preeclampsia is associated with several maternal comorbidities, which increase the risk of cesarean delivery and preterm birth.

Bariatric Surgery as Weight Loss Procedure—Types and Mechanism to Induce Weight Loss

As obesity increases complications for both mother and offspring during pregnancy and childbirth, obese women are advised to lose weight before conception.[8]

The International Federation for the Surgery of Obesity and Metabolic Disorders suggests that weight loss surgery, known as BS and metabolic surgery, maybe a treatment for patients with class III obesity (BMI $\geq$ 40 kg/m^2) or class II obesity (BMI 35–39 kg/m^2) with comorbidities when therapeutic goals cannot be achieved using only structured lifestyle change and pharmacotherapy.[9]

Various surgical procedures have been used to induce weight loss according to the desired goal, patient aspects, and the presence or absence of comorbidities.[10] A summary of the different types of bariatric surgical procedures, their advantages and disadvantages, is presented in ►**Table 2**. These procedures result in weight loss through three different mechanisms, with some procedures using a combination of them. Restrictive bariatric procedures reduce the gastric pouch size while leaving the rest of the gastrointestinal tract intact. Restricted food intake reduces the percentage of nutrients absorbed from a meal, resulting in weight loss. Sleeve gastrectomy is one of the most popular types of

Table 2 The commonly employed types of bariatric surgical procedures in contemporary practice

Procedure	Class	Features	Advantages	Disadvantages
AGB	Restrictive	an inflatable band divides into two, which restricts food intake	–Adjustable –Reversible –Minimally Invasive –Gradual Weight Loss –No dumping syndrome	–Slow weight loss –Limited effectiveness - need periodic adjustments –Diet restrictions –Potential complications
VSG	Restrictive	Part of the stomach is removed; a tube-like stomach is formed, thus restricting food intake.	–Technically simple—for high-risk medical conditions –Effective weight loss	–Nonreversible procedure –May worsen reflux –Less impact on metabolism
RYGB	Restrictive/ malabsorptive	A pouch on the stomach is created, and a section of duodenum is attached to it. Thus, food bypasses the duodenum	–Long-lasting weight loss –Effective for obesity-associated conditions –Standardized technique	–Technically complex –More vitamin deficiencies –Risk for complications –Risk of ulcers—“dumping syndrome”

Abbreviations: AGB, adjustable gastric banding; VSG, vertical sleeve gastrectomy; RYGB, Roux-en-Y gastric bypass.
Note: Types of bariatric surgical procedures with their advantages and disadvantages

restrictive BS. In a sleeve gastrectomy, approximately 80% of the stomach is removed, including the part responsible for producing the satiety-controlling hormone ghrelin. Malabsorptive processes are characterized by bypassing the duodenum and jejunum and decreasing the amount of intestine available for absorption. In mixed procedures, both energy intake and absorption are limited. Food intake is reduced by creating a gastric pouch, and less intestine, gastric acid, bile, and pancreatic enzymes are available for absorption. Gastric bypass surgery is the oldest and most commonly performed BS. This procedure, together with reducing the size of the stomach, bypasses or omits a sizable part of the upper part of the small intestines where nutrients such as fat, protein, and vitamins are absorbed.[11]

BS can be a very effective approach to weight loss. Fewer nutrients are absorbed, and additional weight is lost. However, supplements should be taken because nutrients are insufficient to ensure the body gets the necessary vitamins and minerals.[12]

Typically, the patients lose the most weight 1 or 2 years after BS and experience substantial improvements in obesity-related conditions. As much as 60% of excess weight may be lost 6 months after surgery and 77% as early as 12 months after surgery. On average, patients maintain 50% of their excess weight loss 5 years after surgery. Moreover, BS results in an improvement in all obesity-related comorbidities.[13] Most BS women with diabetes, dyslipidemia, hypertension, and obstructive sleep apnea experience remission of these obesity-related diseases. In addition, BS is the best approach to reversing type 2 diabetes (T2D), normalizing blood glucose levels, and improving fertility by regularizing menstruation, improving ovulation, and changing hyperandrogenism.[14]

Effect of Bariatric Surgery in the Preconception Period

Women of childbearing age who have undergone BS may seek to start or expand their families. This group of patients may have special considerations regarding the potential, best timing, preparation, and pre- and postconception care.

