Laboratory Testing for and Diagnosis of Nutritional Deficiencies in Pregnancy Before and After Bariatric Surgery

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Abstract

Objective: Bariatric surgery can reduce the risk of obesity-related complications of pregnancy, but may cause essential nutrient deficiencies. To assess adherence to laboratory testing guidelines, we examined frequency of testing for and diagnosis of deficiency during preconception and pregnancy using claims data in women with a delivery and bariatric surgery.

Methods: Retrospective analysis of claims from seven Blue Cross Blue Shield plans between 2002 and 2008. We included women with a delivery and bariatric surgery within the study period. We used common procedural terminology (CPT) and ICD-9 codes to define laboratory testing and deficiencies for iron, folate, vitamin B12, vitamin D, and thiamine. Using Student's *t*-test and chi-square testing, we compared frequency of laboratory tests and diagnoses during 12 months preconception and 280 days of pregnancy between women with pregnancy before versus after surgery. We used multivariate logistic regression to evaluate for predictors of laboratory testing.

Results: We identified 456 women with pregnancy after bariatric surgery and 338 before surgery. The frequency of testing for any deficiency was low (9%–51%), but higher in those with pregnancy after surgery ($p < 0.003$). The most common deficiency was vitamin B12 (12%–13%) with pregnancy after surgery ($p < 0.006$). Anemia and number of health provider visits were independent predictors of laboratory testing.

Conclusion: Women with pregnancy after bariatric surgery were tested for and diagnosed with micronutrient deficiencies more frequently than those with pregnancy before surgery. However, most laboratory testing occurred in less than half the women and was triggered by anemia. Increased testing may help identify nutrient deficiencies and prevent consequences for maternal and child health.

Introduction

NEARLY 35% OF WOMEN AGED 20–39 YEARS in the United States are obese, and 60% are either overweight or obese.¹ Maternal obesity during pregnancy is associated with increased risk of complications of pregnancy such as hypertensive disorders in pregnancy, gestational diabetes mellitus, congenital abnormalities,² stillbirth,³ and maternal mortality.⁴ Bariatric surgery is an effective treatment for Class III obesity (body mass index [BMI] > 40 kg/m²) and can promote rapid,

often sustained weight loss.⁵ It reduces obesity-related morbidities and mortality, including pregnancy-related complications.^{6–9} While preconception bariatric surgery results in weight loss and has generally been considered safe and beneficial for mothers and neonates,¹⁰ malabsorptive procedures may also lead to nutritional deficiencies that could adversely affect pregnancy.¹¹

Deficiencies of essential micronutrients, such as iron, folate, and vitamin D, can lead to maternal anemia and impaired neural tube development and may be associated with

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preeclampsia.^{12–15} The monitoring of nutrient deficiencies after bariatric surgery, despite routine multivitamin supplementation, is important.^{16–18} Guidelines suggest screening for micronutrient deficiencies annually beginning the year after bariatric surgery.^{19,20} There are no prior investigations of laboratory testing for and diagnosis of micronutrient deficiency in women who become pregnant after bariatric surgery.

Our objective was to assess the frequency of screening for deficiencies of iron, folate, and vitamins B1, B12, and D in women who became pregnant after bariatric surgery compared to those who became pregnant before bariatric surgery. We also assessed the frequency of diagnoses for vitamin deficiencies and determined the predictors of testing for vitamin deficiencies in pregnant women following bariatric surgery. We hypothesized that testing would occur more frequently in women with a pregnancy after bariatric surgery than those with a pregnancy before bariatric surgery.

Methods and Procedures

Study design and data source

We performed a retrospective analysis using insurance claims data from 2002 to 2008. We used claims data from seven Blue Cross Blue Shield health plans, providing coverage in seven areas: Tennessee, western Pennsylvania, Michigan, North Carolina, the city of Philadelphia in Pennsylvania, South Dakota and Iowa (included in the same plan), and Hawaii. The data included insurance claims information (including hospitalizations, clinic visits, and laboratory tests) and variables for age, sex, and geographic area, but not clinical variables such as BMI or demographic information such as race or socioeconomic status. Inclusion in this obesity-related data set required at least one of the following criteria at any point during 2002–2008: completed health risk assessment or other survey; claim for a diagnosis of obesity; claim for bariatric surgery; prescription claim for a weight reduction medication; or diagnosis code of hyperlipidemia, type 2 diabetes, sleep apnea, gallbladder disease, or metabolic syndrome. These diagnoses were identified by common procedural terminology (CPT) codes, ICD-9-CM (International Classification of Disease, ninth revision, clinical modification codes), or diagnosis-related group codes. We acquired data on enrollment files for administrative data; benefits information to determine medical coverage; and inpatient and outpatient claims records containing ICD-9 diagnosis, common procedural terminology codes, and costs and charges.

