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RESEARCH ARTICLE

Class III Obesity and its Relationship with the Nutritional Status of Vitamin A in Pre- and Postoperative Gastric Bypass

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Abstract
Background Epidemiological findings have shown the rise of the prevalence of obesity in several segments of the world population, and more recent evidences point to a possible association with vitamin A deficiency (VAD). The aim of this study was to investigate vitamin A nutritional status in individuals with class III obesity in the preoperative period and 30 and 180 days after Roux-en-Y gastric bypass, correlating these findings with lipid profile and body mass index (BMI).
Methods The sample was composed of class III obese individuals, males and females, in the preoperative period (T1) and 30 (T2) and 180 days (T3) after bariatric surgery with 5,000 IU of supplementation of retinol acetate. Vitamin A nutritional status was assessed through biochemical indicators (retinol and β-carotene serum levels), which were quantified by high-performance liquid chromatography with an inadequacy cutoff of <1.05 μmol/L and ≥40 μg/dL, respectively.
Results Out of the 114 assessed patients, the mean age was 36.9±11.6 years and BMI was ≥40 kg/m^2. The prevalence of VAD was 14%, being 37.5% in T1, 50.8% and 67.8% in T2, and 52.9% and 67% in T3, according to retinol and serum β-carotene, respectively. A decrease of retinol and β-carotene serum levels was observed with BMI increase in T1. An increase of very-low-density lipoprotein cholesterol (VLDLc) and triglycerides was verified with the increase of retinol, being VLDLc in T3 and triglycerides in T1 and T2. In T1, high-dense lipoprotein cholesterol presented a positive and significant correlation with β-carotene and a negative and significant correlation in T3.
Conclusion High prevalence of VAD in the preoperative period and in 30 and 180 postoperative days, even during supplementation, with higher inadequacy of β-carotene in all the three studied time periods, probably occurred because of its bioconversion to retinol due to the increased demand to which those individuals were exposed. It is suggested that the oral intake supplementation does not

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present the expected impact, and the need of assessing the nutritional status of vitamin A in the pre- and postoperative Roux-en-Y gastric bypass is emphasized. High prevalence of VAD in T1, with severity in T2 and T3, corroborates the utilization of the cutoff of <1.05 μmol/L as a VAD marker in the studied segment and reinforces its utilization as a tool in clinical practice to identify VAD in morbid obese patients who underwent bariatric surgery.

Keywords Vitamin A · Retinol · β-carotene · Morbid obesity · Gastric bypass

Introduction

Obesity is recognized as a public health issue, and it is characterized by the excessive accumulation of body fat in such a way that it brings damages to health [1] because it favors cardiovascular diseases (CVDs), dyslipidemias, diabetes mellitus, and some types of cancer [2]. According to *Instituto Brasileiro de Geografia e Estatística* [3], 40.6% of the Brazilian population presents overweight, with 11.1% being related to obesity.

A cross-sectional study showed that the highest rise of prevalence of obesity in the last decade was in the group of class III obesity or morbid obesity [4]. In these cases, the clinical approach is generally inefficacious, and bariatric surgery presents itself as an important option for treatment because it brings a significant improvement of comorbidities [5]. Even with this improvement and the maintenance of overweight loss in the long run, the countless metabolic alterations due to surgical procedures generate nutritional disorders. This is mainly caused by malabsorption, which is secondary to alterations in the gastrointestinal tract that both associate with the decrease in the intake and the tendency of the individual to avoid consumption of food sources when gastrointestinal disorders occur, such as dumping syndrome [6].

Deficiencies of macronutrients in these individuals frequently associate with those of micronutrients leading, on account of a combination of factors, to the development of anemias, bone demineralization, and several hypovitaminosis. This occurs because of the lack of understanding of the magnitude of metabolic abnormalities, which results in the lack of a specific recommendation of supplements for this group [6–8].

Only a few studies have reported vitamin A deficiency (VAD) after malabsorptive surgeries, and it is even harder to find reports about this deficiency in patients submitted to Roux-en-Y gastric bypass [9]. VAD is one of the most prevalent health public issues in the world, being more severe in developing countries. This deficiency may bring several damages to health, including death [10–12].

