

Verification of Macro- and Micronutrient Intake in the First Year of Roux-En-Y Gastric Bypass Using MSM Method

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Abstract

Background: Bariatric surgery is an alternative treatment for obesity. However, physicians need to be aware of the possible consequences of nutritional deficiencies with this type of surgery. This study aimed to determine the prevalence of inadequacy of macro- and micronutrients from the diet in patients undergoing Roux-en-Y gastric bypass after 3, 6, and 12 months postoperatively. **Methods:** We performed a longitudinal, observational, clinical study during preoperatively and 3-, 6-, and 12-month postoperatively (n = 95 patients). We collected information from medical records of patients in a Reference Clinic of Bariatric Surgery. Quantitative food intake was analyzed by ADS Nutri[®] and Multiple Source Method[®] software. The obtained data were compared with the daily-recommended intake in accordance with specific guidelines for bariatric surgery. Data were analyzed using t-tests, Mann-Whitney test, one-way analysis of variance (ANOVA), and Tukey's test. **Results:** There was a high prevalence of inadequacy of macronutrients and micronutrients from food in the postoperatively period. However, only vitamin B12 intake was adequate based on the daily recommended intake. **Conclusions:** Our study suggests that the intake of nutrients by feeding is below current recommendations. Individual nutritional counseling with a therapeutic plan for adequate nutrition and prescription supplements are important to ensure that nutritional recommendations are adhered to.

Keywords

Macronutrients, Micronutrients, Bariatric Surgery, Gastric Bypass, Food Intake

1. Introduction

Obesity is a metabolic and multifactorial disease associated with genetic, behavioral, environmental, and endocrine disorders. Therefore, obesity is considered the epidemic of the century, as well as a major problem of global public health [1]. Obesity is the second leading cause of preventable and premature death in the United States [2]. In Brazil, 50.8% of the population is overweight and 17.5% is obese [3].

Conventional treatments for obesity include nutritional counseling, physical activity, drug treatment, and psychological treatment [4]. Surgical intervention is an alternative treatment if conventional treatments fail. [5]. The Roux-en-Y gastric bypass corresponds to 49% of all bariatric surgeries performed worldwide [6].

Patients undergoing this surgical technique are at high risk of developing nutritional deficiencies, because of reduced absorption, after intestinal bypass [7]. The combination of restrictive and disabsorptive components increases the nutritional risk, requiring intensive and continuous nutritional monitoring [8]. Moreover, the prevalence of symptoms, such as nausea, vomiting, diarrhea, dumping syndrome, and food intolerance, is high in Roux-en-Y gastric bypass, contributing to development of micro- and macronutrient deficiency [9].

The main deficiency of macronutrients after Roux-en-Y gastric bypass occurs because of a lack of protein [10]. Deficiencies in micronutrients postoperatively involve iron, folate, B vitamins (mainly B12), calcium, vitamin D, selenium and zinc [11].

Anatomical and physiological changes can affect food intake in patients who undergo Roux-en-Y gastric bypass. Correcting deficiencies in micro- and macronutrients to maintain adequate nutritional status is important. However, there is a lack of studies on Roux-en-Y gastric bypass that quantitatively assess nutrients from food postoperatively. Therefore, this study aimed to determine the prevalence of inadequacy of macro- and micronutrients at 3, 6, and 12 months postoperatively in patients who underwent Roux-en-Y gastric bypass.

2. Materials and Methods

2.1. Study Design

We performed a longitudinal, observational, retrospective, clinical study during preoperatively and 3-, 6-, and 12-month postoperatively. We studied patients in a reference bariatric surgery clinic. Approval for the study was obtained by the Ethics Committee of the Pontifical Catholic University of Paraná (PUCPR) under the following registration number: 13491913.8.0000.0020.

2.2. Sample

The sample population was selected by convenience. Inclusion criteria were as follows: adult patients of both sexes underwent Roux-en-Y gastric bypass from 2003 to 2014; nutritional records included preoperative data and data at 12 months postoperatively; and there was at least one nutritional record at 3 or 6

months postoperatively.

