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Nutritional deficiencies in pregnancy after surgery for morbid obesity

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Abstract

Objectives: The rate of morbid obesity among women of reproductive age continues to rise worldwide. Surgical treatment remains the most effective mean to face it. Anatomical, physiological and nutritional modifications lead to several challenges for pregnancy after bariatric procedures. In spite of routine supplementation after bariatric surgery, vitamin and mineral deficiency frequently appear in bariatric pregnancies. The aim of this review is to summarize the existing data on the prevalence and management of nutritional deficiencies in pregnancy after bariatric surgery.

Methodology: A comprehensive search of Pubmed Database was conducted for English-language studies using a list of key words.

Results: The most common post-operative deficiencies in pregnancy include iron, vitamin B12, folate, vitamin D and magnesium deficiency. Less common are selenium, vitamin A, vitamin B6 and vitamin C deficiency. Finally, copper, vitamin K, vitamin B1, vitamin E and albumin deficiencies are considered to be relatively rare.

Conclusions: Pregnancy after bariatric surgery has been proven to be safe for both the mother and the fetus. However, there is still the risk of significant nutritional deficiencies with adverse effects on pregnancy and lactation. As a result, a thorough customized nutritional assessment is mandatory for every woman in reproductive age who has undergone a bariatric operation, with strict regular follow-up during pregnancy and lactation.

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Introduction

Obesity has taken an epidemic form during the last two decades. The World Health Organization (WHO) assessed than in 2008 there were more than 1.4 billion overweight and more than half a billion obese adults. Excess body weight is the 5th leading risk factor for global deaths. More than 2.8 million adults die each year due to being overweight or obese[1]. It is estimated that in Greece, the prevalence of obesity in the adult population is approximately 17.3%, 0.8 units over the mean prevalence of Europe[2]. All age groups face this problem but the incidence is greater for females. About 25% of women meet the obesity criteria, one-third of which are in the reproductive age[3].

Maternal obesity has turned out to be one of the most commonly occurring risk factors for pregnancy, delivery and postpartum complications, not to mention the negative effects on fertility as it is characterized by polycystic ovarian syndrome leading to oligo- or amenorrhea[4].

Maternal risks associated with obesity include increased prevalence of stillbirth and intrauterine fetal death, preterm labor, miscarriage, fetal chromosomal anomalies and macrosomia. Obese women are more likely to suffer from thromboembolism, gestational diabetes and pre-eclampsia. Moreover dysfunctional labour, cesarian section, perioperative complications and postpartum hemorrhage are more common in these women [5,6].

Therefore, weight loss, ideally before conception, appears imperative. Bariatric surgery (BS) remains the only effective means of treatment for morbid obesity[7]. It promotes weight loss, ameliorates related comorbidities and improves reproductive function and infertility. Pregnancy outcome following bariatric surgery depends on the procedure type that has been performed.

Two of the most common bariatric procedures are Roux-en -Y gastric bypass (RYGBP) and the vertical sleeve gastrectomy (VSG). During RYGBP, the stomach is divided and a small gastric pouch that can hold approximately 30ml is created, thus inducing a restriction of the amount of food the recipient can ingest. Subsequently, the jejunum is divided 0.6 -1 meter distally to the ligament of Treitz with the distal segment anastomosed to the gastric pouch (gastro-jejunal anastomosis, GJ), thus reducing the absorbing capacity of the alimentary tract. Eventually, the continuity of the alimentary tract is restored with the construction of a jejuno-jejunal anastomosis (JJ) 1-1.5 meters distally to the gastro-jejunal anastomosis. So RYGBP is a combined restrictive and malabsorptive procedure. The VSG on the other hand is a purely restrictive procedure. The greater curvature of the stomach is resected, leaving a narrow vertical tube that can hold a volume of approximately 150 ml [7,8]. This reduction of the gastric capacity along with the loss of appetite, induced by the lower levels of ghreline, an orexigenic peptide normally secreted by the cells of the gastric fundus which is resected, result in considerable excess weight loss with profound effects on the general health status.

Nevertheless, in both techniques the anatomy of the gastrointestinal tract is modified and this leads to micronutrient deficiencies. Risk factors for this include preoperative malnutrition, decreased food intake, food intolerances, excessive vomiting, inadequate nutrient supplementation and nutrient malabsorbtion. All of these problems are amplified for women in pregnancy or lactation since during both of these conditions the demands for micronutrients are increased[3,7]. Women of reproductive age are advised to avoid pregnancy for at least one year after surgical treatment of morbid obesity, but since at some point this will definitely occur for an increasing number of women, a review of the existing data concerning the nutritional status and needs after bariatric surgery can be very useful for any clinician dealing with these patients.