Vitamin A participates in several important functions in the human system, such as visual acuity, immunological activity, cellular proliferation, and differentiation [13]. Lately, this vitamin, as well as its precursors, has received special attention for its role against free radicals because it protects the body against oxidative stress and, consequently, it prevents damages and tissue lesions related to several nontransmissible chronic diseases [3, 14, 15].

Although literature does not present many works that assess the nutritional status of vitamin A in individuals with obesity, Viroonudomphol et al. [16], Switzer et al. [17], and Silva et al. [18] showed a negative correlation between the degree of obesity and the nutritional status of vitamin A. Despite the lack of knowledge about the clinical consequences of VAD after bariatric surgery, reports of cases have shown the occurrence of ophthalmic complications, such as night blindness and corneal xerosis [19–22].

As has been shown, many factors may justify VAD in patients submitted to surgical treatment of obesity because these individuals are more susceptible to oxidative stress, which alone much increases the intake of substances with antioxidant function [23]. Besides, surgical procedures reduce the area of the sites of absorption of vitamin A, which, when associated with the decrease in food ingestion followed by a frequent lipid restriction in the postoperative period, including foods that are sources of vitamin A, may also be a contributing risk factor for VAD in this group. The aim of this article was to assess the relationship of class III obesity with the nutritional status of vitamin A in the preoperative period and 30 and 180 days after Roux-en-Y gastric bypass, relating these findings to lipid profile and body mass index (BMI).

Materials and Methods

This study included patients attended at *Clínica Cirúrgica Carlos Saboya* in the city of Rio de Janeiro with class III obesity [24], BMI≥40 kg/m^2, in the age range of 19–60 years in the pre- and postoperative periods of Roux-en-Y gastric bypass [25], followed up by dietitians of the multidisciplinary team of the clinic. The patient inclusion in the project was done through the signing of an informed consent. For assessment of the nutritional status of vitamin A, samples of 5 ml of blood were obtained by vein punction from patients after a 12-h overnight fast for determining the serum concentrations of retinol and β-carotene. Analysis was performed by high-performance liquid chromatography as recommended by the World Health Organization (WHO) [26].

The obtained serum values of retinol were compared with the cutoffs for normality proposed by WHO [26], and accordingly, they were presented in interval classes of

Table 1 General characteristics of the sample

Characteristics	*n*	%
Age (years)		
19–30	36	31.5
31–50	64	56.1
51–70	14	12.4
Total	114	100
Gender		
Male	28	24.5
Female	86	75.5
Total	114	100
BMI (kg/m^2)		
40–44.9	73	64
45–49.9	27	23.7
50–54.9	8	7
55–59.9	6	5.3
Total	114	100

0.35 μmol/L. Thus, VAD was classified as severe (<0.35 μmol/L), moderate (≥0.35<0.70 μmol/L), and light deficiency (≥0.70<1.05 μmol/L). In the present study, the value of serum retinol that was considered as adequate was ≥1.05 μmol/L, and <1.05 μmol/L was the cutoff utilized to indicate VAD, as suggested for investigation of marginal deficiency of vitamin A due to the increased risk of morbid-mortality associated with the subclinical or prepathological deficiency of this vitamin [26–28]. The cutoff utilized to indicate inadequacy of β-carotene serum values was under or equal to 40 μg/dL, as suggested by Sauberlich et al. [29].

Other laboratory tests were carried out for assessment of the lipid profile. Total cholesterol and triglycerides were assessed by the enzymatic colorimetric method, whereas very-low-density lipoprotein (VLDL), low-density lipoprotein (LDL), and high-density lipoprotein (HDL) were assessed by the selective inhibition method, being classified according to the IV Brazilian Guideline on Dyslipidemia [30]. The anthropometric assessment included weight and height calculation for classification of BMI, and the adopted cutoffs were those recommended by WHO [24] for classification of eutrophy; overweight; and class I, II, and III obesity.

Statistical analyses were performed in the statistical package SPSS for Windows, version 10.0. In the sample description, data were expressed in mean±standard deviation for numeric variables and in percentage variables for qualitative variables. Measures of central tendency and of dispersion of the continuous variables were calculated. Comparison of the numeric variables between the groups was conducted through Mann–Whitney test. Correlations were assessed by Spearman coefficient and Pearson chi-square test. The significance level adopted was $p \geq 0.05$.