Selection of study sample

We included women who had claims for both bariatric surgery (see Appendix A) and a delivery, defined as one or more live births or stillbirths (Appendix B) associated with a claim with an inpatient point of service code. We excluded delivery dates either less than 280 days after bariatric surgery or less than 31 days before surgery. If a woman had two or more deliveries, or had a delivery both before and after surgery, we selected the delivery closest to her bariatric surgery, which maximized coverage. For women with more than one claim around the time of their delivery, we identified the

delivery date for this analysis as the date of service with the most delivery records/claims.

For each woman, we compared the delivery date(s) with the date of the claim for bariatric surgery. Women were classified into groups that delivered before or after surgery based on date of delivery in relation to surgery such that no woman was included in both before and after surgery groups. The study group of interest was women who had a delivery after bariatric surgery and the comparison group was women who had a delivery prior to bariatric surgery. We chose our comparison group because it likely included women with Class II obesity with comorbid conditions or Class III obesity since these are the indications for bariatric surgery and our claims database does not provide BMI data.

We further excluded women with pre-existing disorders that could impact micronutrient absorption and consequently affect frequency of testing and deficiency: pernicious anemia (ICD-9 281.10), alcoholism (ICD-9 303), pancreatic diseases (577.xx), and Crohn's disease (555.xx). We restricted our analyses to women aged 12–45 years at the time of delivery, who had continuous insurance coverage during pregnancy (280 days prior to delivery) and during the year prior to the estimated date of conception.

Definitions of outcomes: micronutrient testing and deficiencies

We assessed primary outcomes during the 12 months prior to conception and 280 days of pregnancy. Primary outcomes were laboratory testing for the following micronutrients: iron, folate, vitamin B12, thiamine, and vitamin D. We chose these nutrients to reflect the deficiencies that occur following bariatric surgery, for which expert recommendations suggest screening^{19,20} and which may impact both maternal and fetal outcomes.^{13,15,21} We defined laboratory testing using CPT codes for both basic and optimal laboratory tests (Table 1) for the micronutrients of interest. “Basic” was defined as a laboratory test for the micronutrient of interest, and “optimal” included laboratory testing according to recent guidelines for postbariatric surgery management.²⁰

The secondary outcomes were the diagnoses of nutrient deficiencies during the preconception and pregnancy periods, including iron, folate, vitamin B12, thiamine, and vitamin D deficiencies. We used both ICD-9 and procedure codes to define both the deficiency and the conditions (e.g., anemia) resulting from deficiency (Table 1). A diagnosis of any anemia due to nutritional deficiency was identified through ICD-9 codes (281.1, 281.2, 281.3, 280, 280.1, 280.9). As a control for universally recommended pregnancy-specific testing, we assessed syphilis screening (RPR) during pregnancy (defined by CPT codes 80055, 86592, 86593, 86781, 87166, 87164, 87285).

Definitions for other covariates

In the multivariate logistic regression analyses, our covariates included maternal age, number of visits to a health care professional (categorized into tertiles) as a proxy for contact with a health care provider and medical complexity, and Blue Cross Blue Shield insurance plan. Maternal age was categorized into two groups, ≤ 33 years or ≥ 34 years, to include approximately 50% of the sample in each group. We categorized number of visits into “low” (0–7 visits), “medium” (8–15 visits), and “high” (> 16 visits) groups.