2.3. Nutritional Record Information

Data were collected from the electronic nutritional records. The following information was collected: name, sex, age, initial weight and weight at each period, height, and 24-h food recall recorded at 3-, 6-, and 12-month visits. We calculated body mass index (BMI) and the percentage of excess weight loss (% EWL) [12]. The nutritionist and the surgical team collected nutritional data and medical data, respectively. The same surgeon performed all surgeries.

2.4. Analysis of Food Intake

The food intake data were assessed from quantitative analysis of 24-h food recall recorded at three time points. Estimation of food intake can be performed from two repeated measures that include different days of the week and periods during 1 year [13]. For this analysis, we used ADS Nutri[®] diet software (<http://www.adsnutri.com.br/>). Energy, carbohydrates, proteins, lipids, fiber, vitamin B12, iron, calcium, zinc, and selenium were evaluated. The usual intake of micronutrients was calculated using the Multiple Source Method[®] software (<https://msm.dife.de/>), which controls individual variability using statistics.

2.5. Analysis of the Prevalence of Inadequate Macronutrients and Micronutrients

For determining the inadequacy of macronutrients and micronutrients, we used quantitative analysis of food intake and compared it with specific recommendations. Micronutrients were compared with the estimated average requirement according to sex and age, and macronutrients were compared with the guidelines for bariatric surgery [10].

2.6. Statistical Analysis

We used SPSS version 2.0 (SPSS Inc., Chicago, IL, USA) to perform normal tests, categorize variables as parametric and non-parametric, for descriptive analysis, and to compare means. Parametric variables analyzed by descriptive statistics are shown as the mean and standard deviation, while nonparametric variables are shown as median, minimum, and maximum values. The t-test was used for independent samples and the Mann-Whitney test was used to compare the means and medians of the three periods. ANOVA and Tukey's test were used for comparison of means between different periods. The level of significance was $p < 0.05$.

3. Results

The sample consisted of 95 patients. At 3 and 6 months postoperatively, data from 92 and 88 patients were available, respectively, because of the absence of some patients from consultations. The final study population consisted of 84 (88.4%) women. Age ranged 20 - 64 years. For preoperative weight, median

weight was 104 kg, with a minimum of 75 kg and maximum of 178 kg (Table 1).

There was an important reduction in weight and BMI at 3, 6, and 12 months compared with that before surgery. The mean BMI of patients preoperatively was 39.3 kg/m² and 31.22 kg/m² at 3 months after surgery, with a decline to 26.63 kg/m² at 12 months postoperatively. EWL at 3 months postoperatively was 56.39% ± 17.32%. At 6 months, EWL reached 74.5% (33% - 139%), and at 12 months, it was 88.57% ± 23.7% (Table 1).

Medium energy intake increased over the postoperative period, with a significant increase compared with energy recommendations at each time point ($p < 0.05$). However, there was no significant difference in medium energy intake of the three periods after surgery compared with that before surgery ($p > 0.05$). The highest percentage of inadequacy was protein intake at 12 months postoperatively (66.32%). The percentage of inadequate energy and lipids was higher at 6 months postoperatively, during which no patients had adequate intake of these variables, compared with 3 and 12 months postoperatively. The prevalence of inadequate zinc intake gradually declined over the three periods (Table 2). There was a gradual increase in the intake of micronutrients, with the exception

Table 1. Characteristics of the study population pre- and post-surgery.

Variables	Pre-surgery Average/Median*	3 months Average/Median*	6 months Average/Median*	12 months Average/Median*
Number of patients	95	92	88	95
Age (years)	46 (20 - 64)	-	-	-
Height (m)	1.63 ± 0.07	-	-	-
Weight (kg)	104 (75 - 178)	83 (65- 140)	75.45 (56 - 131)	71 (47 - 127.5)
BMI (kg/m ²)	39.3 (29 - 67.83)	31.22 (23.92 - 53.35)	28.79 (22.39 - 49.92)	26,63 (19.07 - 48.58)
% weight loss	-	56.39 ± 17.32	74.5 (33 - 139)	88.57 ± 23.7

*Mean ± SD/median (minimum-maximum); Note: BMI, body mass index.

Table 2. Energy and macronutrient consumption at 3, 6, and 12 months postoperatively.