Results

The sample was composed of 114 patients, with 28 (24.5%) males and 86 (75.5%) females. Mean age of the individuals was 36.9±11.6 years, ranging from 19 to 60, with 56.1% of the sample in the 31–50 age range (Table 1). There was no significant difference between the basal concentrations of serum retinol and β-carotene of the age ranges (p=0.9 and 0.3) and between females and males of the sample (p=0.07 and 0.09) (Table 1). Out of the individuals studied before the surgical procedure (T1), mean serum concentration of retinol was 1.21 μmol/L±0.58 μmol, with 14.0% below the cutoff point of <1.05 μmol/L, thus characterizing inadequate levels of vitamin A. Dividing them into interval classes, 62.5% presented marginal VAD, 25% moderate VAD, and 12.5% severe VAD (Table 2). Assessment of serum concentrations of β-carotene showed that 37.5% of the patients presented inadequacy (≤40 μg/dL) and mean was 62±43.7 μg/dL.

When the means of the serum concentrations of retinol and β-carotene were assessed within the first 30 postoperative days (T2), they were 1.17±0.54 μmol/L and 30.95±19.45 μg/dL, respectively, and 50.8% of the patients showed VAD and 67.8% showed deficiency of β-carotene. In T3, the means of the serum concentrations of retinol and β-carotene were 1.23±0.49 μmol/L and 36.02±23.50 μg/dL, and 52.9% presented inadequate levels of retinol, whereas 67.0% presented inadequate levels of β-carotene (Table 2). In T2, dividing into interval classes, 39.0% showed

Table 2 Means of retinol in the three times analyzed according to interval classification

Times	Severe VAD <0.35 μmol/L		Moderate VAD 0.35–0.69 μmol/L		Light VAD 0.70–1.05 μmol/L		Adequate serum retinol ≥1.05 μmol/L		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
T1	2	1.7	4	3.5	10	8.8	98	86	114	100
T2	5	4.4	11	9.6	39	34.3	59	51.7	114	100
T3	0	0	12	10.5	32	28.1	70	61.4	114	100

T1, preoperative; T2, 30 postoperative days; T3, 180 postoperative days

Table 3 Correlation between BMI and serum concentrations of retinol and β-carotene

Variable	Serum retinol (μmol/L)			β-carotene (μg/dL)		
	n	r_s	*p* value	*n*	r_s	*p* value
BMI TI	114	−0.21	0.02[a]	114	−0.22	0.01[a]
BMI T2	114	0.22	0.81	114	0.56	0.55
BMI T3	114	−0.10	0.27	114	−0.06	0.48

r_s=Spearman correlation coefficient
[a] Statistical significance

marginal, 11.0% moderate, and 5.0% severe deficiency, whereas in T3 (Table 2), 52.9% showed marginal deficiency and 36.4% moderate deficiency.

BMI variable presented a negative correlation coefficient with statistical significance only in T1, as in retinol and β-carotene. In the other two studied periods of time, no significant correlation was observed between these variables (Table 3). VLDL variables and triglycerides presented a positive correlation coefficient with statistical significance with regard to retinol, being VLDL in T1 and T3 and triglycerides in T1 and T2. With regard to β-carotene, the HDL variable presented a significant positive correlation coefficient in T1 and a significant negative correlation in T3. Triglycerides also presented a significant negative correlation in T3.

Discussion

In view of the rise of malnutrition in the last decades, obesity is considered one of the main issues of public health, especially because of the risk of associated diseases, such as arterial hypertension, CVDs, and type 2 diabetes, among others. Nowadays, the approximate rate of mortality due to obesity is around 200,000 people annually, which is one of the highest indices of mortality in the world, with most of the deaths caused by comorbidities [2, 4, 5]. Besides this, it is assumed that in the year 2020, two-thirds of the overall number of diseases will be attributed to nontransmissible chronic diseases [1, 3, 4].

A higher percentage of obesity was observed in females (75.5%) in the present study. In Brazil, the prevalence of obesity has increased much in the last decade [31], especially in adult females, reaching 13.3% and causing a huge impact on public health. When the rate of obesity rise was assessed in Brazil, the results were 0.36% for the female population and 0.20% for the male population annually. It is important to point out that data showed that the prevalence of obesity occurred in nearly all social groups, in urban and in rural populations, and in both genders, affecting 6.9% of males and 12.5% of females [3].