The preconception period is defined as the period from 14 weeks before to 10 weeks after conception. The effect of BS during this critical period is positive in improving fertility by modifying the postoperative metabolic homeostasis closer to the normal level. This results in regular development of the follicles, an increased quality of egg maturation, and a positive result in implantation.

Optimizing women's diet and weight through BS before conception appears to reverse the infertility induced by overweight or obesity and result in a higher pregnancy success rate. Spontaneous pregnancy can occur within a year after BS due to higher levels of sex hormone-binding globulin, as well as follicle-stimulating hormone and decreased androgen levels.[15] Reduced follicular fluid insulin, triglycerides, free fatty acids, proinflammatory cytokines, oxidized low-density lipoprotein, and fatty acid composition as a result of weight loss positively affect implantation, pregnancy success, and live births. Also, patients who underwent assisted reproductive technologies after BS have been found to have increased egg counts, better egg quality, and higher live birth rates.

Contemporaneously, it has to be considered that the period after BS is characterized by fast and excess weight loss due to iatrogenic malnutrition status performed after BS. It has been shown that dietary and environmental exposures during these sensitive periods of life can affect fetal development and the development of normal organ and system functions.[16] Indeed, an increased rate of spontaneous missed abortions has been observed in conceptions closer to BS. Also, permanent changes in many physiological processes of embryonic programming can modify gene expression patterns, with consequent impact on phenotypes and functions (epigenetic mechanisms). These changes in the placenta/embryo/fetus formulate the basis for the concept of the fetal origin of adult diseases.[17]

During this period after surgery, delaying pregnancy is recommended to ensure maximal weight loss and weight stabilization of the pregnant woman and minimize fetal malnutrition rates and obstetric complications.

Effect of Bariatric Surgery on Obesity Comorbidities during Pregnancy

During pregnancy, the development of GDM could be because of the significant increase and the further exacerbated baseline insulin resistance accompanied by β-cell dysfunction. The "Hyperglycemia and Adverse Pregnancy Outcomes" Study showed a continuous and graded relationship between maternal hyperglycemia and the risk for an adverse perinatal outcome.[18] Short-term risks for the baby include neonatal hypoglycemia, hyperbilirubinemia, and respiratory distress syndrome. However, postterm birth and large for gestational age are associated with decreased odds after BS.

As obesity is associated with hyperglycemia and hyperlipidemia, lipids may provide additional substrates for fetal overgrowth. This notion is confirmed by recent studies showing that in GDM, there is a preferential activation of lipid genes in the placenta in contrast to the activation of glucose metabolic pathways.[19]

GDM is also associated with pregnancy-induced hypertension and pre-eclampsia. Although the mechanisms by which obesity increases the risk for hypertensive disorders are not fully understood yet, obesity-related metabolic factors seem to cause cytotrophoblast dysfunction and subsequent placental ischemia and hypertension.[20] BS being the most effective obesity treatment, it can be assumed that women who conceive after BS have a lower risk of developing hypertension disorders. The available data support this presumption.

Obese women who undergo BS before pregnancy are less likely to experience obesity-related comorbidities such as gestational diabetes and hypertension. ►**Table 3** summarizes the effects of BS on maternal and fetal outcomes.

However, the malabsorption of nutrients or the endocrine dysregulation after BS can cause long-term changes in different systems, affecting perinatal outcomes, fetal development, and offspring.

Table 3 The impact of bariatric surgery on maternal and fetal outcomes

Complications:	Risk
A. conception and pregnancy outcomes:	
• Miscarriages	?
• Artificial reproductive technology success	↑
• Postterm births	↓
• Preterm delivery	↑
• NICU admissions	↑
• Low-segment cesarean section	?
B. Maternal outcomes	
• Gestational diabetes	↓
• Hypertension	↓
• Preeclampsia	↓
C. Fetal outcomes	
• Macrosomia/LGA	↓
• IUGR/SGA	↑
• Congenital malformations	?