TABLE 1. CODES FOR LABORATORY TESTING FOR AND DIAGNOSIS OF MICRONUTRIENT DEFICIENCY

Micronutrient	Laboratory testing				Deficiency or medication	
	Basic	CPT code ^a	Optimal	CPT code ^a	ICD-9 ^b	CPT code ^a
Vitamin D	25-OH vitamin D OR 1,25-OH vitamin D	82306 82652	25-OH vitamin D AND intact PTH	82306 83970	268 268.0 268.1 268.2 268.9	J1270
Vitamin B12	Vitamin B12	82607	Vitamin B12 AND homocysteine OR MMA	82607 83090 83921	281.1 281.3 266.2	J3420
Folate	Folate OR RBC folate	82746 82747	RBC folate	82747	281.2 281.3 266.2	
Iron	Iron	83540	Iron AND TIBC	83540 83550	280 280.1 280.9	J1750 J1751 J1752 Q0138 Q0139 Q4098
Thiamine	Thiamine	84425	Thiamine	84425	265 265.0 265.1	

^aCPT, common procedural terminology code.

^bICD-9, International Classification of Diseases, Ninth Revision.

PTH, parathyroid hormone; MMA, methylmalonic acid; RBC, red blood cell; TIBC, total iron binding capacity.

Statistical methods

We compared the clinical characteristics of women who delivered before and after surgery using Student's *t* tests for continuous variables and χ^2 tests for categorical variables. We calculated the proportion of women with the desired testing for nutrient deficiency outcomes in the before and after bariatric surgery groups. We tested for the differences between groups using Fisher's exact test.

In the second part of our analysis, we used logistic regression to calculate the odds ratio and confidence intervals for the primary outcomes of laboratory testing. We created a composite laboratory testing outcome, combining basic and optimal laboratory testing outcomes, and controlled for insurance plan and the time between surgery and delivery as

covariates in the model. We then used a stepwise analysis to identify predictors for laboratory testing, including visit frequency, maternal age at delivery, and diagnosis of anemia.

P values less than 0.05 were considered significant. Statistical analyses were performed with SAS statistical software, version 9.1 (SAS, Cary, NC).

Results

Figure 1 displays the flow of the selection of subjects for the study. We identified 456 women with a pregnancy after bariatric surgery and 338 women with a pregnancy before bariatric surgery.

The characteristics of the women with deliveries before or after bariatric surgery are presented in Table 2. The majority of

FIG. 1. Enrollment flow for selection of study sample.

TABLE 2. CHARACTERISTICS OF WOMEN AND PREGNANCY COMPLICATIONS BEFORE OR AFTER BARIATRIC SURGERY

Characteristic (mean $\pm$ SD)	Pregnancy before surgery (N=338)	Pregnancy after surgery (N=456)	p-value ^a
Age at delivery	31.3 $\pm$ 4.3	32.9 $\pm$ 4.7	<0.0001
Age at surgery	32.9 $\pm$ 4.5	30.7 $\pm$ 4.6	<0.0001
Time between delivery and surgery	608.2 $\pm$ 394.9	823.2 $\pm$ 383.7	<0.0001
No. of visits in year prior to conception	7.7 $\pm$ 8.7	13.7 $\pm$ 11.6	<0.0001
No. of visits to generalist physician	3.0 $\pm$ 4.9	5.2 $\pm$ 5.9	<0.0001
No. of visits to obstetrician/gynecologist	1.0 $\pm$ 2.1	1.6 $\pm$ 4.1	0.005
No. of visits during pregnancy	11.4 $\pm$ 13.3	14.8 $\pm$ 14.8	0.0006
No. of visits to generalist physician	3.1 $\pm$ 4.8	3.8 $\pm$ 5.1	0.04
No. of visits to obstetrician/gynecologist	2.7 $\pm$ 3.9	4.0 $\pm$ 7.5	0.002
Gestational hypertension, N (%)	105 (31)	78 (17)	<0.0001
Pregestational diabetes, N (%)	30 (9)	41 (9)	1
Gestational diabetes, N (%)	124 (37)	133 (29)	0.03
Cesarean section, N (%)	159 (47)	178 (39)	0.02
Multifetal, N (%)	0 (0)	4 (0.1)	0.14
Anemia in year prior to conception, N (%)	6 (2)	86 (19)	<0.0001
Anemia during pregnancy, N (%)	36 (11)	20 (4)	0.001
Surgery type (%)			
Laparoscopic bypass	45	30	<0.0001
Open bypass	12	50	
Laparoscopic adjusted banding	30	5	
Restrictive other	4	4	
Bilio-pancreatic diversion	0	0	
Unknown	11	7	