Methodology

A comprehensive search of Pubmed Database was conducted between April and May 2014. The review covered a period from 1991 to 2014. The keywords which were used individually or in combination were: bariatric surgery (BS), obstetric outcome, nutritional deficiencies, iron, Vitamin D, B12, B6, B1, C, A, E, K, folate, albumin, zinc, magnesium, calcium, biotin, copper, selenium and supplementation.

Results

IRON: Many studies have shown that iron deficiency exists already pre-operatively in obese patients and more particularly in female bariatric surgery patients of childbearing age due to heavy menstrual periods. Even

more, all patients after bariatric surgery face a decrease in the production of hydrochloric acid, subsequently contributing to a lower iron uptake, since the Fe^{3+} to Fe^{2+} conversion is reduced, due to the resection of 75-80% of the stomach and the administration of PPIs (proton pumps inhibitors). Futhermore red meat, which is rich in iron, is less well-tolerated after BS [9-11]. As a result iron deficiency often is seen among bariatric patients who have undergone RYGBP as this procedure leads to iron malabsorbtion and reduced food intake but also after VSG due to lower acid content in the stomach. As a result, iron deficiency is one of the most common nutritional deficiencies after bariatric surgery **(Table 1)** [10,12-15]. In 2014, Alexandrou et al, in their pilot study have reported that in 40 patients undergoing BS, 30% of them developed iron deficiency and 7% ferritin deficiency after a 4-year follow up [16] . During the same year, Van Rutte et al, found that in 200 patients who underwent VSG, one year post-operatively, 37 of them (18,5%) had iron deficiency and in 16 of them (8%) ferritin levels were below the normal range. Before the operation the prevelance of iron and ferritin deficiency was 38% and 7% respectively[17] . In 2012, two studies reported iron deficiency from 0% - 10.5% 1 to 5 years postoperatively [18,19] .

The main cause of anemia in pregnancy is iron deficiency. Pregnancy anemia can be aggravated by various conditions such as uterine or placental bleedings, gastrointestinal bleedings, and peripartum blood loss. In addition to the general consequences of anemia, there are specific risks during pregnancy for the mother and the fetus such as intrauterine growth retardation, prematurity, feto-placental miss ratio, and higher risk for peripartum blood transfusion [3,7,20,21].

VITAMIN B12: Vitamin B12 deficiency is also very common before and after bariatric surgery **(Table 2)**. Its preoperative prevalence ranges between 3-18%[22-25]. After bariatric surgery the absorption of the B12 may be impaired at different levels depending on the type of procedure. Absence of acid environment following gastric bypass surgery, inadequate secretion of intrinsic factor and malabsorption result in the decrease of vitamin B12 absorption in the terminal ileum leading to B12 deficiency [3]. Two studies have found that cobalamin deficiency after BS was 11,5% and 5%, after a one year and a four year follow-up, respectively [16,17] . Moreover, there is another study which has reported that in 41 patients having udergone BS, vitamin B12 deficiency was 20% post-operatively [22] . In addition, Pech et al, found that in their two different studies, the need for supplementation after BS procedure in a total of 182 patients was between 42 and 46,3% during the first two postoperative years, and vitamin B12 levels remained clearly within the lower third of the reference ranges during this period, which means that without the supplementation, a vitamin B12 deficiency would likely

Table-1. Prevalence of iron or ferritin deficiency after bariatric surgery.

Year	Author	Number of patients	Years of follow up	Prevalenc of iron deficiency postoperatively (%)	Prevalence of ferritin deficiency postoperatively (%)
2014	Van Rutte et al.[17]	200	1	18.5	8
2013	Alexandoru et al.[16]	40	4	30	7
2013	Coupaye et al.[43]	30	1	NR	30
2013	Eltweri et al.[22]	41	NR	NR	8
2012	Saif et al.[19]	82	1 / 3 / 5	3 / 10.5 / 0	8.6 / 15.8 / 5.6
2012	Damms-Machado et al. [18]	54	1	4.3	NR
2010	Aarts et al.[104]	60	1	43	NR
2010	Gehrer et al.[27]	50	3	18	NR
2009	Hakeam et al.[37]	61	1	4.9	NR
2009	Toh et al.[105]	64	1	11	0

NR: Not Reported

have occurred [23,24] . In three more studies, vitamin B12 deficiency fluctuated between 0% and 17,2% one year after BS [18,25,26] and Gehrer et al, reported that cobalamin deficiency after a 3-year follow-up in 50 patients was 18% [27] . Apart from the obvious hematologic effects, low concetration of cobalamin may result in elevation of serum homocystein. Hyperhomocysteinemia is known to be directly related to early loss of pregnancy. Moreover, inappropriate levels of B12 during pregnancy due to lower intake can result in neurobehavioral disorders and anemia in the infants [28,29].