Abbreviations: IUGR, intrauterine growth restriction; LGA, large for gestational age; NICU, neonatal intensive care unit; SGA, small for gestational age.
↑: Increased; ↓: reduced; ?: limited data.

Partial stomach resection removes the cells that secrete intrinsic factor necessary for vitamin B12 absorption; gastric acid secretions are altered, which influences absorption of iron, calcium, selenium, copper, and zinc; the duodenum and jejunum are bypassed with the Roux-en-Y gastric bypass (RYGB) and biliopancreatic diversion with duodenal switch (BPD/DS), and these are the primary sites of absorption for many nutrients; and vitamins A, D, E, and K are poorly absorbed due to inadequate mixing of bile and pancreatic enzymes in addition to reduced small bowel absorption[21]

In addition, obesity is characterized by chronic inflammation, which is aggravated by rapid weight loss soon after RYGB. It has been proposed that the resulting elevation of some proinflammatory cytokines increases the likelihood of inflammation and anemia, which can also induce myelodysplastic-like features in the marrow that persist in the long term after RYGB.[22]

The American Association of Clinical Endocrinologists, the Obesity Society, and the American Society for Metabolic and Bariatric Surgery recommend that women avoid conception for 12 to 18 months after BS.[23] The delay is intended to optimize the likelihood of maternal weight stability during fetal growth. This recommendation is due to recent evidence suggesting that conception within 2 years of BS increases the risk for premature, small-for-gestational-age (SGA) infants and neonatal intensive care unit (NICU) admissions. ►**Table 4** lists the relative risks of various contraceptive methods that can be offered to patients going for or after BS. However, other factors such as obesity, diabetes, and hypertension should be considered in making individual choices.[24]

Metabolic Alterations in Pregnancy before and Postbariatric Surgery

Pregnancy itself has been shown to induce substantial time-dependent alterations in physiology and metabolism under the constantly changing demand as the mother responds to the needs of the growing fetus. Nevertheless, the effect of BS on the metabolic profiles is superimposed on the changing metabolic landscape.

During pregnancy and due to blood volume expansion, there is a physiological decrease of hemoglobin (Hb) and hematocrit by 50 and 25%, respectively—half of the cases present iron deficiency, followed by folic acid and vitamin B12. Although iron absorption increases during pregnancy, an appropriate diet alone seems insufficient to meet those requirements.[25]

Weight loss after BS leads to possible improvement in iron status. However, patients who underwent malabsorptive surgery showed increased anemia rates probably because of reduced caloric intake, intolerance for red meat, reduced stomach acid production, and decreased dietary iron bioavailability. Anemia is usually prevalent from 12.2% at baseline to 25.9% after 2 years. A history of BS before pregnancy

Table 4 The relative risk associated with contraception methods in postbariatric surgery is associated with various degrees of obesity

Contraceptive method	With BMI < 30	With BMI > 30–34	With BMI > 35
Copper intrauterine device	1	1	1
Levonorgestrel intrauterine device	1	1	1
Implant progestogen only	1	1	1
Progestogen injectable	1	1	1
Progestogen-only pill	1	1	1
Combined hormonal contraception	1	2	3

Abbreviation: BMI, body mass index.
Note: Category 1: There is no restriction; Category 2: Advantages outweigh the theoretical or proven risk, Category 3: Theoretical or proven risks outweigh the advantages of using the method.

increases the risk of developing iron deficiency anemia during pregnancy. Hence, iron deficiency is the most frequent anemia in pregnant women.[26]

