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ORIGINAL CONTRIBUTIONS

Oral Hydration, Food Intake, and Nutritional Status Before and After Bariatric Surgery

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Abstract

Background and Aims Bariatric surgery is considered to be the most effective treatment of morbid obesity. Sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGBP) are the most popular procedures. We evaluated nutritional status, micro- and macronutrient intake, and oral hydration in patients before and regularly during 1 year after RYGBP and SG.

Methods All patients that had been through bariatric surgery with at least 1-year post-surgery were retrospectively included in the study. All participants were evaluated once during the 2 months before the surgery and at 1, 3, 6, and 12 months after surgery. Clinical and biological evaluations as well as dietary investigations were performed.

Results Fifty-seven patients were included in this study (28 RYGBP and 29 SG). Patients in the RYGBP group had significantly higher body weight (132.3 ± 22 versus 122.2 ± 22.2 kg, $p = 0.039$) than patients in the SG group. Before surgery, total energy intake, oral hydration, and vitamin and mineral intakes were not different between the two groups. RYGBP and SG induced significant similar excess weight loss 1 year after surgery, 48.6 29.8% and 57.6 27.6% of body weight respectively. Energy intake significantly decreased 1 month after surgery and slightly increased from 1 to 12 months without reaching baseline intake levels. Macronutrient repartition did not change during follow-up. Oral hydration significantly decreased after RYGBP (− 58%) and showed a trend to be decreased after SG (− 49%). Sixty-five percent of patients still had vitamin D deficiency 1 year after surgery. Whatever the type of surgery, more than 20% had some vitamin deficiency 1 month after surgery.

Conclusions Calories intake decreases after bariatric surgery, whatever the type of procedure. In addition, the prevalence of vitamin deficiency is high after bariatric surgery. Lastly, oral hydration is importantly decreased after bariatric surgery, especially after RYGBP.

Keywords Obesity · Bariatric surgery · Oral hydration · Vitamin deficiency

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Introduction

The prevalence of obesity keeps increasing in industrialized countries [1]. According to a study recently published by Webber et al., Europe will face an obesity crisis of enormous proportions by 2030 [2]. Obesity is a chronic disease that predisposes to many complications, including type 2 diabetes, cardiovascular disease, several forms of cancers, and cognitive decline [3].

Bariatric surgery is considered to be the most effective long-term treatment of morbid obesity [4]. Different procedures of bariatric surgery have been developed. The adjustable gastric banding (AGA) (a restrictive adjustable reversible procedure), the sleeve gastrectomy (SG) (an irreversible restrictive procedure), and the Roux-en-Y gastric bypass (RYGBP) (a restrictive and malabsorptive reversible procedure) are the most common. The two latter procedures are nowadays the most popular both in Europe and in the USA [5]. They can induce a significant and sustained body weight loss as well as improvement of comorbidities especially type 2 diabetes [4, 6]. RYGBP is both a restrictive and malabsorptive procedure and can therefore induce vitamin and micronutrient deficiencies. Therefore, serious neurologic complications have been described after bariatric surgery in the context of vitamin deficiencies especially after RYGBP [7, 8]. However, although SG is only a restrictive procedure, there is now evidence that vitamin deficiencies can also occur after SG [9]. Only few studies have compared post-bariatric vitamin deficiency according to the type of procedure, i.e., SG or RYGBP [9]. In addition, micro- and macronutrient intake and nutritional biological status have been rarely investigated together.

Therefore, in the present study, we retrospectively recorded nutritional status, micro- and macronutrient intake, and oral hydration before and regularly up to 1 year after RYGBP and SG.

Subjects and Methods

Subjects

All patients that had been through bariatric surgery at the French Obesity Specialized care centers (CSO) of Haut Leveque Hospital, Bordeaux, with at least 1-year post-surgery follow-up were retrospectively included in the study.