FOLATE(VITAMIN B9): Folate absorption occurs along most of the small intestine, mainly in the duodenum and in the jejenum, and depends on pH level, mechanisms of the intestinal wall which have to do with nutrient's transport, and saturation points [30,31]. After bariatric surgery,follic acid can be absorbed throughout the entire intestinal tract, through mechanisms of adaptation [15]. Therefore, folate deficiency after BS ensues primarily due to low intake of folate-rich food, such as legumes, lettuce and green leafy vegetables, and/or due to vitamin B12 malabsorption [32,33] . If maternal folate stores are insufficient prior to conception, the risk of folic acid deficiency is higher and is associated with fetal neural tubes disorders (NTDs), while also the risk of an adverse pregancy outcome such as a preterm delivery and birth defects in the following pregnancy increases. [20, 42]. According to the results of the reviewed studies **(Table 3)**, pre-operative folate deficiency has been estimated to exist in up to 54% of the subjects, whereas recent studies from the USA support that this prevalence is much lower, about 0-6% [34-36]. Five studies found that the prevalence of follic acid deficiency one year after BS ranges between 0% and 15% [17,19,25,26,37] . Furthermore, Ruiz-Tovar et al. found that in 30 BS patients the prevalence of follic acid deficiency was 0% after a two-year follow-up. On the same wavelength, Toh et al. observed in their study that none of the patients developed folate deficiency one year postoperatively, too[26]. On the other hand, Gehrer et al, found the highest prevalence of this deficiency in the literature, which was 22% in fifty patients 3 years after the BS [27,38]. Finally, Aarts et al. and Hakeam et al. found in their studies that folate deficiency occurred in 15% and 9,8% of their patients respectively, one year after VSG [25,37].

VITAMIN D, CALCIUM, PARATHORMONE (PTH): The mechanisms which affect calcium metabolsim after-

Table-2. Prevalence of vitamin B12 deficiency after bariatric surgery.

Year	Author	Number of patients	Years of follow-up	Prevalence of vitamin B12 deficiency postoperatively (%)
2014	Van Rutte et al.[17]	200	1	11.5
2013	Alexandrou et al.[16]	95	4	5
2013	Eltweri et al.[22]	41	NR	20
2012	Moizẽ et al.[44]	61	5	12.5
2012	Saif et al.[19]	82	1 / 3 / 5	2.9 / 0 / 0
2012	Damms-Machado et al. [18]	54	1	17.2
2010	Aarts et al.[104]	60	1	9
2010	Gehrer et al.[27]	50	3	18
2009	Toh et al.[105]	64	1	0

NR: Not Reported

bariatric procedures are not clearly understood. Lower Vitamin D - mediated absorption of calcium due to Vitamin-D deficiency, changes in HCl (hydrochloric acid) secretion and intolerance of calcium-rich food after bariatric procedures are pathways which can influence calcium nutrient status. Moreover, hypovitaminosis D may occur due to less sun exposure, increased uptake of Vitamin D in adipose tissue and vitamin D malabsorption caused by bypassing segments of the intestine where it is naturally absorbed. Because of the inverse relationship between the levels of serum Vitamin D/serum calcium and the levels of serum PTH, vitamin D deficiency pro-

Table-3 Prevalence of folate deficiency after bariatric surgery

Year	Author	Number of patients	Years of follow-up	Prevalence of folate deficiency postoperatively (%)
2014	Van Rutte et al.[17]	200	1	12.5
2013	Eltweri et al.[22]	41	NR	3
2012	Saif et al.[19]	82	1 / 3 / 5	8.8 / 5.5 / 0
2012	Damms-Machado et al. [18]	54	1	13.8
2011	Ruiz-Tovar et al.[106]	30	2	0
2010	Aarts et al.[104]	60	1	15
2010	Gehrer et al.[27]	50	3	22
2009	Toh et al.[105]	64	1	0
2009	Hakeam et al.[37]	61	1	9.8