The amount of iron that a woman needs during her pregnancy is 1,200 mg. The fetus takes up to 400 mg over full gestation, and the placenta accumulates up to 175 mg. Pregnant women require an extra 1 mg/day in the first trimester, 4 to 5 mg/day in the second trimester, and an extra 6 mg/day in the third trimester.[27] Maternal iron deficiency during pregnancy seems to be linked with an increased risk of an SGA fetus and is associated with increased placental weight and reduced ratio of fetal weight to placental weight. The placental structure is altered in maternal anemia as the surface area of capillaries involved in gas exchange is strongly related to maternal serum ferritin and Hb concentration levels. An association between relatively low umbilical cord serum ferritin levels and lower scores on certain mental and psychomotor tests at 5 years of age has been reported, where a poor intrauterine iron status (low ferritin) was associated with less favorable cognitive and psychomotor development. Maternal anemia also increases the risk of spontaneous or medically induced premature delivery. Birth weight has been strongly linked to high preterm birth rates, neonatal cardiovascular morbidity and mortality, and NICU admission.[28]

Another cause of anemia could be a deficiency of vitamin B12. Following BS, the absorption of the B12 may be impaired to varying extents depending on the type of the procedure. Low maternal vitamin B12 was associated with a higher risk of neural tube defects (NTDs) in the offspring and increased risk for poor fetal growth, reported as low birth weight (LBW), SGA, or intrauterine growth restriction (IUGR). An imbalance in B12-folate status (low B12-high folate) was associated with a higher risk for GDM and subsequent permanent diabetes, greater insulin resistance, and adiposity in the offspring during childhood. Inappropriate levels of vitamin B12 can result in neurobehavioral disorders in infants, presenting with symptoms of impaired ability to concentrate, depression, problems with abstract thought, and memory impairment and confusion. The low concentration of cobalamin may also result in elevation of serum homocysteine. Hyperhomocysteinemia is directly related to early pregnancy loss,[29] preeclampsia and preterm delivery as outcomes, and LBW. Higher homocysteine was also associated with higher systolic and diastolic blood pressure. The daily dose of cobalamin during pregnancy after BS should be increased from 3 to 10 mcg. When this therapy is insufficient, intramuscular injections are recommended in a monthly dose of 1,000 mcg.[30]

Fetal NTDs, which occur when the fetal brain, skull, spinal cord, and spinal column do not develop properly within 4 weeks after conception, are linked with folic acid deficiency. The most common NTDs are anencephaly, incompatible with life and spina bifida, which may result in partial and total paralysis.[31] Prenatal supplementation with 4 mg of folic acid before and during pregnancy maintains adequate serum levels to reduce the risk of neural tube defects.

Pregnancy is mainly characterized by an increased need for nutrients, allowing for the development and growth of the placenta and fetus. Maternal kidney function adapts to the clearance of fetal and maternal metabolic waste, resulting in an increased urine excretion of water-soluble vitamins.[32] In normal pregnancy, therefore, the need for most micronutrients is increased. Serum concentrations of the water-soluble vitamin B-6, vitamin B-12, folate, and thiamin, together with the fat-soluble vitamin A, phylloquinone, and the inactive form of vitamin D (25-hydroxyvitamin D [25 (OH)D]) decrease, whereas vitamin E serum concentrations and the active metabolite of blood vitamin D increase. The need for minerals and trace elements is most often increased during pregnancy.

Micronutrient deficiencies are increased after BS. Malabsorptive procedures such as RYGB and BPD decrease the absorption of micronutrients because part of the small intestine is bypassed. In contrast, restrictive procedures such as laparoscopic adjustable gastric banding and vertical sleeve gastrectomy (VSG) reduce stomach capacity.[25]

These anatomical and pathophysiological maternal nutritional status and alterations of the gastric environment can influence general cellular function, metabolism, and gut microbiota, affecting fetal growth and metabolism.[33] Inadequate or imbalanced maternal nutrition during pregnancy can alter physiological structures and/or functions, leading to an increased risk of chronic disease in later life.[34]

The plasma vitamin K concentrations are important for fetal development and neonatal outcomes. Vitamin K is a fat-soluble vitamin with limited placental transfer during normal pregnancy. The high adipose tissue concentrations of K1 and the excessive vomiting or fat malabsorption, affecting pregnant women after BS, lead to a higher risk of vitamin K-deficient bleeding disorders in the neonates of these mothers. Intracranial hemorrhages have been reported in neonates after BS,[35] reflecting lifelong consequences, including psychomotor and mental retardation and a high risk of perinatal death. Almost 88% of the women during the first pregnancy trimester and approximately 50% of the women at birth had low phylloquinone concentrations (<0.8 nmol/L). However, there are no recommendations for supplementation of vitamin K.