RYGBP or SG was performed according to the criteria defined by international guidelines: body mass index (BMI) ≥ 40 kg/m^2 or ≥ 35 kg/m^2 with at least one severe obesity-related comorbidity [10]. Patients had to follow a multidisciplinary program with psychologists, physiotherapists, and dieticians group sessions in addition to medical doctor's visits for at least 6 months before surgery. The decision of surgery was systematically discussed and approved by a multidisciplinary staff. The type of procedure was decided taking into account the patient's BMI, comorbidities and treatments, history of obesity, and the patient's choice.

All participants were evaluated once during the 2 months before the surgery and at month 1 (M1), M3, M6, and M12 after surgery. Clinical and biological evaluations as well as dietary investigations were performed.

Clinical and Dietary Assessments

Body weight (kg) and height (m) were collected in order to calculate BMI (BMI (kg/m^2) as body weight (kg) divided by height (m) squared).

Evaluation of food intake was based on 7-day food records. All foods and beverage consumed at breakfast, lunch, dinner, and snacks were recorded. An album with pictures of food-portion sizes was used to increase the accuracy of the food-intake estimates. Daily energy intake, proteins, carbohydrate and fat intake, and micronutrients (vitamins and minerals) were estimated by BILNUT software [11]. Oral hydration was estimated from the addition of water included in food and consumption of beverages.

Whatever the type of surgery, all patients systematically received a multivitamin supplementation with two tablets per day of SURGILINE® (one tablet contains 7 mg iron, 0.3 mg vitamin A, 0.0015 mg vitamin B_{12}, 0.1 mg folic acid, 1.25 mg vitamin B_1, 3 mg vitamin B_5, 1 mg vitamin B_6, 0.005 mg vitamin D_3, 9 mg vitamin E, 60 mg vitamin C, 150 mg magnesium, 6 mg zinc, 0.025 mg selenium, 0.01 mg chrome, 4.5 mg vitamin PP). Additionally, patients had a personalized supplementation according to the results of their blood exams. Supplementations in vitamins (preventive or curative) were not included in the calculation of micronutrients.

Surgical Procedures

All surgical procedures were performed laparoscopically by the same surgeon. RYGBP consisted of the creation of a 15–20-ml gastric pouch, a 150-cm Roux limb, and a 50-cm biliopancreatic limb. SG involved a gastric-volume reduction from 75 to 80% by resecting the stomach alongside a 30-French tube beginning 3 cm from the pylorus and ending at the angle of His.

Biochemical Analysis

Blood samples were collected after an overnight fast to measure biochemical parameters before and at 1 (M1), 3(M3), 6 (M6), and 12 (M12) months after surgery. Magnesium and iron were assessed by colorimetry after enzymatic reaction. Vitamins B_1, B_6, A, and E were assessed using high-pressure liquid chromatography. Vitamins B_9, B_{12}, and D, parathyroid hormone (PTH), and ferritin were assessed by chemiluminescent assay. Zinc and selenium were assessed using atomic absorption spectrometry.

Vitamin deficiencies were defined as serum concentrations below 30 ng/ml for vitamin D and as concentrations below the lower value of the normal range of the laboratory for the other vitamins.

Statistical Analysis

Quantitative data were presented with means and standard derivations whereas qualitative data were presented with percentages.

Due to the small sample size, the Wilcoxon test was used to compare paired data of patients from a same group between two times of evaluation. In order to compare the two groups of patients, the Mann-Whitney test has been used whereas the Friedman test has been used for multiple comparisons within each group. Data analyses were performed with STATA 13.1 software.

p values less than 0.05 were considered statistically significant.

Results

Baseline

Fifty-seven patients were included in this study (28 RYGBP and 29 SG). The two groups of patients were similar regarding age (42.9 ± 11 versus 45.2 ± 9.2 years respectively, NS). Patients in the RYGBP group had significant higher body weight (132.3 ± 22 versus 122.2 ± 22.2 kg, $p = 0.039$) and BMI (46.8 ± 6.9 versus 44.1 ± 9.4 kg/m^2, $p = 0.02$) than patients in the SG group. Before surgery, total energy intake and oral hydration were not different between the two groups (Table 1). Patients in the RYGBP group ate fewer proteins than patients in the SG group before surgery. They also tended to eat more lipids (Table 1). Vitamin and mineral intakes were similar between the two groups except for sodium, phosphorus, and iron (Table 1). Vitamin deficiencies were equally present in both groups before bariatric surgery (BS) except for vitamin B_{12} deficiency that was more prevalent in RYGBP patients (Table 2).