NR: Not Reported

voking secondary hyperparathyroidism is frequently observed post-operatively. However, serum calcium levels are usually within the normal ranges [11,39-42]. Four different studies with one year follow up reported that the prevalence of vitamin D deficiency fluctuated between 39 and 70,4 % and true secondary hyperparathyroidism occurred in 18 and 39% of the patients. However, it was found that calcium levels were within the normal ranges for almost all the patients in all these studies [17,18,25,43] In addition, one study with 40 individuals reported that four years after BS, hypovitaminosis D was found in 56,3% of the patients and elevated levels of PTH in 43,3% of them [16]. Furthermore, on the same wavelength was also the study of Saif et al., who found that 5 years after, BS vitamin D deficiency and hyperparathyroidism were present in 42% and 58,3% of 82 patients respectively. However, calcium levels were within normal values [19]. On the other hand, Moize et al, did not find any vitamin deficiency D, 5 years after BS in 61 patients although, it should be noticed that the prevalence of hypovitaminosis D, 4 years after the procedure, was 44,4% [48]. The prevalence of calcium deficiency was 12,5% and hyperparathyroidism was present in 87,5% of them. [44] Furthermore, in another study, the prevalence of Vitamin D deficiency and elevated PTH was only 3,3% for both markers in 30 patients 2 years after BS, whereas, pre-operatively it was 96,7% and 20% respectively[38]. Finally, Gehrer et al, reported in their study that hypovitaminosis D and elevated levels of PTH was found in 32% and 14% of 50 patients, who underwent BS, after a 3-year follow-up, with calcium levels within normal ranges for all of them [27] . Data regarding the frequency of vitamin D deficiency, calcium deficiency and hyperparathyroidism after bariatric surgery is presented in **Table 4**.

Pregnancy is characterized by many hormonological and metabolic changes [45] and vitamin D deficiency is relatively common, especially in obese women [46,47] . Bodnar et al. documented a significantly higher percentage of vitamin D deficiency in obese pregnant women. Bariatric surgery also can lead to a postoperative vitamin D deficiency in pregnant women [55]. Maternal vitamin D deficiency is associated with a variety of maternal and fetal complications, such as pre-eclampsia, gestational diabetes and a higher risk of asthma and schizophrenia in childhood [48]. The exact mechanism by which vitamin D can facilitate the onset of pre-eclampsia is unclear [49,50].. Another important observation is that maternal vitamin D levels can influence the bone status of the newborn. Viljakainen et al. showed a significant smaller tibia mineral content in the newborns of pregnant women with lower levels of 25(OH)D during pregnancy [50] .

ZINC: Zinc is a trace element which is only second to iron in concentration in the human body [51]. Zinc plays a pivotal role in the cellular metabolism, being essential for more than three hundred enzymatic reactions [52]. Prior to bariatric surgery, serum zinc levels in obese women are generally lower than in healthy ones [53]. Zinc deficiency after bariatric surgery should always be considered, especially for pregnant women, since many factors could contribute to it. These include bypassing intestinal segments of zinc absobtion duode-

Table-4 Prevalence of vitamin D as well as calcium deficiency, and rates of secondary hyperparathyroidism after bariatric surgery.

Year	Author	Number of patients	Years of follow-up	Prevalence of Vitamin D deficiency postoperatively (%)	Prevalence of calcium deficiency postoperatively (%)	Prevalence of hyperparathyroidism (%)
2014	Coupaye et al.[43]	43	1	70	0	NR
2014	Van Rutte et al.[17]	200	1	36	2	18
2013	Alexandrou et al. [16]	40	4	56.3	NR	43.3
2012	Saif et al.[19]	82	1 / 3 / 5	34.3 / 55.6 / 42	0 / 0 / 0	23.2 / 7.7 / 58.3
2012	Moizẽ et al.[44]	61	4 / 5	44.4 / 0	4.8 / 12.5	57.1 / 87.5
2012	Damms-Machado etal.[18]	54	1	70.4	0	NR
2011	Ruiz-Tovar et al. [106]	30	2	3.3	NR	3.3
2010	Aarts et al.[104]	60	1	39	0	39
2010	Gehrer et al.[27]	50	3	32	0	14

NR: Not Reported

num and jejunum), intolerance to zinc-rich sources (red meat, fish), reduced gastric acid production (required for zinc absorbtion and bioavailability) and bacterial overgrowth (due to alterations of the intestinal tract) [54-57]. In addition to these, zinc levels decline by about 30% during pregnancy. Low levels of zinc have been associated with premature deliveries, low birth weight, abnormal fetal development and neurological defects such as spina bifida. Cases of zinc deficiency during lactation are accompanied by skin rashes or dermatitis, often in combination with failure to thrive and irritability [58-60]. Zinc deficiency is not invariably reported after bariatric surgery **(Table 5)**. Reportedly, it was calculated approximately 5%, one year after BS [17] . Hair loss, as a sign of zinc deficiency, was observed in 30% of the 43 individuals who underwent BS, one year postoperatively [43] . Moreover, Moize et al, found that 5 years after BS, zinc deficiency was 12,5% in 61 patients, while 4 years postoperatively, in the same study, zinc deficiency was 47,6% [44] . Furthermore, Gehrer et al, reported that zinc was below the normal ranges in 34% of the fifty patients who underwent BS, after a 3-year follow-up period [27] and Salle et al, found in their study that zinc deficiency was 18,8% one year after BS [61]. In addition, one study found that zinc deficiency was 14% two years after BS [23], which was in agreement with another study which reported 14,3% zinc deficiency five years after the operation [19] .