surgical procedures performed were laparoscopic or open Roux-en-Y gastric bypass surgeries (80%). Women who had a pregnancy after bariatric surgery were, on average, older at delivery (32.3 vs. 31.3 years, $p<0.0001$) and younger at time of surgery (30.7 vs. 32.9 years, $p<0.0001$) and had a higher number of outpatient visits in the year prior to conception (13.7 vs. 7.7 visits, $p<0.0001$) and during pregnancy (14.8 vs. 11.4 visits, $p=0.0006$). Women who had a pregnancy after bariatric surgery were more frequently diagnosed with anemia in the preconception period (19% vs. 2%, $p<0.0001$) and had a lower frequency of hypertensive disorders in pregnancy, gestational diabetes, and cesarean section ($p<0.02$) compared with women who had a pregnancy before surgery. The mean time between surgery and delivery was about 2.25 years for those with a pregnancy after surgery, and 1.66 years for those with pregnancy before bariatric surgery. There was no difference in incidence of multifetal pregnancy between the two groups, an outcome that should not be affected by bariatric surgery. Screening for syphilis in pregnancy occurred with high frequency in both groups, slightly more (92% vs. 85%) in those with pregnancy after bariatric surgery.

Table 3 presents the frequency of testing for micronutrient deficiencies during preconception and pregnancy. The overall rates of testing were low, and the highest (51%) were for vitamin B12 in the preconception period for women with pregnancy after bariatric surgery, as compared to 2% in women with pregnancy before bariatric surgery ($p<0.001$). There were no major differences in testing frequency if analyses were restricted to Roux-en-Y procedures alone.

Figure 2 shows that laboratory testing occurred more frequently during both the preconception period and pregnancy after surgery than before surgery ($p<0.003$). The only exception was optimal lab testing for vitamin B12 during pregnancy, which did not differ, and was very low in both

groups (0%–1%, $p=0.14$). Table 4 shows the multivariate analysis. Predictors of laboratory testing for nutrient deficiency included a diagnosis of nutritional anemia for iron (OR 1.772; 95% CI 1.084, 2.898), folate (2.021; 1.240, 3.295), vitamin B12 (1.955; 1.199, 3.189) and a high number of visits for iron (2.023; 1.208, 3.386), folate (1.838; 1.086, 3.110), and vitamin B12 (1.938; 1.168, 3.215). With vitamin B12 as the outcome, a moderate number of outpatient visits was associated with increased laboratory testing (OR 1.681; 95% CI 1.028, 2.749). Maternal age had no effect on any micronutrient laboratory test.

The frequency of diagnoses of the deficiencies is presented in Table 5. In general, nutrient deficiencies occurred more often in women with pregnancies after bariatric surgery ($p<0.0001$ during the preconception period and $p<0.006$ during pregnancy) and were most frequent for vitamin B12 in both preconception (13%) and pregnancy (12%; $p<0.0001$). Vitamin D deficiency in preconception was the only exception, with 2% of women with pregnancies after surgery and 1% in those with pregnancies before surgery having vitamin D deficiency.

Discussion

In our investigation of testing for and diagnosis of micronutrient deficiencies during preconception and pregnancy after bariatric surgery, overall frequency of laboratory testing was low but was significantly higher in those with a pregnancy after surgery. Laboratory testing occurred most often for micronutrient deficiencies that are associated with anemia, iron, folate, and vitamin B12, but it was still only performed in half of those at risk. In women who became pregnant after surgery, deficiencies in folate, iron, thiamine, and vitamin B12 were relatively rare (all <15%) but occurred more commonly

TABLE 3. LABORATORY TESTING^a RATES FOR MICRONUTRIENT DEFICIENCIES PRIOR TO CONCEPTION AND DURING PREGNANCY AMONG WOMEN WHO WERE PREGNANT BEFORE COMPARED TO AFTER BARIATRIC SURGERY IN THE COMPLETE SAMPLE AND IN SUBGROUP OF WOMEN WITH GASTRIC BYPASS SURGERY