Table 1 Intakes at baseline before sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGBP). Results are expressed in mean ± SD

	RYGBP (*N* = 17)	SG (*N* = 21)	*p* value
Caloric intake (kcal/jr)	1829.2 ± 394.1	1933 ± 494.8	0.6145
Carbohydrates (%)	45.2 ± 5.7	45.5 ± 6	0.9999
Fat (%)	36.9 ± 3.8	33.7 ± 6	0.0675
Proteins (%)	18.5 ± 3.1	20.8 ± 3.3	0.0406
Oral hydration (g)	2193.6 ± 672.1	2175.9 ± 905.8	0.6144
Fibers (g)	22.1 ± 6.6	24.5 ± 7.8	0.4187
Cholesterol (mg)	293.2 ± 112.3	285 ± 58.4	0.6137
Sodium (mg)	1469.2 ± 532.6	1972.5 ± 693.7	0.0172
Potassium (mg)	3383.2 ± 841.3	3886.8 ± 1028.5	0.1478
Magnesium (mg)	271.4 ± 84.7	308.7 ± 71.3	0.0706
Phosphorus (mg)	1269.6 ± 221.6	1492.2 ± 340.3	0.0494
Calcium (mg)	911.2 ± 247.9	1094.8 ± 371	0.1394
Iron (mg)	9.9 ± 1.85	21.7 ± 44.7	0.0554
Zinc (mg)	7.56 ± 2.8	9.25 ± 4.2	0.1611
Vitamin A (μg)	295.9 ± 134	243.2 ± 105.2	0.2532
Carotene (μg)	865.4 ± 462.6	992.6 ± 407.7	0.3078
Vitamin B_1 (mg)	1.34 ± 2.24	1.45 ± 2.72	0.6981
Vitamin B_6 (mg)	0.72 ± 0.26	0.88 ± 0.31	0.1462
Folic acid (mg)	257.1 ± 74.4	289.8 ± 73.9	0.1747
Vitamin B_{12} (μg)	1.39 ± 0.67	1.37 ± 1.1	0.5265
Vitamin C (mg)	110.5 ± 44.3	122.3 ± 46.5	0.3608
Vitamin E (mg)	6.66 ± 5.2	7.1 ± 4	0.4996
Vitamin PP (mg)	5.4 ± 2.19	7 ± 3.5	0.0961
Vitamin B_5 (mg)	2.92 ± 0.9	2.8 ± 0.77	0.9459

Post-operative Follow-up

Roux-en-Y Gastric Bypass

Twenty-five patients (89%) completed the first month of follow-up after RYGBP, 25 (89%) completed 3 months of follow-up, 25 (89%) 6 months of follow-up, and 26 (93%) 12 months of follow-up.

RYGBP induced significant excess weight loss with a mean weight loss of 48.6 29.8% of body weight 1 year after surgery. Energy intake significantly decreased at M1 and slightly increased from M1 to M12 without reaching baseline intake levels (Table 3). Macronutrient repartition did not change during follow-up. Oral hydration

Table 2 Biological characteristics at baseline before sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGBP). Results are expressed in mean ± SD. Number and percentage of patients whose blood concentrations are below. The lower value of the normal range of the laboratory are given. *PTH* parathyroid hormone

