Revista Portuguesa de Endocrinologia, Diabetes e Metabolismo
www.spedmjournal.com

Artigo Original

Pregnancy Outcomes After Bariatric Surgery: Should We Favour Restrictive Procedures in Women of Reproductive Age?

Bárbara Araújo [a,*,#], Ana Carreira [a,#], Mariana Lavrador [a,b], Inês Vieira [a,b], Dírcea Rodrigues [a,b], Sandra Paiva [a], Miguel Melo [a,b], Isabel Paiva [a]

[a] Department of Endocrinology, Diabetes and Metabolism, Centro Hospitalar e Universitário de Coimbra, Coimbra, Portugal
[b] Faculty of Medicine, University of Coimbra, Coimbra, Portugal
[#] Joint first authors / Co-primeiros autores

INFORMAÇÃO SOBRE O ARTIGO

Historial do artigo:
Received/ Recebido: 2023-01-26
Accepted/Aceite: 2023-07-03
Publicado / Published: 2023-10-18

Keywords:
Bariatric Surgery;
Micronutrients/deficiency;
Nutritional Status;
Pregnancy;
Pregnancy Complications;
Pregnancy Outcome.

A B S T R A C T

Introduction: Bariatric surgery (BS) is frequently performed in women of reproductive age, and is often associated with nutritional deficiencies and increased risk of adverse outcomes during pregnancy, such as small for gestational age (SGA) neonates. Whether we should favour restrictive procedures in this population, to minimize these risks, is still uncertain. Our aim was to evaluate the impact of the type of BS procedure on micronutrient deficiencies and on maternal and foetal outcomes during pregnancy.

Methods: Single centre retrospective study, including a cohort of 47 pregnancies after BS, with follow up between 2008-2020. Neonates were classified as SGA if birth weight was <10th percentile. Data collection included type of surgery, body mass index (BMI) before surgery and before pregnancy, micronutrient levels and supplementation, and pregnancy outcomes (anaemia, preeclampsia, gestational diabetes, caesarean delivery, abortion, pre-term delivery, SGA).

Results: The more frequently performed procedures were gastric bypass (36.2%) and sleeve gastrectomy (36.2%), followed by adjustable gastric banding (23.4%) and biliopancreatic diversion (4.2%). BMI mean reduction from surgery to pregnancy was higher in malabsorptive procedures. The BS-to-conception interval did not differ between surgery types. Micronutrient deficiencies were frequent during pregnancy (vitamin D: 75.9%, calcium: 43.8%, vitamin B12: 23.5%, folic acid: 8.7%, iron: 77.8%), despite multivitamin supplementation in most women. The prevalence of SGA neonates was elevated (26.3%). There were no differences considering micronutrient deficiencies or pregnancy outcomes between surgical procedures. The prevalence of SGA neonates was increased in the presence of vitamin B12 deficiency in the first trimester of pregnancy (33.3 *vs* 0.0%, p=0.027) and in pregnant women not supplemented with iron in addition to multivitamins (46.2% *vs* 14.8%, p=0.052).

Conclusion: Micronutrient deficiencies were frequent, despite multivitamin supplementation. Micronutrient deficiencies and pregnancy outcomes were similar between BS procedure types. Our results suggest that in lieu of favouring restrictive procedures in women of reproductive age, the procedure decision should be based on individual characteristics. Following BS, women should be monitored and supplemented using a close individualized approach during pre-conception and pregnancy.

Palavras-chave:
Cirurgia Bariátrica;
Complicação na Gravidez;
Estado Nutricional;
Gravidez;
Micronutrientes/deficiência;
Resultado da Gravidez.

Resultados da Gravidez Após Cirurgia Bariátrica: Devemos Preferir Procedimentos Restritivos em Mulheres em Idade Fértil?

R E S U M O

Introdução: A cirurgia bariátrica (CB) é frequentemente realizada em mulheres em idade fértil, estando associada a uma elevada prevalência de défices nutricionais na gestação e a risco aumentado de desfechos neonatais adversos, como recém-nascidos leves para a idade gestacional (LIG). Os procedimentos malabsortivos parecem estar associados a um risco superior, contudo, ainda não é

* Autor Correspondente / Corresponding Author.
E-Mail: barbarafilipaca@gmail.com (Bárbara Araújo)
Department of Endocrinology, Diabetes and Metabolism, Centro Hospitalar e Universitário de Coimbra
Praceta Prof. Mota Pinto 3000-075 Coimbra, Portugal

https://doi.org/10.26497/ao230007

claro se deve haver uma preferência por estas técnicas nesta população. O nosso objetivo foi avaliar o impacto do tipo de procedimento cirúrgico no risco de défices de micronutrientes e resultados materno-fetais da gravidez.
Métodos: Estudo retrospetivo unicêntrico, que incluiu uma coorte de 47 gestações após CB, com seguimento entre 2008-2020. Foram classificados como LIG os recém-nascidos cujo peso ao nascimento fosse <percentil 10. Recolhidos dados acerca do tipo de procedimento cirúrgico; índice de massa corporal (IMC) antes da CB e antes da gestação; doseamentos de micronutrientes e dados da suplementação; desfechos materno-fetais (anemia, pré-eclâmpsia, diabetes gestacional, parto por cesariana, abortamento, prematuridade e LIG).
Resultados: Os procedimentos mais frequentes foram o *bypass* gástrico (36,2%) e gastrectomia em sleeve (36,2%), seguidos da banda gástrica ajustável (23,4%) e derivação biliopancreática (4,2%). A redução média de IMC entre a CB e a gravidez foi superior nos procedimentos malabsortivos. O intervalo de tempo entre a CB e a gravidez foi semelhante em ambos os tipos de cirurgias, a idade materna era inferior nos procedimentos restritivos. Os défices de micronutrientes foram frequentes durante a gravidez (vitamina D: 75,9%, cálcio: 43,8%, vitamina B12: 23,5%, ácido fólico: 8,7%, ferro: 77,8%), apesar da suplementação multivitamínica na maioria dos casos. A prevalência de recém-nascidos LIG foi elevada (26,3%). Não se registaram diferenças entre os procedimentos cirúrgicos quanto ao risco de défices de micronutrientes ou desfechos materno-fetais. A prevalência de recém-nascidos LIG foi superior na presença de défice de vitamina B12 no primeiro trimestre (33,3 *vs* 0,0%, *p*=0,027), e nas grávidas que não foram suplementadas com ferro em adição ao multivitamínico (46,2% *vs* 14,8%, *p*=0,052).
Conclusão: Os défices de micronutrientes foram prevalentes, apesar da suplementação vitamínica. Os défices vitamínicos e os desfechos materno-fetais da gravidez foram semelhantes entre os tipos de procedimento. Os nossos resultados sugerem que, ao invés de se favorecer procedimentos restritivos em mulheres em idade fértil, a decisão do tipo de procedimento deve ser fundamentada em características individuais da doente. Após CB, as mulheres devem ser monitorizadas e suplementadas de forma individualizada, quer no período pré-concecional, quer durante a gravidez.