In the present study, high means of BMI were found in the young population. When the weight history of women belonging to class III obesity was compared with that of women from classes I and II, Crerand et al. [32] observed that women in class III obesity had a longer history of obesity, which had generally begun in their adolescence; hence, they maintained a higher body weight along life than those belonging to obesity classes I and II. Studies have shown that a longer period of obesity may bring a higher risk for development of chronic diseases, such as CVDs, due to the longer time of exposure to risk factors [33].

In obesity, besides BMI and the time of exposure, other factors, such as distribution of body fat mainly in the abdominal area (android obesity), keep a relationship with metabolic disorders that may be pointed out as a secondary cause of nutrient deficiency with antioxidant action [34]. The main etiological factor in epidemiological level related to VAD is the inadequate intake of food sources to satisfy the physiological needs of the individual [35]. Although the present study did not assess the dietary intake of the patients, evidences demonstrated that obesity, defined as the positive balance between what is ingested and what is spent [36, 37], is directly related to the quantity and not to the quality of what is consumed; that is, it is associated with a rich intake of calories and a poor intake of micronutrients [38, 39].

Such fact reinforces the thesis that the increase of total intake of foods does not necessarily increase the consumption of foods that are sources of vitamin A, which suggests that, in obesity, there is an insufficient intake of the sources of this vitamin that may lead to a deficiency in the liver store if it remains for a long period, thus increasing the risk for development of metabolic disorders [13].

Studies showed lower serum concentrations of retinol and carotenoids in obese individuals when compared with individuals with normal weight with no significant difference as regards the dietary ingestion of sources of these nutrients, as it was shown by data obtained by an inquiry of food history [18, 31, 40]. Therefore, the higher serum inadequacy of antioxidant nutrients observed in the present study may still be derived from their higher metabolic utilization against oxidative stress because it is known that these individuals are more exposed to it than eutrophics [41]. Studies with obese individuals presented a negative correlation between retinol, β-carotene, and BMI [16, 18], and in the present study, a statistical significance was observed when the means of BMI in T1 were compared with the levels of retinol and β-carotene.

The prevalence of inadequate serum levels of retinol found in the present study was 14.0%, and the inadequacy of β-carotene was 37.5%. In adults, a significantly higher risk for CVD in individuals with decreased serum concentrations of β-carotene was reported [46]. Low concentrations of

circulating antioxidants may contribute to an increased risk and to severity of atherosclerotic disease. In Brazil, information on the prevalence of VAD in individuals with disease profiles similar to the present study is not available; nonetheless, the VAD found in the present study, even being lower than that described for the classic groups of risk in Brazil in the preoperative period (14.0%), was high and rose in the periods of 30 and 180 postoperative days, 50.8% and 52.9%, respectively [42].

The results presented here are alarming and point to the need of conducting more studies addressed to this population group. As has been corroborated by literature, in the present study, a predominance of inadequacy of β-carotene was found, which is considered the most powerful free radical sweeper, hence suggesting that its largest part was converted into retinol. This finding is similar to that reported by Mecocci et al. [43], who demonstrated that the adequate nutritional status of vitamin A decreased the conversion of carotenoids into retinol, therefore evidencing the existence of a relationship between the nutritional status of retinol and carotenoids and that β-carotene is recognized as the most potent precursor of retinol [44].

Although there was significant weight loss with regard to T1, suggesting improvement of comorbidities and reduction of oxidative stress, the surgical procedure to which the patient was submitted consisted in the reduction of the gastric capacity and malabsorption on account of exclusion of the duodenum and of 30–50 cm of jejunum of food transport, besides 1 to 2 m of proximal jejunum without the presence of digestive enzymes [45].

It is worth pointing out that diets administered on the 30 initial days after surgery were aim at gastric rest and hydration to reduce risks such as fistules, usually offering an intake of 300 to 500 kcal daily, which is recognizably deficient in macro- and micronutrients [46]. The literature is consensual with regard to vitamin and mineral supplementation in the postoperative period of bariatric surgery, but the actual vitamin recommended daily intake (RDI) that would indicate the best route of administration and the form of presentation of the nutrients has not been established yet [8, 47].