RYGBP	RYGBP (*n* = 28)	SG (*n* = 29)	*p value*
Vitamin B_1 (nmol/l)	135.8 ± 20.25	122.9 ± 40.5	0.337
<66.5 nmol/l, *N* (%)	0 (0)	1 (3.8)	
Vitamin B_6 (nmol/l)	46.5 ± 71.3	45.2 ± 36.1	0.347
< 20 nmol/l, *N* (%)	6 (24)	3 (11.5)	
Folic acid (ng/ml)	8.2 ± 5.6	8.4 ± 8.3	0.865
< 3 ng/ml, *N* (%)	0 (0)	0 (0)	
Vitamin B_{12} (ng/ml)	286.4 ± 126.7	370.7 ± 170	0.049
< 180 ng/ml, *N* (%)	4 (16)	1 (4.3)	
Vitamin A (μmol/l)	1.83 ± 0.48	1.78 ± 0.43	0.854
< 1.2 μmol/l, *N* (%)	1 (4)	2 (7.7)	
Vitamin E (μmol/l)	27.6 ± 5.53	29.7 ± 6.7	0.229
< 10 μmol/l, *N* (%)	0 (0)	0 (0)	
Vitamin D (ng/ml)	17.8 ± 7.6	22.4 ± 10.9	0.088
< 30 ng/ml, *N* (%)	22 (91.7)	19 (73)	
PTH (pg/ml)	50.5 ± 15.3	55.6 ± 26.6	0.866
> 88 pg/ml, *N* (%)	1 (4.2)	2 (7.7)	
Magnesium (nmol/l)	0.79 ± 0.06	0.8 ± 0.07	0.699
< 0.65 nmol/l, *N* (%)	0 (0)	0 (0)	
Iron (μmol/l)	13.8 ± 6.1	13.4 ± 5.2	0.892
< 8 μmol/l, *N* (%)	2 (9.1)	4 (16.7)	
Ferritin (μg/l)	86.1 ± 85.5	120.4 ± 123.8	0.155
< 24 μg/l, *N* (%)	1 (4)	3 (11.5)	
Zinc (μmol/l)	13.4 ± 1.58	13.5 ± 1.68	0.928
< 12 μmol/l, *N* (%)	1 (4)	3 (11.5)	
Selenium (μmol/l)	0.98 ± 0.13		0.189
< 0.75 μmol/l, *N* (%)	1 (4)		

Table 3 Calories intake, macronutrient repartition, and oral hydration before and after RYGBP (results are expressed in mean ± SD). *M1* 1 month after procedure, *M3* 3 months after procedure, *M6* 6 months after procedure, *M12* 12 months after procedure

RYGBP	Baseline $n = 28$	M1 $n = 25$	M3 $n = 25$	M6 $n = 25$	M12 $n = 26$	p value
Caloric intakes (kcal/day)	1829.2 ± 394.1	669.1 ± 176	890.7 ± 217	1048 ± 261	1231 ± 158	0.0001
Carbohydrates (%)	45.2 ± 5.7	42.9 ± 6.5	42.9 ± 7	42.7 ± 7.8	41.9 ± 5.5	0.7241
g/day	206	72	95	112	129	
Fat (%)	36.9 ± 3.8	32.7 ± 6.6	34.4 ± 6.7	36.7 ± 6.9	36.7 ± 8.8	0.3789
g/day	75	24	34	43	50	
Proteins (%)	18.5 ± 3.1	24.4 ± 5.9	22.3 ± 4.8	20.7 ± 3.9	21.4 ± 4.6	0.1468
g/day	84	41	49	54	66	
Oral hydration (ml/day)	2193.6 ± 672.1	920.9 ± 536.8	1023 ± 683	1290 ± 940	1458 ± 652	0.0311

significantly decreased with a reduction of 58% on M1. Then, it slightly increased from M1 to M12 without reaching baseline (Table 3). Micronutrient intakes had the same pattern (Table 4). Vitamin D supplementation allowed a significant increase in vitamin D level at M3 that slightly decreased at M6 and M12. Sixty-five percent of patients still had vitamin D deficiency 1 year after RYGBP. Regarding other nutritional deficiencies, 5 (20%) patients had vitamin A deficiency and 5 (20%) others had selenium deficiency 1 month after surgery. Iron deficiency progressively increases during follow-up with 4 patients having an iron deficiency at M1 and 9 patients at M12.