MAGNESIUM: Since magnesium is an essential trace element for optimal metabolic function, magnesium deficiency may be a risk factor not only for neurological and cardiovascular complaints but also for metabolic syndrome [62-65]. Futhermore adequate intake of the mineral is needed for normal embrionic and fetal development [66]. Magnesium deficiency is not reported as commonly as other nutritional deficiencies and accordingly there are only sparse data about postoperative hypomagnesemia **(Table 6)**. One study, found that magnesium deficiency was present in 3% of 200 subjects having undergone BS (versus 2% preoperatively) one year after the procedure [17] . Furthermore, there are two different studies which agree that magnesium deficiency did not occur after BS [19,22] , whereas Moize et al, reported that hypomagnesemia was observed in 12,5% of 61 patients, five years after BS [44] . Finally, Coupaye et al, reported that cramps were observed in 3% of 43 individuals who underwent BS[43] . Although COPPER: Copper as a nutrient is essential in many enzymatic reactions and is involed in red cell production and function of the nervous system [76,77]. It is absorbed in the stomach and the proximal duodeum [78,79]. Patients undergoing malabsorptive bariatric sur-

Table-5 Prevalence of zinc deficiency after bariatric surgery.

Year	Author	Number of patients	Years of follow-up	Prevalence of zinc deficiency postoperatively (%)
2014	Van Rutte et al.[17]	200	1	5
2012	Saif et al.[19]	82	5	14.3
2012	Moizẽ et al.[44]	61	4 / 5	47.6 / 12.5
2012	Pech et al.[23]	100	2	14
2010	Salle et al.[107]	33	1	18.8
2010	Gehrer et al.[27]	50	3	34

Table-6 Prevalence of magnesium deficiency after bariatric surgery.

Year	Author	Number of patients	Years of follow-up	Prevalence of magnesium deficiency postoperatively (%)
2014	Van Rutte et al.[17]	200	1	3
2013	Eltweri et al.[22]	41	NR	0
2012	Saif et al.[19]	82	5	0
2012	Moizẽ et al.[44]	61	5	12.5

NR: Not Reported

it is not common, maternal magnesium deficiency has been associated with premature labor, small-for-gestational-age (SGA) neonates, pre-eclamsia and the pathogenesis of the sudden infant death syndrom (SIDS). Tayaka et. al., showed a significant lower level of Mg concentrations in umbilical cord blood in SGA neonates compared to that of control group [66-68]. Nevertheless, further studies should investigate the impact of Mg deficit in fetuses.

SELENIUM: Selenium is a trace element with an essential role in human biology [69]. It is necessery for normal growth and reproduction. Selenium deficiency is implicated with maternal and fetal adverse outcomes, such as infertility, miscariagges, pre-eclampsia, pre-term labor, small for gestational age newborns, gestational diabetes and nervous damage of the fetus [70,71]. In addition, Skroder et al, found a possible negative impact in psychomotor and language development of children from mothers with reduced levels of selenium during pregnancy [72]. Searching in the literature, only few data were found referring to selenium deficiency after bariatric surgery [73-75]. Studies have shown a decrease at the level of selenium after RYGBP. One study also reported that 9 out of 21 patients (43%) suffered from selenium deficiency after VSG [22] . Moreover, Pech et al, found that in 100 individuals who underwent VSG, a significant decrease in serum selenium levels occurred three months after the procedure and 8 out of 82 (9,7%) patients suffered from selenium deficiency and were therefore given supplementation[22]

gery are at risk of impaired copper status due to hypoacidity in the remnant stomach pouch and bypass of the duodeum[80]. Deficiency seems to be rare after BS. The only data we found refers to Amar's et. al. study in which they found that there was no deficiency in 41 patients after VSG [22]. Although it is uncommon, clinicians should be vigilant in its early detection as iron and copper deficiency often coexist, especially in pregnancy. As a result, hypocupremia is often misdiagnosed until serious neurological symptoms, anemia and heart enlargement occurs [81].

CHROMIUM AND VANADIUM: There are no reports referring to chromium or vanadium deficiency in pregnant women after bariatric surgery.