Introduction

Overweight and obesity among women of reproductive age has reached a worrying prevalence across many European countries and continues to increase.[1] Obesity is a common cause of anovulation and infertility. In pregnancy, obesity increases the risk of miscarriage, gestational diabetes, hypertensive disorders, cesarean delivery, stillbirth and large for gestational age (LGA) neonates.[2,3] Bariatric surgery (BS) is on the rise as a treatment for severe obesity among women of reproductive age.[4,5] BS comprises restrictive and malabsorptive procedures: sleeve gastrectomy and adjustable gastric banding are examples of purely restrictive procedures, whilst Roux-en-Y gastric bypass and biliopancreatic diversion are also malabsorptive. Sleeve gastrectomy and Roux-en-Y gastric bypass are the most performed procedures worldwide.[6] BS improves factors related to anovulation and reduces obesity-related comorbidities in pregnancy; however, it increases the risk of nutritional deficiencies, that may be further aggravated by physiological changes of pregnancy. Furthermore, pregnancies after BS have been associated with increased risk of some adverse perinatal outcomes, such as small for gestational age (SGA) neonates and preterm births.[7-9] SGA is defined as birth weight of less than the 10th percentile for gestational age,[10] and may be a marker of foetal growth restriction, which is associated with increased perinatal morbidity and mortality.[11] Moreover, SGA neonates are at higher risk of developing metabolic disease later in life.[12] Micronutrient deficiencies can occur in both restrictive and malabsorptive procedures; therefore, adequate supplementation with multivitamins and minerals is recommended regardless of procedure type.[13,14] Still, these deficiencies are generally more pronounced and more extensive in malabsorptive procedures, usually requiring larger doses of supplements.[13] Currently, there is limited evidence and no consensus regarding the optimal nutritional monitoring and supplementation in pregnancies after BS. Some recommendations advocate that daily vitamin and mineral supplements should be initiated at least 3-6 months prior to conception and contain the following at a minimum: copper (1-2 mg), zinc (8-22 mg), selenium (50-60 μg), calcium (1200-2400 mg), folic acid (0.4 mg or 4-5 mg if obesity or diabetes), iron (45-60 mg), thiamine (>12 mg), vitamin D (>1000-3000 IU), vitamin B12 (1 mg oral or 1 mg depot injection every 3 months), vitamin E (15 mg), beta-carotene (vitamin A, 5000 IU) and vitamin K (300 μg if malabsorptive procedures). Micronutrient levels should be monitored throughout pregnancy, at least once every trimester, and supplementation should be adjusted to maintain concentrations within normal limits.[14,15]

The potential for malnutrition after BS has been linked to the increased risk of adverse perinatal outcomes in these patients, with several studies suggesting an association between micronutrient deficiencies, inadequate weight gain and SGA.[16,17] Studies comparing micronutrient deficiencies and SGA risk between different BS procedures have shown conflicting results, with some reporting a higher risk following malabsorptive procedures[7,16,18,19] and others reporting no significant differences.[20,21] Thus, the question whether we should favour restrictive procedures in female patients of reproductive age remains unanswered, as there is still no solid scientific evidence to guide clinicians on the most appropriate type of procedure in this population.[13] Understanding the factors associated with increased risk of adverse outcomes in pregnancies after BS is essential to adjust and improve the periconceptional counselling and pregnancy surveillance. Therefore, the aim of our study was to evaluate the impact of malabsorptive and restrictive bariatric surgery procedures on micronutrient deficiencies during pregnancy and on maternal and perinatal outcomes.

Material and Methods

Study Design and Participants

We performed a retrospective cohort study of pregnant women with a history of bariatric surgery, that were followed in the obstetrics department in a University Hospital Centre in Portugal, between 2008-2020. We included all singleton pregnancies that were followed from the first trimester of pregnancy by our multidisciplinary team. Multiple pregnancies and pregnancies without birth data were excluded. The multidisciplinary team included obstetricians, endocrinologists, and dietitians, and follow-up was performed at least once every trimester, or more frequently if needed. Our approach consisted in prescribing multivitamin supplements specifically designed for pregnancy, monitoring for nutritional deficiencies at every visit and adding and adjusting specific micronutrient supplements (such as calcium, vitamin D, vitamin B12, iron and folic acid), according to individual needs. Screening for gestational diabetes was performed in the first trimester, by fasting plasma glucose ≥ 92 mg/dL, and repeated, if negative, in the second trimester (between 24-28 weeks of gestation), through capillary blood glucose monitoring 4 times a day during one week (diagnosis if fasting capillary glucose ≥ 95 mg/dL or ≥ 140 mg/dL 1 hour after meals).