Surgery type	All bariatric surgery types (N=794)						Gastric bypass surgery only (N=561)					
	Preconception			Pregnancy			Preconception			Pregnancy		
	Before surgery	After surgery	p-value	Before surgery	After surgery	p-value	Before surgery	After surgery	p-value	Before surgery	After surgery	p-value
	N=338 n (%)	N=456 n (%)		N=338 n (%)	N=456 n (%)		N=195 n (%)	N=366 n (%)		N=195 n (%)	N=366 n (%)	
Folate												
Basic lab	4 (1)	192 (42)	<0.0001	1 (0)	155 (34)	<0.0001	1 (1)	173 (47)	<0.0001	1 (1)	138 (38)	<0.0001
Optimal lab	0 (0)	32 (7)	<0.0001	1 (0)	24 (5)	<0.0001	0 (0)	31 (8)	<0.0001	1 (1)	20 (5)	0.0019
Iron												
Basic lab	12 (4)	210 (46)	<0.0001	10 (3)	156 (34)	<0.0001	7 (4)	184 (50)	<0.0001	5 (3)	137 (37)	<0.0001
Optimal lab	7 (2)	155 (34)	<0.0001	9 (3)	107 (23)	<0.0001	4 (2)	137 (37)	<0.0001	5 (3)	93 (25)	<0.0001
Thiamine												
Basic lab	0 (0)	42 (9)	<0.0001	0 (0)	36 (8)	<0.0001	0 (0)	38 (10)	<0.0001	0 (0)	33 (9)	<0.0001
Vitamin B12												
Basic lab	6 (2)	232 (51)	<0.0001	4 (1)	185 (41)	<0.0001	3 (2)	206 (56)	<0.0001	2 (1)	166 (45)	<0.0001
Optimal lab	0 (0)	11 (2)	0.0034	0 (0)	4 (1)	0.1407	0 (0)	10 (3)	0.0176	0 (0)	4 (1)	0.3035
Vitamin D												
Basic lab	0 (0)	54 (12)	<0.0001	2 (1)	50 (11)	<0.0001	0 (0)	46 (13)	<0.0001	2 (1)	45 (12)	<0.0001
Optimal lab	0 (0)	19 (4)	<0.0001	0 (0)	15 (3)	<0.0001	0 (0)	15 (4)	0.0019	0 (0)	12 (3)	0.0105
Screening syphilis	57 (17)	119 (26)	<0.002	287 (85)	419 (92)	<0.002						

^a“Basic” and “optimal” testing defined in Table 1. χ^2 tests used to determine p-values.

during the preconception period, and deficiencies in all micronutrients were seen more often during pregnancy. We also found an association between laboratory testing and more frequent clinical visits prior to and during pregnancy, as well as an association between laboratory testing and the diagnosis of nutritional anemia.

Bariatric surgery is an effective treatment for severe obesity, leading to improvement in obesity-related comorbidities and mortality.⁶ The weight loss promoted by bariatric surgery has been shown to improve pregnancy outcomes, including hypertensive disorders of pregnancy, preeclampsia, preterm

birth, and gestational diabetes.⁶⁻⁹ However, weight loss after surgery is related to decreased caloric consumption and a state of some malabsorption. The type of bariatric surgeries that lead to the highest risk of nutrient deficiencies are extended Roux-en-Y gastric bypass procedures, or bilio-pancreatic diversions.¹¹ These malabsorptive procedures may cause deficiencies of fat-soluble vitamins, including vitamins A, D, E, and K.¹¹ Iron is principally absorbed in the duodenum, which is bypassed in a Roux-en-Y gastric bypass procedure.²² In our investigation, 75% of women with pregnancies after surgery underwent a Roux-en-Y surgical procedure. Only 8% underwent a restrictive procedure, either gastric banding or vertical banded gastroplasty, which carries a lower risk of micronutrient malabsorption postoperatively.