VITAMIN A: Vitamin A is included in the fat-solube vitamins and its absorption occurs in the small intestine either as retinol (animal sources) or qas caroten (plants and vegetables). Vitamin A plays an important role in cells' reproduction, differentiation and proliferation and its' requirements during pregnancy and lactation are higher by 20% [82]. Adequate levels of vitamin A are necessery, especially in the second and third pregnancy trimester, for normal fetal lung development and maturation, vision and immunity [77,83]. Also Vitamin A deficiency has been shown to increase the risk of maternal mortality, premature birth, intra-uterine growth retardation, low birth weight and ante-partum hemorrhage due to abruption placentae [84-86]. Finally vitamin A deficiency may exacerbate iron deficiency, which is relativly common during pregnancy [82].

After a bariatric procedure Vitamin A deficiency can arise due to the bypassing of intestinal segments, reduced dietary intake, oxidative stress, lipid malabsoption and excessive vomiting, which can be even more profound during pregnancy [87]. Two different studies reported that Vitamin A deficiency was present in 20% of 43 patients, and in 4% of 60 patients respectively one year after BS [25,43] . On the other hand, Saif et al. found that hypovitaminosis A did not occur five years after BS . However, there are also three studies which have reported a vitamin A excess with a prevalence between 7,9% and 55,5% . Rates of vitamin A excess and deficiency after surgery for morbid obesity are presented in **Table 7**.

VITAMIN K: Vitamin K is another fat-solube vitamin which is absorbed primarily in the ileum. It is notable that vitamin K has an already limited placental transfer during pregnancy, but its deficiency is rare. The excessive vomiting or fat malabsorption affecting pregnant women, particularly after bariatric surgery, may lead to a higher risk of vitamin K deficiency and concomitant disorders such as clotting abnormalities and an increased bleeding tendency [88]. Eerdekens et. al. have reported on 5 cases with severe neonatal intracranial bleeding, complicating births from women who had undergone BS, all possibly related to Vitamin K deficiency [89].

Table-7 Prevalence of vitamin A deficiency or excess after bariatric surgery.

Year	Author	Number of patients	Years of follow-up	Prevalence of Vitamin A deficiency postoperatively (%)	Prevalence of vitamin A excess postoperatively (%)
2014	Coupaye et al.[43]	43	1	20	NR
2014	Van Rutte et al.[17]	200	1	NR	55.5
2012	Saif et al.[19]	82	5	0	NR
2012	Damms-Machado et al. [18]	54	1	NR	7.9
2010	Aarts et al.[104]	60	1	4	48

NR: Not Reported

VITAMIN E: Vitamin E, being also a fat-solube vitamin, is mainly absorbed in the small intestine, especially in the terminal ileum. Since the intestinal segment which is bypassed in malabsoptive procedures such as RYGBP is jejunum and not the distal ileum, vitamin E deficiency seems to be uncommon after bariatric surgery. One study reported that hypovitaminosis E was found in 3% of 43 patients who underwent BS one year after the procedure [43]. Furthermore, on the same wavelength, an-

other study reported that there were not any patients who were deficient regarding vitamin E one year after BS [18] . Although uncommon, women in pregnancy should be monitored, because low concentration of Vitamin E has been accosiated with abruptio placentae in normal pregnancies and higher incidence of miscarriages [82].

VITAMIN B1 (THIAMINE): Water-soluble vitamin B1 is absorbed in the proximal small intestine (mainly in the ileum) and its deficiency may occur due to persistent vomiting, from which pregnant women commonly suffer, reduced intake and malabsorption. Thiamine deficiency has been associated with encephalopathies, namely Wernicke's encepalopathy and Korsakoff's syndrome, dry Beri-Beri, ataxia and mental status changes [90,91] . Although Vitamin B1 deficiency seems to be relatively rare, it may lead to serious health problems. Rates of vitamin B1 deficiency and excess after surgery for morbid obesity are presented in **Table 8**. Gehrer et. al. reported in their study that there was no thiamine deficient patient three years after VSG, and Moize et al. concluded the same after a five-year follow-up period [27,44] . Nevertheless, in a small sample of 13 individuals, vitamin B1 deficiency was about 30,8% five years after VSG and in three other studies the prevalence of this deficiency flunctuated between 9% and 23% one year after the procedure. It should be highlighted that none of these four studies, which reported a higher prevalence of thiamine deficiency, noticed any clinical comorbidities relevant to the reported deficiency [17,19,25,43] . On the other hand, there were two studies which found a thiamine excess after BS. The prevalence of this excess was 4,5% and 31% respectively [17,25] .