Bariatric surgery procedures comprised adjustable gastric banding, sleeve gastrectomy, Roux-en-Y gastric bypass and biliopancreatic diversion. These procedures were performed from 2005 to 2018. Data collection on age, demographics, comorbidities, type and date of bariatric surgery, pre-gestational body mass index (BMI) and BMI before surgery, gestational weight gain, micronutrient deficiencies and pregnancy outcomes was obtained from electronic health records.

Gestational weight gain was defined according to the pre-gestational BMI, and classified as adequate for weight gains of 11.5-16.0 kg (BMI 18.5-24.9 kg/m^2), 7.0-11.5 kg (BMI 25.0-29.9 kg/m^2) or 5.0-9.0 kg (BMI ≥30 kg/m^2), based on the 2009 Institute of Medicine (IOM) guidelines for pregnancy.[22] Weight gain inferior or superior to the recommended values was classified as insufficient or excessive, respectively.

Exposures and Outcomes

The exposure of interest was the type of bariatric surgery procedure. Sleeve gastrectomy and adjustable gastric banding were included as restrictive procedures and Roux-en-Y gastric bypass and biliopancreatic diversion as malabsorptive procedures. The outcomes of interest were the prevalence of micronutrient deficiencies and maternal and perinatal outcomes: preeclampsia, gestational diabetes, maternal anaemia, caesarean delivery, abortion, preterm delivery, SGA and LGA. Micronutrients were assessed through the levels of ferritin, folate, vitamin B12, vitamin D, calcium and magnesium; deficiencies were considered if present in one or more trimesters of pregnancy. Deficiencies were classified according to our hospital centre laboratory reference values for iron (ferritin < 30 ng/mL), folate (<3.5 ng/mL), vitamin B12 (<187 pg/mL), total calcium corrected to albumin (<8.8 mg/dL) and magnesium (<1.9 mg/dL). Vitamin D deficiency was defined as a level of 25(OH)D <20 ng/dL, according to the recommendations from the Endocrine Society, and classified as severe if <10 ng/dL.[23] Maternal anaemia was defined according to World Health Organization (WHO) as haemoglobin <11.0 g/dL in the first and third trimesters or <10.5 g/dL in the second trimester. SGA and LGA were defined as birth weight inferior to the 10th percentile and above the 90th percentile, respectively, according to the WHO growth charts in term births, or Fenton curves in preterm births. Preterm births were defined as births occurring before 37 completed weeks of gestation, and classified according to WHO as extremely preterm if birth occurred before 28 weeks, very preterm from 28-32 weeks and moderate to late preterm from 32-37 weeks.

Statistical Analysis

Analyses were performed with the use of IBM SPSS Statistics 26.0. Categorical variables are presented as frequencies and percentages, and continuous variables as means and standard deviations, or medians and interquartile ranges (IQR) for variables with skewed distributions. The means or medians of continuous variables were compared between patient groups using the Student's T-test for independent samples or the Mann Whitney test, respectively. Associations between categorical variables were assessed using the Chi-square test. All reported p values are two-tailed, with a p value of less than 0.05 indicating statistical significance.

Results

Baseline Pregestational Characteristics

Our study included 47 singleton pregnancies after bariatric surgery. Most were spontaneous pregnancies, but in three women pregnancy was achieved through medically assisted reproduction. Mean maternal age was 34.3±4.5 years and mean BMI at conception was 30.2±5.5 kg/m^2. The most performed procedures were Roux-en-Y gastric bypass (N=17, 36.2%) and sleeve gastrectomy (N=17, 36.2%), followed by adjustable gastric banding (N=11, 23.4%) and biliopancreatic diversion (N=2, 4.2%). Pregnant women submitted to restrictive procedures were younger than those submitted to malabsorptive procedures (33.1±4.4 *vs* 35.9±4.2, p=0.038).

Mean BMI reduction from surgery to conception was 14.4±7.1 kg/m^2; leading to a normal BMI at conception in 19.5% of the women, overweight in 29.3% and obesity in 51.2% (34.1% class I, 12.2% class II and 4.9% class III). Other comorbidities included hypothyroidism in 10.6%, arterial hypertension in 8.5%, type 2 diabetes in 8.5% and thrombophilia (antiphospholipid syndrome or factor V Leiden mutation) in 6.4%.

Median bariatric surgery-to-conception interval was 36 months, ranging from a minimum of 4 to a maximum of 144 months.

Weight Loss Before Pregnancy and Gestational Weight Gain

Pregestational BMI was similar in women submitted to malabsorptive and restrictive procedures, but those submitted to malabsorptive procedures had a higher BMI before surgery [42.0 (IQR 40.4-46.5) *vs* 46.4 (IQR 43.5-50.0), p=0.044] and higher BMI reduction from surgery to conception (16.8±5.9 *vs* 12.8±7.6, p=0.042). BMI mean reduction was highest for biliopancreatic diversion (26.5±3.9 kg/m^2), intermediate for Roux-en-Y gastric bypass (14.6±4.7 kg/m^2) and sleeve gastrectomy (12.9±7.9 kg/m2) and lowest for adjustable gastric banding (9.8±5.3 kg/m^2). BMI reduction showed no correlation with maternal age (p=0.252) or surgery-to-conception interval (p=0.190), and the association between malabsorptive procedures and BMI reduction was sustained after adjusting for maternal age (β=5.5; p=0.023).

Gestational weight gain (GWG) and adequacy of GWG were similar between procedure types. Adequate weight gain was achieved in 21.7% of pregnant women in the restrictive group and 36.8% in the malabsorptive group (p=0.309), as shown in Table 1. There was insufficient weigh gain or weight loss in 6 women in each group (26.1% *vs* 31.6%, p=0.510). There was no association between maternal age and GWG.