Sleeve Gastrectomy

Twenty-eight patients (96.5%) completed the first month of follow-up after bariatric surgery, 20 (69%) completed the 3 months of follow-up, 25 (89%) the 6 months of follow-up, and 28 (96.5%) came to 12 months of follow-up. SG induced significant weight loss with a mean excess weight loss of 57.6 27.6% of body weight 1 year after surgery. Energy intake significantly decreased at M1 and slightly increased from M1 to M12 without reaching baseline intake levels (Table 5). Macronutrient repartition did not change during follow-up. Oral hydration tended to decrease after SG with a reduction of 49.6% 1 month after surgery. It then slightly increased from M3 to M12, without reaching baseline (Table 5). Micronutrient intakes had the same pattern. Despite a vitamin D supplementation, 64.2% of patients still had vitamin D deficiency 1 year after surgery. Concerning other nutritional parameters, 8 (28.5%) patients had vitamin B_6 deficiency, 6 (21.4%) had vitamin A deficiency, and 4 (14.3%) had selenium deficiency 1 month after surgery. Iron deficiency was present for 7 (25.0%) patients at M3 and for 8 patients (28.5%) at M12. Vitamin B_{12} and zinc deficiencies were maximal at M12 with 4 (14.3%) and 7 patients (25.0%) respectively (Table 6).

Comparison Between Gastric Bypass and Sleeve Gastrectomy

No significant difference was found between the two surgical techniques regarding body weight loss ($p = 0.1341$). Energy intake was similar in the two groups of patients during the follow-up (M0, M1, M3, M6, M12). However, 1 year after surgery, patients with RYGB ate significantly less carbohydrate compared with those who had SG (41.9 ± 5.5%/day versus 46.7 ± 6.6%/day, $p = 0.028$) while they tended to eat more lipids (36.7 ± 8.8%/day versus 33.5 ± 4.6%/day, $p = 0.061$). In addition, patients that had been through RYGBP had more important cholesterol intake per day (209 ± 43 mg/day versus 159 ± 54 mg/day, $p = 0.0292$).

Patients that had been through RYGBP had significantly more protein intake (41 g/day versus 37 g/day, $p = 0.004$). Independently of the type of surgery, both groups of patients had similar intake for most of vitamins and minerals. Patients issued from the RYGBP tended to have less oral hydration than patients with SG at M3 (RYGBP 1023 ± 683 g/day versus SG 1323 ± 617 g/day, $p = 0.08$). There were no significant differences between the two groups for individual supplementation at any time of the follow-up.

Discussion

This observational study allowed a report of oral hydration, calories intake, and macronutrient and micronutrient intake and repartition before and at regular time points during the first year after RYGBP and SG.

To our knowledge, this is the first study evaluating changes of oral hydration after bariatric surgery. In addition, none of the previous studies compared all the mandatory follow-up points during the first year post-operatively, i.e., 1, 3, 6, and 12 months after surgery [8, 9].

We have shown that oral hydration significantly decreased after bariatric surgery, especially after RYGBP and to a fewer extent after SG. Several mechanisms can be involved in this

Table 4 Micronutrient values (mean ± SD) and micronutrient deficiency before and after RYGBP (results are expressed in mean ± SD). *M1* 1 month after procedure, *M3* 3 months after procedure, *M6* 6 months after procedure, *M12* 12 months after procedure, *PTH* parathyroid hormone