	3 Months			6 Months			12 Months		
	Average/Median*	Recommendation BariatricPopulatio n	% Inadequacy	Average/Median*	Recommendation BariatricPopulatio n	% Inadequacy	Average/Median*	Recommendation BariatricPopulatio n	% Inadequacy
Energy (kcal)	651.3 ± 151.3 ^{aA}	800 ^b	85.9	729.57 ± 149.38 ^{aA}	1000 ^b	100	902.35 (803.29 - 1882.85) ^{aA}	1200 ^b	85.26
Carbohydrate (g)	77.53 (40.63 - 142.69) ^{aA}	130 ^b	96.74	92.39 ± 21.72 ^a	130 ^{bA}	95.51	116.6 (62.22 - 259.66) ^{aA}	130 ^b	71.58
Protein (g)	43.43 ± 12.28 ^{aA}	60 ^b	82.4	47.73 ± 12.08 ^{aA}	60 ^b	88.77	55.77 ± 12.42 ^{aA}	60 ^b	66.32
Lipids (g)	16.45 (2.71 - 37.06) ^{aA}	40 ^b	100	19.54 ± 5.72 ^{aA}	40 ^b	100	24.42 (7.2 - 55.63) ^{aA}	40 ^b	93.69
Fiber (g)	9.2 ± 2.83 ^{aA}	15 ^b	98.92	9.2 ± 2.83 ^{aA}	15 ^b	93.26	10.39 ± 3.11 ^{aA}	15 ^b	37.37

*Mean ± SD/median (minimum-maximum); ^{a,b}: Significant difference by Tukey's test ($p < 0.05$). The same letter does not indicate a significant difference. ^{A,B}: Significant difference by one-way ANOVA and Tukey's test ($p < 0.05$). The same letter does not indicate a significant difference.

of zinc for men. Despite this increase, all of these nutrients were below the daily recommended intake (**Table 3**).

Unlike the other nutrients, Vitamin B12 was adequate in accordance with the recommendations. The usual intake of zinc in women, iron in older women, calcium in elderly men and women, and calcium and selenium, reached values close to or above 100% inadequacy (**Table 4**).

4. Discussion

In our study, over a 12-month postoperative period, there was a significant increase in %EWL, which indicated surgical success. However, there was a high prevalence of inadequate macro- and micronutrients from food intake. Among

Table 3. Comparison of consumption of micronutrients at 3, 6, and 12 months postoperatively.

Micronutrients	3 Months		6 Months		12 Months	
	Average/Median*	Recommendation	Average/Median*	Recommendation	Average/Median*	Recommendation
Calcium (mg)	354.52 (49.89 - 961.26) ^a	800 ^b	350 ± 165.39 ^a	800 ^b	398.41 (91.88 - 1256.93) ^a	800 ^b
Calcium elderly (mg)	465.03 (324.22 - 1048.56) ^a	1000 ^b	495.33 ± 190.78 ^a	1000 ^b	652.9 (264.85 - 972.57) ^a	1000 ^b
Zinc men(mg)	7.39 ± 3.36 ^a	9.4 ^a	10.86 ± 2.44 ^a	9.4	9.04 ± 3.74 ^a	9.4 ^a
Zinc women (mg)	8.14 ± 2.97 ^a	6,8 ^b	9.23 ± 3.29 ^a	6,8 ^b	10.07 ± 3.18 ^a	6,8 ^b
Iron men (mg)	3.85 ± 1.58 ^a	6 ^b	5.21 ± 0.97 ^a	6 ^a	5.64 (2.33 - 12.22) ^a	6 ^b
Iron adult women (mg)	3.98 ± 1.32 ^a	8.1 ^b	4.46 ± 1.33 ^a	8.1 ^b	5.65 ± 1.28 ^a	8.1 ^b
Iron elderly women (mg)	4.69 ± 1.11 ^a	5 ^a	5.55 ± 1.79 ^a	5 ^a	4.54 ± 0.93 ^a	5 ^a
Selenium (mcg)	8.06(0.00 - 32.24) ^a	45 ^b	3.57 (0.00 - 38.66) ^a	45 ^b	6.69 (0.00 - 45.08) ^a	45 ^b
B12 Vitamin (mcg)	1.41(0.00 - 3.96) ^a	2 ^b	2.54 (1.13 - 3.96) ^a	2 ^b	3.39 (1.69 - 5.80) ^a	2 ^b

*Mean ± SD/median (minimum–maximum); ^{a,b}: Significant difference by Tukey's test (p < 0.05). The same letter does not indicate a significant difference.