Table 1. Baseline characteristics, maternal and neonatal outcomes and micronutrient deficiencies in restrictive and malabsorptive procedures.

Characteristics	Total (N=47)	Restrictive (N=28)	Malabsorptive (N=19)	*p* value
Pregestational characteristics				
Age (years)	34.3±4.5	33.1±4.4	35.9±4.2	0.038
Time from surgery to conception (months)	36.0 (24.0-72.0)	36.0 (24.0-66.0)	58.0 (22.0-96.0)	0.245
BMI at conception (kg/m2)	30.2±5.5	30.6±5.8	29.6±5.2	0.575
BMI reduction from surgery to conception (kg/m2)	14.4±7.1	12.8±7.6	16.8±5.9	0.042
Pregestational obesity	22 (46.8%)	12 (42.9%)	10 (52.6%)	0.976
Class I	15 (31.9%)	8 (28.6%)	7 (36.8%)	0.439
Class II	5 (10.6%)	2 (7.1%)	3 (15.8%)	0.923
Class III	2 (4.3%)	2 (7.1%)	0 (0.0%)	0.200
Arterial hypertension	4 (8.5%)	3 (10.7%)	1 (5.3%)	0.638
Type 2 diabetes	4 (8.5%)	3 (10.7%)	1 (5.3%)	0.638
Abortion or foetal loss	5.0 (10.6%)	5.0 (17.9%)	0.0 (0.0%)	0.072
Maternal/neonatal outcomes[a]				
Gestational weight gain (kg)*	9.1±8.3	9.1±9.2	9.1±7.5	0.973
Insufficient [b]*	12 (28.6%)	6 (26.1%)	6 (31.6%)	0.510
Adequate [b]*	12 (28.6%)	5 (21.7%)	7 (36.8%)	0.309
Excessive [b]*	15 (35.7%)	10 (43.5%)	5 (26.3%)	0.411
Maternal anaemia*	12 (36.4%)	5 (31.3%)	7 (41.2%)	0.554
Gestational diabetes	8.0 (19.0%)	4 (17.4%)	4 (21.1%)	0.764
Caesarean delivery	13.0 (31.0%)	7 (30.4%)	6 (31.6%)	0.257
Preeclampsia	1.0 (2.4%)	1 (4.3%)	0.0 (0.0%)	0.370
Pre-term delivery	3 (7.1%)	3 (13.0%)	0.0 (0.0%)	0.102
SGA	10 (23.8%)	7 (30.4%)	3 (15.8%)	0.267
Multivitamin supplementation [a]	31 (73.8%)	15 (65.2%)	16 (84.2%)	0.119
Micronutrient deficiencies [ac]				
Iron*	21 (77.8%)	11 (73.3%)	10 (83.3%)	0.535
Vitamin B12*	8 (23.5%)	3 (15.8%)	5 (33.3%)	0.231
Folic acid*	2 (8.7%)	2 (14.3%)	0 (0.0%)	0.235
Vitamin D*	22 (75.9%)	11 (78.6%)	11 (73.3%)	0.742
Calcium*	14 (43.8%)	7 (38.9%)	7 (50.0%)	0.530
Magnesium*	8 (32.0%)	4 (28.6%)	4 (36.4%)	0.678

Continuous data are presented as mean ± SD or median (interquartile range); categorical data are presented as frequencies (percentages). BMI – body mass index.

[a] Excluding cases of spontaneous abortion or foetal loss: N=42, restrictive=23 and malabsorptive=19.

[b] Adequacy of gestational weight gain according to the IOM recommendations (2009).

[c] Considered if present in one or more trimesters of pregnancy.

*Missing values: 2 for gestational weight gain [2 for restrictive (R), 0 for malabsorptive (M) procedures], 3 for adequacy of gestational weight gain (2R, 1M), 9 for anaemia (7R, 2M), 15 for iron (8R, 7M), 8 for vitamin B12 (4R, 4M), 19 for folic acid (9R, 10M), 13 for vitamin D (9R, 4M), 10 for calcium (5R, 5M), 17 for magnesium (9R, 8M).

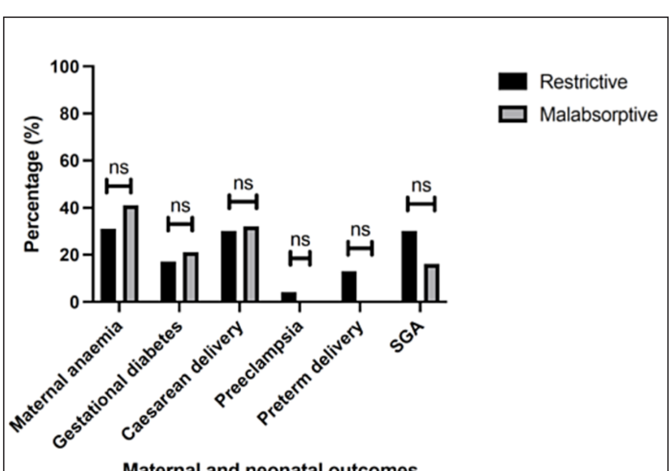

Figure 1. Maternal and neonatal outcomes in restrictive versus malabsorptive procedures.