Clinically, the nutritional deficiencies we identified may manifest as anemia in those women who became pregnant after bariatric surgery. In our analysis, nearly one quarter of those with a pregnancy after surgery carried a diagnosis of nutritional anemia, a prevalence that is significantly higher than in those with pregnancy before surgery (13%). Investigations over the past decade suggest that iron deficiency early in pregnancy may result in preterm birth.¹⁵ In a small study of 16 patients who had received Roux-en-Y gastric bypass surgery and were taking daily routine multivitamin supplementation, the frequency of iron deficiency at 3 years was 54%, and the diagnosis of anemia was 63.9%.²³ A recent study of 170 patients assessed anemia and iron deficiency at 36 months after Roux-En-Y gastric bypass surgery and found 33.5% with anemia and 23.5% with iron deficiency as determined by low ferritin concentrations.²⁴ Nomura and colleagues²⁵ identified higher need for intravenous iron supplementation or red blood cell transfusion among women who conceived 4 years or more after surgery.

FIG. 2. Differences before and after bariatric surgery determined using χ^2 test. Syphilis screening during pregnancy is the control measure. All comparisons other than the control measure of prenatal syphilis screening are $p < 0.001$.

TABLE 4. ODDS OF LABORATORY TESTING FOR MICRONUTRIENT DEFICIENCY IN WOMEN WITH PREGNANCY AFTER BARIATRIC SURGERY (OR, 95% CI)

Predictor	Vitamin B12 (N=417)	Folate (N=347)	Iron (N=366)	Vitamin D (N=104)	Thiamine (N=78)
No. of visits					
High	1.94 (1.17, 3.22)	1.83 (1.09, 3.11)	2.02 (1.21, 3.39)	2.01 (0.94, 4.28)	2.36 (0.96, 5.79)
Medium	1.68 (1.03, 2.75)	1.62 (0.97, 2.69)	1.19 (0.72, 1.99)	1.20 (0.56, 2.58)	1.55 (0.63, 3.84)
Age ≥ 34	1.09 (0.73, 1.61)	1.17 (0.78, 1.76)	1.15 (0.77, 1.72)	0.96 (0.53, 1.73)	1.30 (0.66, 2.56)
Diagnosis of anemia	1.96 (1.20, 3.19)	2.02 (1.24, 3.30)	1.77 (1.08, 2.90)	1.80 (0.92, 3.52)	1.24 (0.55, 2.78)

Bolded terms represent predictors of micronutrient deficiency with $p < 0.05$.

CI, confidence interval; Determined through logistic regression analyses, OR (95% CI).

Beyond iron, deficiencies of other essential minerals and fat-soluble vitamins may also impact on fetal and infant health. Low 25(OH) vitamin D levels in pregnancy may contribute to increased placental inflammation and even preeclampsia.^{12,26} Maternal folate deficiency is implicated in fetal neural tube defects.^{14,21} The effects of vitamin B12 deficiency on pregnancy outcomes have not been well-studied; however, one study showed an association with future insulin resistance in the offspring.²⁷ Finally, bariatric surgery may increase the risk of small for gestational age infants, perhaps in part due to nutrient deficiencies resulting from malabsorption after surgery.²⁸

The American College of Obstetrics and Gynecology Practice Bulletin and a clinical practice guideline produced by a consortium of the American Association for Clinical Endocrinologists, The Obesity Society, and the American Society for Metabolic and Bariatric Surgery recommend micronutrient screening in pregnant women after bariatric surgery.^{19,20} Based on expert opinion and supplemented by case reports of observed nutrient deficiencies after bariatric surgery, these guidelines recommend testing for relevant micronutrient deficiencies in all individuals every 3–4 months during the first year after bariatric surgery and annually thereafter.^{22,29–31} Our findings show that while women who have a pregnancy after surgery are screened more often than those with a pregnancy before surgery, the occurrence of any laboratory testing still remains far below goal. However, several gaps remain in our knowledge of the clinical relevance and impact of these nutrient deficiencies, such as maternal

and fetal outcomes and optimal treatment doses and routes of supplementation. Longitudinal evaluation of the nutritional consequences of bariatric surgery on pregnancy and child health outcomes through well-characterized prospective cohort studies could support evidence-based guideline development. Furthermore, we need to improve overall preconception and pregnancy care for women following bariatric surgery, through care coordination between multiple providers to standardize the process of laboratory testing and capture missed opportunities for treatment for micronutrient deficiency.