Devlieger et al report a vitamin A deficiency in up to 58% of women after a bronchopulmonary dysplasia (BPD) operation accompanied by maternal night blindness, preterm birth, and vision complications in neonates. Vitamin A is important in cell reproduction, differentiation, and proliferation. An adequate level of vitamin A is necessary, especially in the second and third pregnancy trimesters, for normal fetal lung development and maturation. Several studies presented an increased risk in preterm infants with insufficient vitamin A status of BPD, respiratory infections, and diarrhea. Plasma retinol levels have to be examined periodically to avoid these complications. Oral supplement therapy should be introduced, but without exceeding the dose of 5,000 IU/d, as it is teratogenic.[32]

Vitamin D deficiencies arise more frequently in post-BS pregnancies as the intake of dairy products is limited due to dietary intolerance and the bypassed primary absorption sites of calcium and vitamin D.[36] This vitamin has been recognized as a risk factor for many diseases, such as developing rickets in childhood and osteomalacia in adulthood. In addition, it may contribute to the immune system's dysfunction and increase the risk of cancers, diabetes mellitus, autoimmune diseases, and CVD.[37] The recommended dose for nonpregnant individuals after BS is between 3,000 IU daily and 50,000 IU one to three times weekly, based on professional guidelines.[38] However, during pregnancy, there is no special recommendation on the dose after surgery; lower doses are generally recommended since higher doses of vitamin D failed to get superior in terms of fetal outcomes[39]

Zinc, magnesium, iodide, and other antioxidants, such as vitamin C, vitamin E, selenium, and lycopene, are monitored in many studies for their increased requirement in pregnant women after BS. Low levels of zinc have been combined with premature deliveries, LBW, abnormal fetal development, and spina bifida, and its optimal recommended supplemental dose is 15 mg daily. Magnesium supplementation at 200 to 1,000 mg daily during pregnancy may reduce fetal growth retardation and preeclampsia and increase birth weight. Iodide deficiency can cause maternal and fetal hypothyroidism and impair the neurological development of the fetus, with cretinism as the most severe manifestation. The intake of 250 mcg daily of iodide is the most frequent suggestion for pregnant women after bariatric treatment.[40]

Antioxidants could neutralize free radicals, improve insulin sensitivity, and prevent dangerous conditions in pregnancy, such as serious complications for the woman involving the liver, kidneys, brain, or blood clotting system, early-pregnancy miscarriages, preeclampsia, or other pregnancy complications.[41] Unfortunately, for most of them, there is no recommended supplementation daily dosage for pregnant women after bariatric treatment. Patients must be informed about the postoperative necessity of supplementation intake, and the supplemented dose has to be reevaluated individually through periodical serum examination.[42]

Effect of Bariatric Surgery as Visceral Surgery on Pregnancy

Postbariatric pregnancy is a high-risk pregnancy not only because of the metabolic and nutritional deficiency effects after the BS but also because of the number of possible complications that may occur to the mother after that visceral surgery.

Early dumping is the most common metabolic effect happening to the mother within an hour after food. Vasoactive intestinal hormones are released, leading to vasomotor symptoms such as flushing, palpitation, perspiration, tachycardia, hypotension, and syncope. This phenomenon is frequently accompanied by gastrointestinal symptoms such as nausea, abdominal pain, borborygmi, bloating, and diarrhea. These symptoms are often confused with morning sickness and other gastrointestinal clinical conditions caused by pregnancy.