*ns, non-significant; SGA, small for gestational age

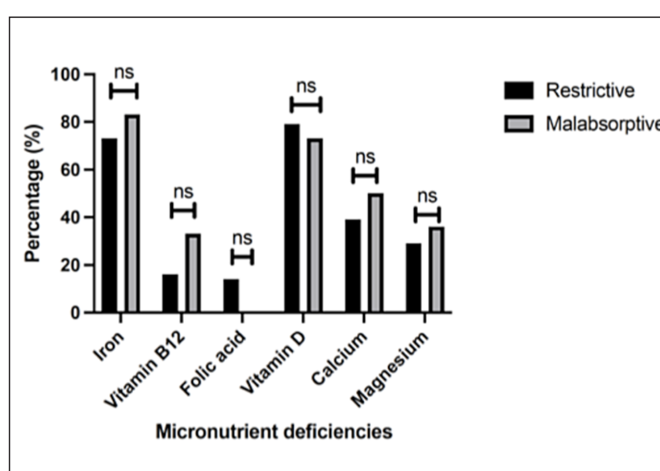

Figure 2. Micronutrient deficiencies in restrictive versus malabsorptive procedures.

*ns, non-significant;

Maternal and Neonatal Outcomes and Micronutrient Deficiencies

From the total of 47 pregnancies, four (8.5%) resulted in first trimester spontaneous abortion and one (2.1%) in foetal demise at 30 weeks. One of the abortions and the foetal demise occurred in women with sleeve gastrectomy and diagnosed thrombophilia; the other three spontaneous abortions occurred in women with adjustable gastric banding. The remaining 42 pregnancies resulted in 39 term births and 3 preterm births (7.1%): one extremely preterm and 2 moderate to late preterm.

Median foetal birth weight was 3103 g (IQR 2780-3361 g), with a prevalence of SGA of 23.8% (10 neonates) and LGA of 2.4% (one neonate). A percentage of 90% of SGA neonates were born at term, with median gestational age of 38 weeks (IQR 38-39 weeks) and mean birth weight of 2498±233 g. Most neonates (83.3%) had birth weight inferior to the 50th percentile (P): 23.8% inferior to P10, 19.0% between P10-P25 and 40.5% between P25-P50; 11.9% had birth weight between P50-P75, 2.4% between P75-P90 and 2.4% above P90. Considering maternal outcomes (N=42), eight women (19.0%) were diagnosed with gestational diabetes; 13 (31.0%) had a caesarean delivery; one (2,4%) had preeclampsia; and 12 (36.4%) had anaemia, mostly due to iron deficiency. Pregnant women with gestational diabetes were significantly older (38.9±2.4 *vs* 33.2±4.1, p=0.001). Supplementation with multivitamins with general formulation for pregnancy was carried out by 73.8% of all pregnant women, with a slightly higher prevalence in the group of malabsorptive procedures (84.2% *vs* 65.2%, p=0.119). Additionally, individualised supplementation with folic acid, iron, calcium, and vitamin D was also prescribed, according to measured analytes: 27 patients (64.3%) were supplemented with iron, 24 (57.1%) with folic acid beyond the first trimester of pregnancy, 16 (38.1%) with calcium, 15 (35.7%) with vitamin D, 5 (11.9%) with vitamin B12 and 5 (11.9%) with magnesium. There was no association between bariatric procedure type and the analysed maternal or foetal outcomes. Older maternal age increased the risk of gestational diabetes (odds ratio: 1.78; confidence interval 1.16-2.73) but showed no association with the other analysed outcomes. The prevalence of vitamin D deficiency was 75.9% (severe in 24.1%), calcium deficiency 43.8%; vitamin B12 deficiency 23.5% and folic acid deficiency 8.7%. Iron deficiency was found in 77.8% of pregnancies, with 33.3% requiring supplementation with intravenous iron (31.5% corresponding to malabsorptive and 30.4% to restrictive procedures, p=0.972). The prevalence of micronutrient deficiencies did not differ significantly between restrictive and malabsorptive procedures.

Analysing the possible association of micronutrient deficiencies and SGA, we found a higher prevalence of SGA neonates in pregnant women with vitamin B12 deficiency in the first trimester (33.3 *vs* 0.0%, p=0.027); and no associations between other vitamin deficiencies and SGA. Even though no association was found between iron deficiency and SGA, there was a trend towards a higher prevalence of SGA in patients not taking individualised iron supplements (46.2% *vs* 14.8%, p=0.052). Regarding the possible association between gestational weight gain and SGA, there was a higher prevalence of SGA neonates in pregnancies with insufficient and excessive weight gain than in those with adequate weight gain, but this difference did not reach statistical significance (33.3% and 26.7% *vs* 8.3%, p=0.32). Moreover, 44.4% of all SGA were born from mothers with insufficient weight gain (*vs* 55.6% from mothers with adequate or excessive weight gain, p=0.238).

There was no record of other pregnancy complications, such as dumping syndrome, internal hernias or other complications requiring surgery.

Discussion

In the analysed cohort, micronutrient deficiencies were highly prevalent in pregnancies after both types of BS, despite supplementation with multivitamins in most patients. Even though there was significant weight loss after BS, most women had pregestational obesity. Nonetheless, obesity-related pregnancy complications such as LGA or preeclampsia were uncommon. The prevalence of SGA in our study was more than double that of the reported in the Portuguese population (23.8% *vs* 8.9%).[24,25] We found no significant differences in the prevalence of micronutrient deficiencies, preeclampsia, gestational diabetes, maternal anaemia, caesarean delivery, preterm delivery, SGA and LGA between restrictive and malabsorptive bariatric procedures. Spontaneous abortion occurred only in pregnancies following restrictive procedures, but the small number of cases and the high prevalence of significant additional risk factors such as thrombophilia does not allow for a reliable comparison between surgical procedure types. Pregnant women submitted to malabsorptive procedures were older, had a higher BMI before surgery and a more pronounced weight loss from surgery to conception, but showed no difference in weight gain during pregnancy. We also found a higher prevalence of SGA in pregnancies with vitamin B12 deficiency in the first trimester, in those not supplemented with iron in addition to usual multivitamins and in the presence of insufficient gestational weight gain.