Several limitations of this qualitative study should be considered. First, our analysis included the use of insurance claims data rather than data collected from clinical encounters. We relied on definitions for micronutrient deficiencies using ICD-9 and CPT codes entered by physicians, which are subject to errors, overcoding, and undercoding. Given the limitations of claims data, we cannot determine the clinical indications leading to physicians' ordering of laboratory testing. Additionally, claims data may not provide population-based prevalence of micronutrient deficiencies in this population, since not everyone received a screening test and opportunity for diagnosis. However, we believe these prevalences may be more representative of actual clinical practice. For the article's primary outcome of frequency of testing, our methodology using claims data does represent actual testing completion rates. Second, ICD-9 diagnosis codes may have been used as indications to support laboratory testing rather than as reflective of actual clinical diagnoses, thus

TABLE 5. DIAGNOSIS OF MICRONUTRIENT DEFICIENCIES^a PRIOR TO CONCEPTION AND DURING PREGNANCY IN WOMEN WITH A PREGNANCY BEFORE COMPARED TO AFTER BARIATRIC SURGERY IN THE COMPLETE SAMPLE AND IN A SUBGROUP OF WOMEN WITH GASTRIC BYPASS SURGERY

	All bariatric surgeries (N=794)						Gastric bypass surgery only (N=561)					
	Preconception			Pregnancy			Preconception			Pregnancy		
	Before surgery	After surgery	p-value	Before surgery	After surgery	p-value	Before surgery	After surgery	p-value	Before surgery	After surgery	p-value
	N=338 n (%)	N=465 n (%)		N=338 n (%)	N=456 n (%)		N=195 n (%)	N=366 n (%)		N=195 n (%)	N=366 n (%)	
Folate	0 (0)	33 (7)	<0.0001	2 (1)	34 (7)	<0.0001	0 (0)	27 (7)	<0.0001	1 (1)	30 (8)	<0.0001
Iron	5 (1)	38 (8)	<0.0001	5 (2)	40 (9)	<0.0001	3 (2)	37 (10)	<0.0001	2 (1)	37 (10)	<0.0001
Thiamine	0 (0)	0 (0)		0 (0)	0 (0)		0 (0)	0 (0)		0 (0)	0 (0)	
Vitamin B12	2 (1)	57 (13)	<0.0001	5 (2)	55 (12)	<0.0001	1 (1)	49 (13)	<0.0001	3 (2)	49 (13)	<0.0001
Vitamin D	2 (1)	10 (2)	0.0812	1 (0)	13 (3)	0.0056	1 (1)	9 (2)	0.0731	1 (1)	12 (3)	0.0405

^aMicronutrient deficiency defined in Table 1. χ^2 tests used to determine p -values.

overestimating the frequency of micronutrient deficiencies we reported, which were overall quite low. Third, our data did not include sociodemographic or other clinical information, such as socioeconomic status or parity, limiting our examination of predictors of receipt of testing. However we were able to include maternal age and insurance plan or region. Fourth, we cannot assess causality using this observational data source. We observed an association between more outpatient clinical visits and increased laboratory testing for micronutrient deficiency, which could reflect confounding by indication since women with pregnancy after bariatric surgery may have required more frequent monitoring because of increased pregnancy risk and therefore were more likely to receive laboratory testing because of their complexity. Thus, the number of outpatient visits may not be a predictor of nutrient deficiency but rather a consequence of surgical or medical complications. Fifth, we found that a diagnosis of nutritional anemia was positively associated with receipt of laboratory testing for iron, folate, and vitamin B12. However, the ordering of the laboratory tests for these micronutrients may have been linked with an ICD-9 code corresponding to anemia, even though the clinical diagnosis of anemia may not have existed. Thus, coding for anemia in women with pregnancy after bariatric surgery may reflect a diagnosis code used for laboratory testing for iron, folate, or vitamin B12, rather than a true diagnosis of nutritional anemia.

The strengths of our study included a large dataset with over 1400 women and continuous enrollment information throughout the periods of preconception and pregnancy. Although our data did not include information on maternal BMI, our comparison of laboratory testing during preconception and pregnancy before and after surgery was designed to compare women who had similar BMI and potential for obesity-related comorbidities. We restricted our analysis to those with continuous coverage during the preconception and pregnancy periods to serve as a proxy for access to care and to minimize loss to follow-up. Syphilis testing occurs with the high frequency among those becoming pregnant before or after surgery, suggesting that women in our study population are receiving other recommended prenatal screening tests regardless of bariatric surgery status.