Postgastric bypass hypoglycemia (PGBH) is another known metabolic complication of BS (specifically gastric bypass). It is a hypoglycemic episode that typically occurs 1 to 3 hours after a high simple carbohydrate meal. PGBH usually is considered a long-term complication of gastric bypass (within 1–3 years after surgery). Clinical presentation is variable, but it includes diaphoresis, tremulousness, poor concentration, altered consciousness, palpitation, syncope, or even loss of consciousness and death (though it is not common; Ref attached). In general, during pregnancy, the physiological increase in insulin secretion and sensitivity during the early gestation phase increase the risk of hypoglycemia. This effect could be augmented by the added risk of PGBH in women who conceive following BS.[43] A meta-analysis of six studies evaluating pregnancy after BS has shown a prevalence of up to 58% of pregnant ladies treated with BS experiencing hypoglycemia during pregnancy.[44] Managing PGBH is a challenge outside the domain of pregnancy, and during pregnancy, it becomes even more difficult to control. The mainstay of management is a dietary modification with or without pharmacological options, all of which may not yet approved by the Food and Drugs Administration.

Additionally, several mechanical complications during postbariatric pregnancy have been reported, although no study has shown an increased prevalence. The kind of surgical complication depends upon the type of surgery done. The most common include small bowel obstruction, volvulus, intussusception, internal hernias, cholelithiasis, gastric band erosion or migration, slipping of the gastric band, gastric ulcers, stitch-line leak, and potentially life-threatening peritonitis.[45]

Early signs and symptoms could be crampy pain in the left upper quadrant or epigastric region that may radiate to the back. Vital signs, physical examination, and laboratory studies may be normal. This condition may be mistaken for common and benign pregnancy-related complaints.[46]

Guidelines for Managing Postbariatric Conception and Pregnancy

Pregnant women who have undergone BS before pregnancy may have a reduced risk of obesity-related complications but an increased risk of mechanical complications such as small bowel obstruction and complications due to malabsorption. Managing these unique obstetric populations, mothers, and their offspring is challenging as bariatric procedures are anatomically different and, therefore, differentially impact the rate and extent of weight loss and postoperative physiological changes.

Although few studies have attempted to compare outcomes between procedures directly, there are specific guidelines that define micronutrient needs and their monitoring in pregnancies after BS. Most opinions urge women to postpone pregnancy to ensure maximal weight loss and stabilization and decrease the risk of macronutrient and micronutrient deficiencies and electrolyte imbalances.[47] This is typically achieved 1 year after VSG or RYGB procedures and 2 years after the adjustable gastric band (AGB).[48]

Women should be aware of postoperative increases in fertility, as BS improves the metabolic and hormonal profile involved in anovulation, and be offered an appropriate type of contraception. Individualization of the choice of contraceptive method should be individualized, taking into account parameters such as the type of BS performed, the patient's BMI, comorbidities of obesity such as diabetes and associated conditions, history of CVD and hyperlipidemia, as well as the age of the patient. As different bariatric procedures alter the intestinal anatomy differently, they affect the absorption and pharmacokinetics of oral hormonal contraceptives differently, altering their efficacy.[49] Obesity is an additional parameter that should be considered in the choice of contraceptive method due to an increased risk of venous thromboembolism and arterial thrombosis.[50] Long-acting reversible contraceptives (etonogestrel implants and intrauterine devices) appear to be the best options before and after BS.[51]

In preparation for pregnancy, guidelines from different medical associations recommend taking multivitamins and mineral supplements. A 400 µg folic acid supplement should be taken, and women with a BMI that remains in the obese range or with T2D should receive 5 mg/day until the 12th week of gestation.[52] All guidelines recommend multivitamin and mineral supplementation during pregnancy for post-BS women, adjusted for deficiencies identified during the initial nutritional and biochemical assessment, which should be repeated quarterly.[41] ►**Table 5** compares the recommended requirements of nutritional supplements during normal pregnancy and pregnancy after BS.[23,26,46]

Close ultrasound monitoring of fetal growth should be offered to all women with a history of BS, as BS is considered a risk factor for IUGR, and most of its types appear to double the risk of fetal growth restriction.[53] Although it is still unclear whether BS increases the risk of congenital malformations in offspring, monthly ultrasound screening for viability and an additional detailed scan for abnormalities during the first or second trimester are highly recommended when additional risk factors are present (e.g., smokers, low gestational weight gain, and teenagers).[54–56]