To date, few studies have focused on maternal vitamin deficiencies following BS and its association to neonatal outcomes. Recently, some authors described an association between levels of vitamins B9, B12, calcium, iron and birth weight[19,26]; others reported that women receiving nutritional advice were significantly less likely to have an SGA neonate.[16] In the latter – the AURORA prospective case-control study,[16] the authors describe that pregnant women with SGA neonates had slightly lower levels of iron and vitamin B12 when compared to women giving birth to adequate for gestational age neonates, but did not find an association between serum levels of micronutrients and the risk of SGA. Nevertheless, their analysis was limited by the amount of missing data (10%-72%) on nutritional levels.

Currently, guidelines on pregnancy after BS recommend individualised supplementation with multivitamins and minerals in both types of procedures, that should ideally be optimized 3-6 months prior to conception and adjusted during pregnancy based on serum levels of nutrients.[13,14] It is known that malabsorptive procedures may lead to more pronounced micronutrient deficiencies and some studies suggest that these may impair gestational weight gain and influence the risk of adverse perinatal outcomes. Most studies that associate malabsorptive procedures with increased risk of lower birth weight, SGA and other adverse foetal outcomes, hypothesize that the reason behind this may be the increased prevalence of micronutrient deficiencies, but lack information on patient's multivitamin supplementation and measured analytes.[7,16,18,19,27,28]

In our cohort, micronutrient deficiencies did not differ between surgery type, which may explain our results regarding pregnancy outcomes. Similar to our study, Hazart *et al*[20] analysed pregnancies with an elevated prevalence of multivitamin supplementation (77.8% to 100.0%) after both types of procedures, and found no significant difference on micronutrient deficiencies and pregnancy outcomes between BS types; Ducarme *et al*[29] performed a prospective study of 87 women with comparable nutritional supplementation and found that serum micronutrient levels of zinc, selenium, vitamins A1, B1, B6, C, and E were similar in pregnancies after Roux-en-Y gastric bypass and sleeve gastrectomy, as were maternal and neonatal outcomes. In the latter, almost all the included women had at least one micronutrient deficiency during pregnancy. Watanabe and colleagues[27] also described that birth weight in pregnancies after malabsorptive procedures without anaemia was similar to that of pregnancies after restrictive procedures, and Mead *et al*[30] found no significant differences in iron, vitamin B12 or calcium deficiencies between biliopancreatic diversion, Roux-en-Y gastric bypass and sleeve gastrectomy in women following nutritional supplement guidelines before and during pregnancy. Additionally, a higher prevalence of supplementation of women submitted to malabsorptive versus restrictive procedures was also found in the studies by Hazart *et al*[20] and by Akhter *et al*,[16] in the first trimester of pregnancy. The elevated prevalence of SGA and the low prevalence of adequate weigh gain in our analysis were also consistent with previous studies.[16,20] In our analysis, and in line with the results from the AURORA study, 44% of mothers of SGA had insufficient weight gain, but in our study this difference did not reach statistical significance.

Our study is important, as it shows the elevated risk of micronutrient deficiencies in our population of pregnant women submitted to BS. Moreover, it emphasises that the risk of micronutrient deficiencies is present in both malabsorptive and restrictive procedures, and reinforces the importance of adequate, intensive and individualized supplementation, starting before conception, in both types of BS. In line with this, our results suggest that, in daily clinical practice, the decision between BS procedures in women of reproductive age should be based on individual characteristics, such as baseline BMI and comorbidities, apart from possible future pregnancies. Therefore, it is our opinion that we should not favour restrictive procedures in women of reproductive age as a general rule, but individualize our choice and adjust follow-up and supplementation accordingly.

Nonetheless, we recognize that micronutrient deficiencies are just one in several factors that may influence foetal birth weight, and that foetal growth is also largely dictated by macronutrient availability. In turn, macro and micronutrient availability is dependent on maternal nutritional intake during preconception and pregnancy, and on the ability of the placenta to transport these nutrients to the foetus. Adequate nutritional counselling and close foetal monitoring are, therefore, also of unneglectable importance.

Strengths of our study include data collection on multivitamin supplementation, micronutrient assessments in each trimester and sample homogeneity between groups. Additionally, the diversity of bariatric procedures and the similarity in multivitamin supplementation in restrictive and malabsorptive procedures, as recommended in the guidelines, reinforced our results. Weaknesses of our study include its retrospective nature and small sample size, which precludes the generalization of the results. It should be noted that the small sample size may have biased the evaluation of uncommon pregnancy outcomes. Additionally, given the low number of biliopancreatic diversion surgeries in our cohort, our results are not representative for this procedure. Similar to some previous studies, we must also point out the significant amount of missing data on micronutrient deficiencies, that limited our analysis; and the fact that the only available analytes were calcium, magnesium, iron and vitamins D, B9 and B12. Venous blood glucose assessment was mostly inaccessible retrospectively; therefore, the prevalence of hypoglycaemia in both types of surgical procedures could not be compared and a possible association with adverse neonatal outcomes could not be assessed. Macronutrients were also not assessed, and would be a relevant complement to our analysis.

Prospective studies with a greater sample size are needed for a better assessment of the risk factors for adverse pregnancy outcomes in women submitted to BS. Future studies should focus not only in gestational weight gain and micronutrient deficiencies, but also in other factors that might influence perinatal outcomes, such as maternal weight loss trajectories, exercise and food intake behaviors, placental function, microbiome profiles and macronutrient and energy status. This evidence will be crucial for the development of more comprehensive follow-up programs and counselling.

Conclusion

Our study showed an elevated prevalence of micronutrient deficiencies, insufficient gestational weight gain and SGA neonates in pregnancies after both types of BS. Malabsorptive procedures were associated with greater weight reduction, but showed no significant differences in the prevalence of micronutrient deficiencies and maternal and foetal outcomes, when compared to restrictive procedures. We hypothesise that the careful management of pregnant women with history of BS, with frequent follow-up, generalised multivitamin supplementation, and additional individualised supplementation according to measured analytes during pregnancy might have mitigated the expected differences between malabsorptive and restrictive procedures. However, other factors besides micronutrient supplementation were not assessed in this study and might have also influenced maternal and neonatal outcomes.