Table 4. Recommendation and prevalence of inadequacy of micronutrients at 1 year postoperatively.

Nutrients	Usual consumption	Recommendation	% Inadequacy
Calcium (mg)	346.65 ± 144.44	800	99.95
Calcium elderly (mg)	469.65 ± 166.14	1000	99.92
Zinc men (mg)	10.17 ± 0.72	9.4	60.26
Zinc women (mg)	9.14 ± 0.98	6.8	100
Iron men (mg)	5.47 ± 0.52	6	83.39
Iron adult women (mg)	4.76 ± 0.37	8.1	100
Iron elderly women (mg)	4.84 ± 0.28	5	67
Selenium (mcg)	8.30 ± 3.85	45	100
B12 Vitamin (mcg)	2.48 ± 0.004	2	0

Note: The data have been adjusted to variability using MSM statistical software.

the micronutrients, vitamins had the lowest index of inadequacy.

The number of women in our study who had surgery was higher than that in men. This finding is consistent with a study that investigated the effect of bariatric surgery on weight loss, and showed that 72.6% of patients who underwent bariatric surgery were women [14].

A deficit in energy intake was found in our population. A previous study (n = 36 patients) showed an intake of 322 kcal preoperatively and 1060 kcal at 6 months after bariatric surgery, using recall 24h and Nutwin[®] software for nutrient calculation [22]. Similarly, another study on bariatric surgery in 93 patients showed a higher energy intake than that found in our study (849 ± 329 kcal at 3 months and 1101 ± 400 kcal at 12 months postoperatively) [23]. However, despite the fact that the 24-h dietary recall method is valid for postoperative follow-up and has a minimal risk of underestimating reduction in weight, these previous reports may have underestimated energy intake.

In our study, patients had inadequate protein intake. This finding is similar to results from another study (n = 137 patients) that investigated progression of weight loss and anemia in patients undergoing Roux-en-Y gastric bypass [16]. This previous study showed 14.2 ± 45.6 g of protein intake at 3 months and 58.5 ± 17.1 g at 12 months. Another study showed that 6 months after the bariatric surgery, protein intake was 47.11 ± 17.70 g [15]. This inadequacy can lead to a reduction in body mass, decrease in metabolic rate, and physiological damage. A protein diet with the recommended amount increases satiety, increases weight loss, and improves body composition [17]. Therefore, maintenance of protein supplementation might achieve the recommended requirements. This supplementation requirement can also be explained by the fact that there is a deliberate reduction in calorie intake of 78% on average because of restrictions for surgery, which contributes to reducing protein intake. There is an association between intolerance to protein and a decrease in secretion of proteolytic enzymes. To avoid the risk of malnutrition, protein supplementation up to 6 months after surgery is recommended and may continue until supply is obtained through food [18].

The recommended 15 g/day fiber intake was not reached until 12 months after surgery in our study. Bariatric surgery leads to a decrease in the volume of eaten food, especially during the first months after surgery. However, changes in the nutritional quality of food intake that occur in the preoperative period must not occur during the postoperative period, as this will lead to health problems. We also analyzed fiber intake in post-surgical patients and found that fiber intake up to 12 months after surgery was less than the recommended intake [19]. This finding reflects the need for continuous nutritional education on an outpatient basis, encouraging the consumption of fruits, vegetables, whole grains, and high-fiber foods.

After Roux-en-Y gastric bypass, clinical symptoms are often due to a poor nutritional standard. This situation is due to changes in dietary pattern induced by the surgical procedure. Postoperative anatomical changes affect bile and pancreatic function, the speed of intestinal transit, production of hydrochloric acid,

and the intestinal absorptive area [20]. There is a high risk of developing nutritional deficiencies after bariatric surgery because of the difficulty of maintaining proper nutrition [21]. In addition to all of the risk factors, there was an inadequate intake of micronutrients of patients in our study because of the difficulty of maintaining adequate food.