RYGBP	Baseline $n = 28$	M1 $n = 25$	M3 $n = 25$	M6 $n = 25$	M12 $n = 26$	p value
Vitamin B_1 (nmol/l)	135.8 ± 20.25	113.3 ± 27.2	127.2 ± 36	148.2 ± 34.3	163.4 ± 38.3	0.008
< 66.5 nmol/l, N (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Vitamin B_6 (nmol/l)	46.5 ± 71.3	39.8 ± 25.9	63.9 ± 60.2	79.3 ± 67.6	92.4 ± 62.0	0.0001
< 20 nmol/l, N (%)	6 (24)	6 (24)	3 (12)	2 (8)	0 (0)	
Folic acid (ng/ml)	8.2 ± 5.6	7.9 ± 3.7	9.6 ± 6.7	9.9 ± 5.6	10.6 ± 5.5	0.19
< 3 ng/ml, N (%)	0 (0)	0 (0)	1 (4)	0 (0)	1 (4.2)	
Vitamin B_{12} (ng/ml)	286.4 ± 126.7	385 ± 192.6	356 ± 195	319 ± 128	288 ± 97	0.0005
< 180 ng/ml, N (%)	4 (16)	1 (4)	2 (8)	0 (0)	4 (16)	
Vitamin A (μmol/l)	1.83 ± 0.48	1.47 ± 0.4	1.45 ± 0.4	1.47 ± 0.29	1.52 ± 0.39	0.0043
< 1.2 μmol/l, N (%)	1 (4)	5 (20)	4 (16)	2 (8.3)	2 (8.3)	
Vitamin E (μmol/l)	27.6 ± 5.53	22.2 ± 4.1	23.8 ± 5	23.5 ± 4.8	31.1 ± 29.2	0.0006
< 10 μmol/l, N (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Vitamin D (ng/ml)	17.8 ± 7.6	27.3 ± 9.4	34.8 ± 10.8	28.5 ± 8.3	26.3 ± 6.1	0.0001
< 30 ng/ml, N (%)	22 (91.7)	16 (64)	7 (28)	15 (62.5)	17 (65.4)	
PTH (pg/ml)	50.5 ± 15.3	49.4 ± 14.6	51.1 ± 15.9	49.6 ± 14.0	46.8 ± 16.9	0.17
> 88 pg/ml, N (%)	1 (4.2)	0 (0)	0 (0)	0 (0)	1 (3.8)	
Magnesium (nmol/l)	0.79 ± 0.06	0.81 ± 0.057	0.82 ± 0.078	0.82 ± 0.07	0.81 ± 0.045	0.022
< 0.65 nmol/l, N (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Iron (μmol/l)	13.8 ± 6.1	12.3 ± 5.4	13.8 ± 5.0	15.4 ± 7.3	18.07 ± 6.2	0.41
< 8 μmol/l, N (%)	2 (9.1)	4 (16)	1 (4)	3 (12.5)	1 (3.8)	
Ferritin (μg/l)	86.1 ± 85.5	136.8 ± 170	95.9 ± 95.5	74.5 ± 71.6	62.6 ± 58.5	0.0008
< 24 μg/l, N (%)	1 (4)	4 (16)	4 (16)	8 (33.3)	9 (34.6)	
Zinc (μmol/l)	13.4 ± 1.58	14.1 ± 3.6	12.3 ± 1.35	12.6 ± 1.61	12.8 ± 1.8	0.25
< 12 μmol/l, N (%)	1 (4)	2 (8)	9 (36)	6 (25)	4 (15.4)	
Selenium (μmol/l)	0.98 ± 0.13	0.88 ± 0.25	0.93 ± 0.127	0.96 ± 0.16	1.05 ± 0.25	0.54
< 0.75 μmol/l, N (%)	1 (4)	5 (20)	1 (4)	8 (8.3)	1 (3.8)	

reduction of oral hydration. First of all, it is noteworthy that gastric volume is dramatically reduced after RYGBP with changes of gut hormone secretion leading to a more rapid sensation of gastric fullness than can clearly impact liquid consumption [12]. Moreover, vomiting can affect one third to two thirds of patients most commonly during the first few post-operative months and can decrease appetence both for food and liquid intakes [13–15]. Besides the deleterious effect of vomiting on food intake and hydration, it must be kept in mind that frequent vomiting may suggest obstruction, reflux, inflammation, erosion/ulceration, or stenosis necessitating specific care [16]. Finally, it is possible that the usual counseling provided after bariatric surgery may neglect oral hydration. Indeed, most of the diet counseling does not include specific advices about fluid intake, or diverging advices are given [17, 18]. When water intake is mentioned, sip administration of water at distance of meals is recommended that can maybe not encourage adequate hydration [19].