Women who have undergone BS are often still affected by obesity or overweight and are at high risk for T2D and CVD compared with healthy-weight women without BS.[57,58] As the data on glucose homeostasis in pregnancy after BS are few and heterogeneous, there are no specific guidelines for diabetes control. However, international consensus emphasizes the importance of screening and treating diabetes during pregnancy after BS. The conventional oral glucose tolerance test should be avoided because a large glucose load can precipitate reactive hypoglycemia (PGBH).[59] In the first trimester, the glycated Hb level should be measured to rule out preexisting diabetes,[60,61] and monitoring of fasting blood glucose levels and postprandial glucose levels over days is recommended as screening for gestational diabetes after 24 weeks of gestation.[60,61] Guidelines also focus on evaluating post-BS complications during pregnancy.[26]

The development of gastrointestinal symptoms should be evaluated for a long list of obstetric and surgical complications related to their primary bariatric procedure. Though surgical complications are not very common, there are reported cases of internal herniation after the RYGB procedure, where patients presented with abdominal pain, nausea, and/or vomiting. The RYGB procedure results in potential internal spaces that predispose to internal herniation. Bowel migrates through the transverse defect of the

Table 5 Recommended nutritional supplementation during normal pregnancy and for pregnancy after bariatric surgery

Nutrient	For normal pregnancy	For postbariatric pregnancy
Iron (mg/d oral)	27	50–100
Folic acid (mcg/d oral	600	400–1,000
Vitamin B1 (Thiamin):		
Oral (mg/d)	140	250–500
IV (mg IV)	–	100–500
Vitamin B12 (cobalamin)		
Oral (mcg/d)	260	250–600
IM (mcg/month)	–	1,000
Vitamin A (IU/d oral)	2,500	5,000–10,000
Vitamin D (IU/d oral)	600	1,000–2,000
Calcium (mg/d oral)	1,000–1300	1,200–2,000
Magnesium (mg/d oral)	300	100–300
Zinc (mg/d oral)	12	15–60
Copper (mg/d oral)	8-10	20
Selenium (µg/d oral	60	50–100

Note: Compiled from references.[23,26,46] mesocolon, mesenteric defects in Petersen's space, and the jejuno-jejunostomy defect, leading to small bowel obstruction and intestinal necrosis.[62] Because of the severity of complications that can lead to severe morbidity and even mortality for the mother and fetus, every post-BS pregnant woman presenting with usual abdominal pain and/or vomiting should be urgently evaluated by a BS surgeon.[63]

A history of BS is not a contraindication for vaginal delivery unless absolute obstetric factors are present.[64] The neonatologist should be aware of the postbariatric maternal history because of the increased risk of SGA and prematurity.[56,65] Cases of neonatal vitamin B12, B9, and K deficiency have been reported,[25,66] and nutritional assessment and necessary supplementation is recommended. Although our knowledge of the effect of BS on breastfeeding is insufficient, women should be encouraged to breastfeed, and nutritional supplementation and monitoring should continue for at least 6 months postpartum.[67]

Conclusions

Pregnancy after BS is increasing. The impact on the fetus and offspring is becoming more recognized. Postbariatric malnutrition and vitamin or mineral deficiencies should be monitored and followed up carefully during pregnancy through regular blood tests and fetal growth ultrasound.

Several guidelines have been developed to determine micronutrient requirements during pregnancy after BS. However, further research is needed to define the optimal time-to-conception interval for reproductive-age women and their macronutrient needs, taking into account the type of surgery, prepregnancy BMI, recommended gestational weight gain, level of physical activity, and presence of PPH or early dumping syndrome.

Individualizing specific supplementation needs should prevent maternal and fetal complications from vitamin deficiencies or excesses due to the overcorrection of deficiencies or supraphysiological vitamin supplementation. Ideally, postbariatric pregnant women should be followed by a multidisciplinary medical team that will address the various metabolic changes that occur after BS and their potential effects on pregnancy. Specialized personnel should provide psychological support and immediate medical care in case of possible surgical complications.

Author Contributions

A.M. drafted the first version of the manuscript. All other authors read and approved the final version.

Compliance with Ethical Principles

Not applicable

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Conflict of Interest

None declared

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