In the current study, there was a high percentage of inadequate iron intake. This finding is consistent with previous studies, which showed that 36% of patients have iron deficiency after 12 months of surgery. Another study showed that 86.11% of the population studied was below 85% of the recommended intake of iron [15]. This deficiency occurs not only due to low iron intake, but also in gastric hypochlorhydria and intolerance to red meat [20]. Guidelines recommend using elemental iron supplementation after surgery, and the daily recommendation is 45 - 60 mg [21]. There may be a need for additional vitamin C concurrently to increase the absorption of iron [22].

Our study showed that the intake of vitamin B12 had the lowest prevalence of inadequate intake. This result may be due to nutritional counseling that is focused on encouraging consumption of food sources (eggs, milk, and dairy products) of this vitamin. However, a previous study showed a high prevalence of vitamin B12 deficiency in patients undergoing gastroplasty with intestinal bypass in Roux-en-Y gastric bypass (42.1%) [21]. Despite many reports of vitamin B12 deficiency, it can vary from 12% - 75% of the population after bariatric surgery. This variation is caused by the individual time taken to exhaust the stock of vitamin B12 in the liver (2 - 5 years). This is exacerbated because of reduced gastric production of hydrochloric acid and decreased production of intrinsic factors in the stomach [20]. Recommended supplementation of vitamin B12 may be orally at 1000 mcg/day, intravenously at 1000 mcg/month, or 3000 mcg every 6 - 12 months [21]. The adequacy of vitamin B12 intake in our study population may have been achieved as a result of preoperative and postoperative encouragement to consume food sources rich in this nutrient, the fact that no patients were vegetarians, or underestimation of the food composition table values.

There was a high inadequate zinc intake in patients in this study. This inadequacy of zinc may be related to food intolerance [22]. More than 18 months after surgery, 20% - 24% of the population is estimated to develop zinc deficiency [23]. Absorption of zinc requires an acidic environment in the stomach, and this absorption occurs in the proximal portion of the intestine [23]. This absorption is compromised by anatomical changes because of bariatric surgery. The recommendation for zinc supplementation is 50 - 60 mg of elemental zinc per day [11].

The high percentage of inadequate calcium intake observed in our population is a concern. Low intake of calcium was also investigated in a study that evaluated patients (n = 36) undergoing gastroplasty with intestinal bypass in Roux-en-Y gastric bypass during the preoperatively and 6 months postoperatively and showed an average calcium intake of 597.03 ± 289.55 mg among participants [15]. A reduction in calcium intake and poor tolerance to milk products can lead to calcium deficiency, which leads to a high long-term risk of developing bone

disease [20]. Dairy products are also good sources of vitamin D. Therefore, reducing dairy product intake has consequences for ingestion and absorption of calcium and vitamin D. This increases the risk of developing osteopenia, osteoporosis, and osteomalacia [24].

This study showed no adequacy of selenium with food intake. The main dietary sources of selenium include nuts, salmon, wheat bran, and raw oysters. By analyzing data from food consumption of our population, we found a low intake of these foods as micronutrient sources. Educating patients and informing them of the main food sources are important for continuous, adequate nutrition.

Patients who undergo bariatric surgery may already show changes in plasma levels of micronutrients in the preoperative period because obesity with a poor quality of diet is a cause of nutrient deficiency. As mentioned above, bariatric surgery causes anatomical and physiological changes that affect the quantity and quality of food intake and absorption. Therefore, nutritional deficiency is directly related to preoperative status and the surgical method, and is also exacerbated by inadequate food intake post-surgically. Therefore, prevention and correction of deficiencies in vitamins and minerals should be initiated preoperatively, minimizing the risk of postoperative deficiency.

5. Conclusion

Food intake deficits of macro- and micronutrients result from eating habits in the first year of Roux-en-Y gastric bypass, indicating an insufficient intake of food sources. Because of the high risk of developing serious nutritional deficiencies, continuous nutritional monitoring, and encouraging adherence to a nutritional plan in accordance with the recommendations proposed for post-bariatric surgery are necessary. Furthermore, a therapeutic plan with supplements should be established, noting the individual nutritional needs.

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Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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