Finally, our results suggest that there may be no benefit in favouring restrictive procedures in women of reproductive age on a routine basis, but studies with a greater sample size are needed to validate this hypothesis. Our analysis also highlights the importance of adequate supplementation and regular follow-up to minimize adverse pregnancy outcomes in both types of BS.

Contributorship Statement / Declaração de Contribuição:

BA and AC: Contributed equally to this study and were responsible for the study conception and design, data collection, data analysis and interpretation and drafting the article.
ML and IV: Were responsible for data collection.
SP: Was responsible for study conception and design.
MM: Was responsible for study conception and design and for critical revision of the manuscript.
DR and IP: Were responsible for critical revision and for important intellectual content.
All authors approved the final version to be published.

BA e AC: Contribuíram igualmente para este estudo e foram responsáveis pela conceção e desenho do estudo, recolha de dados, análise e interpretação dos dados e redação do artigo.
ML e IV: Foram responsáveis pela recolha de dados.
SP: Foi responsável pela conceção e desenho do estudo.
MM: Foi responsável pela conceção e desenho do estudo, pela revisão crítica do conteúdo.
DR e IP: Foram responsáveis pela revisão crítica e pelo conteúdo intelectual importante.
Todos os autores aprovaram a versão final a ser publicada.

Responsabilidades Éticas

Conflitos de Interesse: Os autores declaram a inexistência de conflitos de interesse na realização do presente trabalho.
Fontes de Financiamento: Esta investigação não recebeu qualquer subsídio específico de qualquer agência de financiamento do sector público, comercial ou sem fins lucrativos. Recebeu um subsídio da Sociedade Portuguesa de Endocrinologia, Diabetes e Metabolismo para apresentação no Congresso Europeu de Obesidade (maio/2022).
Confidencialidade dos Dados: Os autores declaram ter seguido os protocolos da sua instituição acerca da publicação dos dados de doentes.
Os autores obtiveram o consentimento informado dos pacientes e/ou sujeitos mencionados no artigo.
Proteção de Pessoas e Animais: Os autores declaram que os procedimentos seguidos estavam de acordo com os regulamentos estabelecidos pela Comissão de Ética responsável e de acordo com a Declaração de Helsínquia revista em 2013 e da Associação Médica Mundial.
Proveniência e Revisão por Pares: Não comissionado; revisão externa por pares.

Ethical Disclosures

Conflicts of Interest: The authors have no conflicts of interest to declare.
Financing Support: This research did not receive any specific grant from any funding agency in the public, commercial or not-for-profit sector. It received a grant from the Portuguese Society of Endocrinology, Diabetes and Metabolism for presentation in the European Congress on Obesity (may/2022).
Confidentiality of Data: The authors declare that they have followed the protocols of their work center on the publication of data from patients.
The authors have obtained the informed consent of the patients and/or subjects mentioned in the article.
Protection of Human and Animal Subjects: The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki as revised in 2013).
Provenance and Peer Review: Not commissioned; externally peer reviewed.