VITAMIN B6 (PYRIDOXINE): Vitamin B6 concetrations decline during pregnancy as a physiologic adjustment secondary to increased blood volume or as a result of increased requirements for active transport across the placenta [82]. Vitamin B6 deficiency is rare but it has been associated with pre-eclampsia, carbohydrate intolerance, hyperemesis gravidarum and neurologic disease of the infants [92]. As a water-soluble vitamin, B6 is absorbed primarily in the duodeum after exposure to the gastric acid [11,30]. Pregnant women with a history of bariatric surgery are in danger due to the bypassing of the responsible for the absorption intestinal segments and the reduction of the gastric acidity, conditions that ensue both after RYGBP and VSG. Rates of postoperative vitamin B6 deficiency and excess are presented in **Table 9**. Three different studies conducted with a one-year follow-up, reported that the prevalence of vitamin B6 deficiency was 4%, 17% and 17,2% respectively after BS, while on the other hand an excess of pyridoxine with a prevalence between 9,2% and 47,5% has also been reported [17,18,43]. Moreover, Aarts et al. found also that 30% of sixty individuals who underwent BS had a vitamin B6 excess, while none of them was deficient [25]. Finally, Moize et al. and Gehrer et al. both reported that the prelalence of vitamin B6 deficiency was 0%,five and 3 years respectively after BS [27,44].

Table-8 Prevalence of Vitamin B1 deficiency or excess after bariatric surgery.

Year	Author	Number of patients	Years of follow-up	Prevalence of Vitamin B1 deficiency postoperatively (%)	Prevalence of Vitamin B1 excess postoperatively (%)
2014	Coupaye et al.[43]	43	1	23	NR
2014	Van Rutte et al. [17]	200	1	9	4.5
2012	Moizẽ et al.[44]	61	5	0	NR
2012	Saif et al.[19]	82	5	30.8	NR
2010	Aarts et al.[104]	60	1	11	31
2010	Gehrer et al.[27]	50	3	0	NR

NR: Not Reported

VITAMIN B2 (RIBOFLAVIN), VITAMIN B3 (NIACIN), VITAMIN B5 (PANTOTHENIC ACID), VITAMIN B7 (BIOTIN): Riboflavin deficiency during pregnancy can result in pre-eclamsia and birth defects including congenital heart deffect and limb deformities [93]. Deficiency of niacin is also a concern during pregnancy but it is relativly common. Finally research data suggest that a substantial number of women develop marginal or subclinicqal biotin deficiecy during normal pregnancy with a potential risk for teratogenesis [94].

For pregnant women who have undergone bariatric surgery the risk of those deficiencies is greater due to malabsorbtion but there are no specific data referring to these water-soluble vitamins either after RYGBP or after VSG.

VITAMIN C (ASCORBIC ACID): Vitamin C is an essential water-soluble vitamin, involved in many biological mechanisms. During pregnancy, serum levels of vitamin C progressively decrease almost by 50%, because of the extra uptake by the fetus and the hemodilution. It's deficiency except from fatigue, bleeding gums, petechia, crockscrew hair, hyperceratosis, myalgias/arthralgias is also associated with pre-eclampsia, poor fetal growth and premature birth [95,96]. This deficiency seems more likely after bariatric surgery, although few data are available in the published literature refering to it. Moreover, during lactation, vitamin C requirements are even higher, and since the maternal vitamin C levels are associated with the levels of vitamin C in the milk, monitoring should be close [82].

TOTAL PROTEIN, PREALBUMIN, ALBUMIN: The evaluation of protein status includes the assessment of the following parameters: 1) total protein, 2) prealbumin and 3) albumin. The majority of the proteins are absorbed in the duodeum. Protein deficiency after BS may occur due to the ensuing anorexia, lower protein uptake, reduced protein digestion caused by poor HCl secretion, and malabsorption. It is associated with loss of muscle, oedema and hypoalbuminaemia. Prealbumin is considered to be an indicative parameter of adequacy of protein intake [97] . Several studies have been conducted in order to assess either all of these parameters or only some of them **(Table 10)**. Coupaye et al. found that one year after VSG, albumin and prealbumin deficiency were both rare (3%), in a sample of 43 subjects [43] .Moize et al. reported in their study that after a five -year follow-up, no one of the 61 patients who had undergone VSG, was deficient, concerning albumin and prealbumin status [44]. On the same wavelength, five more studies, agreed that the prevalence of albumin deficiency after VSG was 0% [18,22,26,38,98] . Furthermore, Saif et al. found that in 18 patients, who had undergone VSG and were assessed for five years, only one (5,5%) had an albumin deficiency [19], and Gehrer et al. reported that 4% of the fifty individulas were deficient with regards to total protein, three years postoperatively [27]. Finally, on the contrary, Aarts et al. reported a prevalence of albumin deficiency of about 15% one year after BS, which was relatively higher, compared to the above mentioned studies [25].