Usually, the polyvitamins that are available in the market and are utilized by the teams of medical doctors and professionals responsible for bariatric surgery offer a dose of 5,000 IU of retinol acetate, which corresponds to twofold RDI for a normal individual [48]. Nonetheless, in the same way that vitamin A and carotenoids are solubilized and absorbed in the lean intestine, the dietary supplement also has its absorption damaged because it is absorbed by passive diffusion. In the intestinal tract, retinol and carotenoids are incorporated into chylomicrons, which leave the intestine and migrate to the liver, the main organ of synthesis and storage [49]. It is calculated that the adequate store of vitamin A might promote protection against the deficiency for a 4-week period in adult individuals with a deficient diet [13].

In the sixth month of the postoperative period (T3), even with a mean intake of 1,200 kcal and vitamin and mineral supplement offering 5,000 IU of retinol acetate, the prevalence of retinol and deficiency of β-carotene were 52.89% and 67.0%, respectively, maintaining themselves equivalent to those found on postoperative day 30, which suggests that the oral intake did not seem to have had the expected impact.

Low intake of proteins, lipids, iron, and zinc in the diet may contribute to the development of VAD on account of the interference in the absorption and transport of this micronutrient [50]. Another relevant aspect is that polyvitamins contain vitamin C, vitamin E, selenium, and zinc, which are nutrients with antioxidant action [48, 51], and the prevalence of VAD was kept high and rising even considering the time of exposure to the supplement and the expected increase in the intake of nutrients in the sixth postoperative month. When assessing the impact of surgery on BMI, it was verified that there was a significant decrease in all three studied periods of time.

Many studies showed that bariatric surgery, due to the intense and maintained loss of overweight, effectively controls comorbidities [52, 53], which may be considered secondary causes of VAD because they interfere in the absorption, storage, and transport of vitamin A or in the conversion of pro-vitamin A into its metabolically active form [34]. Dyslipidemia, which relates to cardiopathies, was found among the secondary causes of VAD, being hypertriglyceridemia recognized as a marker of increased risk for CVDs [54].

Among its numberless functions, HDL protects LDL from lipid oxidation [55] and obese individuals move swiftly to dyslipidemias, which results in an increase of oxidative stress. Serban et al. [56] suggested that individuals with dyslipidemia presented higher levels of lipid peroxidation. With the aim of assessing the hypothesis that low concentrations of HDL interfered in the endothelial function and in lipoprotein oxidation, Toikka et al. [57] found significantly lower levels of LDL oxidized in the group with high levels of HDL when compared with low levels of HDL.

Experimental studies with genetically obese rats evidenced that serum levels of triglycerides and total cholesterol were significantly higher in animals with VAD, and a significant decrease was found in the levels of triglycerides with the supplementation of this vitamin but not in total cholesterol. The explanation given to such a finding was that, in obese individuals with VAD, an increase in the synthesis of free fatty acids and triglycerides occurs on account of the lower antioxidant protection [58].

The present study did not corroborate literature because a positive and significant correlation between retinol and triglycerides was found in T1 and T2; however, a study with diabetic children showed similar results, which the authors justified stating that, due to hypertriglyceridemia, there had been an increase in the serum concentrations of retinol as a factor of atherogenic protection [59].

With regard to β-carotene, a significant and positive correlation with HDL in T1 was found, which suggests that it exerted its protective function against LDL oxidation. This antioxidant acts as an important protector against the oxidative attack of LDL and has also been associated with the increase of HDL, as in vitro as in vivo [55–57]. Nonetheless, triglycerides, as well HDL, presented a significant and negative correlation in T3, which suggests that an increase in oxidative stress may occur in view of the possible increase in calorie intake and of the possible return to food habits and reduction in the speed of weight loss.

Thus, we can conclude that patients with class III obesity showed high percentage of VAD, which was progressive when BMI increased, a fact that may be attributed to the increase of oxidative stress on account of the chronic inflammatory condition presented by patients with obesity. The prevalence of VAD after the first 30 postoperative days increased considerably and may be related to the restriction in the intake of food sources of vitamin A and of lipids, associated with malabsorption, with the exclusion of the main site of absorption, even with a daily oral supplementation of 5,000 IU of retinol acetate. After 180 postoperative days, the progressive increase of prevalence of VAD remained even in view of significant weight loss, with a probable improvement of comorbidities and permanence of oral supplementation of 5,000 IU of retinol acetate and a possible dietary increase, which suggests that the oral intake, either of supplements or dietary, did not present the expected impact.

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