References / Referências

1. World Health Organization. WHO European Regional Obesity Report 2022. Geneva:WHO; 2022.
2. ACOG Practice Bulletin No 156: Obesity in Pregnancy. Obstet Gynecol. 2015;126:e112-e26.
3. Marchi J, Berg M, Dencker A, Olander EK, Begley C. Risks associated with obesity in pregnancy, for the mother and baby: a systematic review of reviews. Obes Rev. 2015;16:621-38. doi: 10.1111/obr.12288.
4. Maggard MA, Yermilov I, Li Z, Maglione M, Newberry S, Suttorp M, et al. Pregnancy and fertility following bariatric surgery: a systematic review. JAMA. 2008;300:2286-96. doi: 10.1001/jama.2008.641.
5. Edison E, Whyte M, van Vlymen J, Jones S, Gatenby P, de Lusignan S, et al. Bariatric Surgery in Obese Women of Reproductive Age Improves Conditions That Underlie Fertility and Pregnancy Outcomes: Retrospective Cohort Study of UK National Bariatric Surgery Registry (NBSR). Obes Surg. 2016;26:2837-42. doi: 10.1007/s11695-016-2202-4.
6. Welbourn R, Hollyman M, Kinsman R, Dixon J, Liem R, Ottosson J, et al. Bariatric Surgery Worldwide: Baseline Demographic Description and One-Year Outcomes from the Fourth IFSO Global Registry Report 2018. Obes Surg. 2019;29:782-95. doi: 10.1007/s11695-018-3593-1.
7. Akhter Z, Rankin J, Ceulemans D, Ngongalah L, Ackroyd R, Devlieger R, et al. Pregnancy after bariatric surgery and adverse perinatal outcomes: A systematic review and meta-analysis. PLoS Med. 2019;16:e1002866. doi: 10.1371/journal.pmed.1002866.
8. Johansson K, Cnattingius S, Näslund I, Roos N, Trolle Lagerros Y, Granath F, et al. Outcomes of pregnancy after bariatric surgery. N Engl J Med. 2015;372:814-24. doi: 10.1056/NEJMoa1405789.
9. Carreau AM, Nadeau M, Marceau S, Marceau P, Weisnagel SJ. Pregnancy after bariatric surgery: balancing risks and benefits. Can J Diabetes. 2017;41:432-8. doi: 10.1016/j.jcjd.2016.09.005.
10. Battaglia FC, Lubchenco LO. A practical classification of newborn infants by weight and gestational age. J Pediatr. 1967;71:159-63.
11. Lees CC, Stampalija T, Baschat A, da Silva Costa F, Ferrazzi E, Figueras F, et al. ISUOG Practice Guidelines: diagnosis and management of small-for-gestational-age fetus and fetal growth restriction. Ultrasound Obstet Gynecol. 2020;56:298-312. doi: 10.1002/uog.22134.
12. Saenger P, Czernichow P, Hughes I, Reiter EO. Small for gestational age: short stature and beyond. Endocr Rev. 2007;28:219-51. doi: 10.1210/er.2006-0039.
13. Ciangura C, Coupaye M, Deruelle P, Gascoin G, Calabrese D, Cosson E, et al. Clinical Practice Guidelines for Childbearing Female Candidates for Bariatric Surgery, Pregnancy, and Post-partum Management After Bariatric Surgery. Obes Surg. 2019;29:3722-34. doi: 10.1007/s11695-019-04093-y.
14. Shawe J, Ceulemans D, Akhter Z, Neff K, Hart K, Heslehurst N, et al. Pregnancy after bariatric surgery: Consensus recommendations for periconception, antenatal and postnatal care. Obes Rev. 2019;20:1507-22. doi: 10.1111/obr.12927.
15. Vanheule G, Ceulemans D, Vynckier AK, De Mulder P, Van Den Driessche M, Devlieger R. Micronutrient supplementation in pregnancies following bariatric surgery: a practical review for clinicians. Obes Surg. 2021;31:4542-54. doi: 10.1007/s11695-021-05546-z.
16. Akhter Z, Heslehurst N, Ceulemans D, Rankin J, Ackroyd R, Devlieger R. Pregnancy after Bariatric Surgery: A Nested Case-Control Study of Risk Factors for Small for Gestational Age Babies in AURORA. Nutrients. 2021;13:1699. doi: 10.3390/nu13051699.
17. Heusschen L, Krabbendam I, van der Velde JM, Deden LN, Aarts EO, Merién AER, et al. A Matter of Timing-Pregnancy After Bariatric Surgery. Obes Surg. 2021;31:2072-9. doi: 10.1007/s11695-021-05546-z.
18. Kwong W, Tomlinson G, Feig DS. Maternal and neonatal outcomes after bariatric surgery; a systematic review and meta-analysis: do the benefits outweigh the risks? Am J Obstet Gynecol. 2018;218:573-80. doi: 10.1016/j.ajog.2018.02.003.
19. Yu Y, Groth SW. Risk factors of lower birth weight, small-for-gestational-age infants, and preterm birth in pregnancies following bariatric surgery: a scoping review. Arch Gynecol Obstet. 2023;307:343-78. doi: 10.1007/s00404-022-06480-w.
20. Hazart J, Le Guennec D, Accoceberry M, Lemery D, Mulliez A, Farigon N, et al. Maternal Nutritional Deficiencies and Small-for-Gestational-Age Neonates at Birth of Women Who Have Undergone Bariatric Surgery. J Pregnancy. 2017;2017:4168541. doi: 10.1155/2017/4168541.
21. Ducarme G, Parisio L, Santulli P, Carbillon L, Mandelbrot L, Luton D. Neonatal outcomes in pregnancies after bariatric surgery: a retrospective multi-centric cohort study in three French referral centers. J Matern Fetal Neonatal Med. 2013;26:275-8. doi: 10.3109/14767058.2012.735723.
22. Institute of Medicine and National Research Council Committee to Reexamine IOMPWG. The National Academies Collection: Reports funded by National Institutes of Health. In: Rasmussen KM, Yaktine AL, editors. Weight Gain During Pregnancy: Reexamining the Guidelines. Washington: National Academies Press; 2009
23. Amrein K, Scherkl M, Hoffmann M, Neuwersch-Sommeregger S, Köstenberger M, Tmava Berisha A, et al. Vitamin D deficiency 2.0: an update on the current status worldwide. Eur J Clin Nutr. 2020;74:1498-513. doi: 10.1038/s41430-020-0558-y.
24. Raposo J. Diabetes: Fatos e Números. Revista Portuguesa de Diabetes. 2020.15(1):19-27.
25. National Institute of Statistics (INE). Live births in Portugal (2017-2021) [database on the Internet]. [accessed on December 2022]. Available from: http://www.ine.pt
26. Faintuch J, Dias MC, de Souza Fazio E, de Oliveira FC, Nomura RM, Zugaib M, et al. Pregnancy nutritional indices and birth weight after Roux-en-Y gastric bypass. Obes Surg. 2009;19:583-9.
27. Watanabe A, Seki Y, Haruta H, Kikkawa E, Kasama K. Maternal impacts and perinatal outcomes after three types of bariatric surgery at a single

institution. Arch Gynecol Obstet. 2019;300:145-52. doi: 10.1007/s00404-019-05195-9.
28. Chevrot A, Kayem G, Coupaye M, Lesage N, Msika S, Mandelbrot L. Impact of bariatric surgery on fetal growth restriction: experience of a perinatal and bariatric surgery center. Am J Obstet Gynecol. 2016;214:655.e1-7. doi: 10.1016/j.ajog.2015.11.017.
29. Ducarme G, Planche L, Abet E, Desroys du Roure V, Ducet-Boiffard A. A Prospective Study of Association of Micronutrients Deficiencies during Pregnancy and Neonatal Outcome among Women after Bariatric Surgery. J Clin Med. 2021;10:204. doi: 10.3390/jcm10020204. .
30. Mead NC, Sakkatos P, Sakellaropoulos GC, Adonakis GL, Alexandrides TK, Kalfarentzos F. Pregnancy outcomes and nutritional indices after 3 types of bariatric surgery performed at a single institution. Surg Obes Relat Dis. 2014;10:1166-73. doi: 10.1016/j.soard.2014.02.011.