POST-OPERATIVE MANAGEMENT OF NUTRITIONAL DEFICIENCIES IN PREGNANCY.

The above mentioned research data have shown that obese women in reproductive age suffer quite often from several nutritional deficiencies, even prior to bariatric surgery, and there is a high risk of aggravation of these defeciencies after either RYGBP or VSG for various reasons. Pregnancy can further amplify some of these nutritional deficiencies either by increasing the demand or by decreasing the intake [99].Therefore, life-long supplementation of vitamins and trace elements is highly recommended after bariatric procedures [10,100-102]. For pregnant women the importance of routine nutritional screening is heightened. They should be closely monitored and clinicians should be vigilant for the detection of any deficiency that may occur, in order to prevent adverse outcomes, maternal or fetal. **Table 11** lists the nutrient supplements which are recommended for patients after BS, for women in normal pregnancies and during pregnancy after BS. These suggested supplementations should be regarded as general recommendations, since individual requirements may vary depending on the results of frequent testing that may detect a state of deficiency or deficiency symptoms.

Further testing should be conducted for the evaluation of more nutrient markers, namely magnesium, PTH, copper and other water-soluble vitamins [10,103] . Overall, in the management of obesity, teamwork has proved to be beneficial, and a comprehensive group of well-trained professionals is vital for the efficient and effective nutritional care of the patient.

Table-9 Prevalence of Vitamin B6 deficiency or excess after bariatric surgery

Year	Author	Number of patients	Years of follow-up	Prevalence of Vitamin B6 deficiency postoperatively (%)	Prevalence of Vitamin B6 excess postoperatively (%)
2014	Coupaye et al.[43]	43	1	17	NR
2014	Van Rutte et al.[17]	200	1	4	47.5
2012	Damms-Machado et al. [18]	54	1	17.2	9.2
2012	Moizẽ et al.[44]	61	5	0	NR
2010	Aarts et al.[104]	60	1	0	30
2010	Gehrer et al.[27]	50	3	0	NR

NR: Not Reported

Table-10 Prevalence of albumin, prealbumin or total protein deficiency after bariatric surgery.

Year	Author	Number of patients	Years of follow-up	Prevalence of albumin deficiency postoperatively (%)	Prevalence of prealbumin deficiency postoperatively (%)	Prevalence of total protein deficiency postoperatively (%)
2014	Coupaye et al.[43]	43	1	3	3	NR
2013	Eltweri et al.[22]	41	NR	0	NR	NR
2012	Saif et al.[19]	82	1 / 3 / 5	5.5	NR	NR
2012	Moizẽ et al.[44]	61	4 / 5	0	0	NR
2012	Damms-Machado et al.[18]	54	1	0	NR	NR
2011	Ruiz-Tovar et al. [106]	30	2	0	NR	NR
2010	Aarts et al.[104]	60	1	15	NR	NR
2010	Gehrer et al.[27]	50	3	0	NR	4
2009	Toh et al.[105]	64	1	0	NR	NR
2006	Hamoui et al.[108]	118	1	0	NR	NR

NR: Not Reported

Table-11. Recommended supplementation for the general bariatric population, for pregnant women and for pregnant women with a history of bariatric surgery

Micronutrient	Recommendation for general bariatric population	Recommendation for pregnant women	Recommendation for pregnant women with a history of bariatric surgery
Iron	65 mg	30 mg	40-65 mg
Vitamin B12	5 mg	3 mg	4-5 mg
Folate		4 mg	4 mg
Calcium	1200-2000mg oral	-	2000mg calcium citrate
Vitamin D	800-1000iu	-	2000-6000iu
Zinc	8-15mg	-	15mg
Magnesium	-	-	200-1000mg (if states of deficiency or symptoms occur)
Vitamin K	300mg	-	Close follow up
Copper	2-8mg	-	2-8mg
Vitamin A	10.000 iu	-	5.000 iu
Vitamin C	500mg	-	500-1000mg

bariatric surgery is associated with several nutritional deficiencies. As a result, it is recommended that a thorough, customized nutrition assessment should be conducted for every woman of reproductive age, potential candidate for bariatric surgery, preoperatively, in regular post-operative intervals, and even more intensively during pregnancy. The most common deficiencies include iron, folate, vitamin B12, vitamin D and calcium deficiency. Most women should be supplemented even before conception and especially during pregnancy . Furthermore, many other nutrients, including vitamins of the B-complex (thiamine, pyridoxal), other fat-soluble vitamins (A, E, K) and minerals (copper, zinc, selenium), although rarely deficient, should be tested periodically, to ensure their levels remain within normal range.

DISCLOSURES

The authors have no interest to disclose.

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