In conclusion, bariatric surgery and the resulting weight loss prior to conception can benefit maternal and fetal outcomes in pregnancy, but may also result in malabsorption and micronutrient deficiencies that can have a similarly detrimental impact on the health of mother and child. Annual laboratory testing for all those who are more than 1 year out from surgery, conforming to expert recommendations, may reduce the potential risks of essential nutrient deficiencies on maternal and fetal health. Our investigation supports the need for future studies to assess whether guidelines on laboratory testing for micronutrient deficiency are being met in women who become pregnant after bariatric surgery. Promotion of scheduled testing by a designated physician providing care during the preconception period may help to ensure adherence to expert recommendations and translate to improved care.

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Author Disclosure Statement

The authors declare no conflicts of interest.

Appendix A

ELEMENTS OF CLAIMS DATA USED TO IDENTIFY AND CLASSIFY BARIATRIC SURGERY PATIENTS

<i>Code type</i>	<i>Restrictive</i>	<i>RYGB</i>	<i>Malabsorptive</i>
CPT	43770 43842 43843 S2082	43644 43645 43844 43846 43847 43659 S2085	43845
ICD-9	44.68 44.95 43.89 ^a 44.38 ^a	44.31 ^a 44.39 ^a	45.50 ^a 45.51 ^a 45.90 ^a 45.91 ^a

^aPatient were considered to have had bariatric surgery only if used in conjunction with ICD-9 278.01 (morbid obesity).

RYGB, Roux-en-Y gastric bypass; CPT, common procedural terminology code; ICD-9, international classification of disease.

Appendix B

Delivery

650 (normal delivery), 651 (multiple gestation), V27.0 (mother with single liveborn), V27.1 (mother with single stillborn), V27.2 (mother of twins, liveborn), V27.3 (mother with twins, 1 stillborn), V27.5 (mother with other multiple births, all liveborn), V27.6 (mother with other multiple births, some liveborn).

CPT cesarean-section codes (595)**

59510, cesarean (C)-section with ante- and postpartum care
 59512, C-section delivery only
 59514, postpartum care only
 59515, Cesarean delivery only; including postpartum care

C-section procedure codes (ICD9 CM)

74.0–74.2, 74.4, 74.99, 669.7

Anesthesia procedure codes for C-section

01961, 01963, 01968, 01969

Others

59620, Cesarean delivery only, following attempted vaginal delivery after previous cesarean delivery
 59622, Cesarean delivery only, following attempted vaginal delivery after previous cesarean delivery; including postpartum care

Multifetal pregnancies

V31**, V32**, V33**, V34**, V35**, V36**, V37**

Gestational Diabetes**Pregestational diabetes**

250.0**, >20 weeks prior to delivery date (i.e., pregnancy weeks 1–19, not 20–40) OR
 648.0*, >20 weeks prior to delivery (i.e., pregnancy weeks 1–19, not 20–40)

Gestational diabetes mellitus

648.8*, at any point in defined 40 weeks pregnancy period OR
 250.**, ≤20 weeks before delivery date (i.e., weeks 20–40) OR
 648.0*, ≤20 weeks before delivery date (i.e., weeks 20–40)

Hypertensive Disorders of Pregnancy**Preeclampsia (mild and severe) and eclampsia**

642.4X, 642.5X, 642.6X, 642.7X,

Hypertension in pregnancy

642.0X, 642.3X, 642.9X

Benign essential hypertension

401.1 and/or 401.9 coded during pregnancy period

Code for pre-existing hypertension complicating a pregnancy

642.2X

Anemia

281.1 (vitamin B12 deficiency anemia), 281.2 (folate deficiency anemia), 281.3 (other specified megaloblastic anemias, not elsewhere classified), 280 and 280.1 and 280.9 (iron deficiency anemia)

Control Screening**Screening for syphilis in pregnancy**

CPT codes: 80055 (prenatal panel), 86592, 86593, 86781, 87166, 87164, 87285

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