Severe post-surgery decline of oral hydration can have serious consequences. For instance, Aman et al. studied early hospital readmission within 30 days after bariatric surgery in a cohort of 36,042 patients. Dehydration was the third reason of readmission (10.54%) just after nausea/vomiting (12.95%) and abdominal pain (11.75%) [20]. Indeed, bariatric surgery has been linked to a higher incidence of post-operative new-onset nephrolithiasis that can be worsened by low hydration [21, 22]. In the context of the growing prevalence of obesity, bariatric surgery now concerns patients with additional serious diseases, including kidney insufficiency, or even obese patients after kidney transplantation [23]. In this context, decreased oral hydration can induce really serious damages like acute kidney insufficiency [24]. Further nutritional guidelines post-bariatric surgery should pay attention to hydration advices, particularly considering that recent data suggest that water with food intake does not influence caloric intake after gastric bypass [18].

Interestingly, we have shown that patients who had been through RYGBP ate significantly less carbohydrates and tend to eat more lipids compared with those who have been through SG 1 year after surgery. Similarly, patients that have been through RYGB had a higher daily cholesterol intake. Indirect and direct measurements of eating behavior in both humans and rodents suggest that food selection does indeed change after BS mostly with a reduction in the preference for food high in sugar and fat [25]. However, using for the first time an ad libitum buffet meal in post-bariatric patients,

Table 5 Intakes and macronutrient assessment following SG (results are expressed in mean ± SD). *M1* 1 month after procedure, *M3* 3 months after procedure, *M6* 6 months after procedure, *M12* 12 months after procedure

Sleeve gastrectomy	Baseline ($n = 29$)	M1 ($n = 28$)	M3 ($n = 20$)	M6 ($n = 25$)	M12 ($n = 28$)	p value
Caloric intakes (kcal/day)	1933 ± 494.8	748 ± 170	943.2 ± 192	1005 ± 272	1204 ± 271	0.0001
Carbohydrates (%)	45.5 ± 6	46.5 ± 11.3	43.3 ± 9	43.6 ± 6	46.7 ± 6.6	0.47
g/day	220	87	102	109	140	
Fat (%)	33.7 ± 6	33.7 ± 9.8	36.3 ± 7.8	35.7 ± 6	33.5 ± 4.6	0.4201
g/day	72	28	38	40	45	
Proteins (%)	20.8 ± 3.3	19.9 ± 3.4	20.5 ± 4	20.7 ± 2.8	20 ± 3.1	0.7713
g/day	100	37	48	52	60	
Total hydration (ml/day)	2175.9 ± 905.8	1095.9 ± 536	1323 ± 617	1181 ± 527	1264 ± 677	0.0933

Nielsen et al. did not see any changes in intake of food from pre-defined food categories and no changes in energy density following bariatric surgery [26]. On the contrary, measuring food preferences by means of verbal report, they found an increased preference for low-fat savory foods following surgery, in line with post-operative dietary guidelines. Therefore, the authors underline the necessity of including methods targeting direct behaviors and that do not exclusively rely on verbal report measures. Using verbal reports, patients from our study reported a higher intake of lipids. This is not in the dietary guidelines after bariatric surgery. Therefore, we can suggest that they report accurate and actual behavior. One proposed mechanism for changes in food preferences after surgical treatment includes a learned restrictive behavior linked to experiences of unpleasant post-ingestive responses after intake of especially high-fat and sugary food [27]. Dumping syndrome is more frequent after RYGBP, and decreasing carbohydrate intake while increasing proteins as well as fats may elicit fewer symptoms [28]. Although we did not record dumping syndrome in our study, we suggest that

Table 6 Micronutrient values (mean ± SD) and micronutrient deficiency before and after SG (results are expressed in mean ± SD). *M1* 1 month after procedure, *M3* 3 months after procedure, *M6* 6 months after procedure, *M12* 12 months after procedure

Sleeve gastrectomy	Baseline ($n = 29$)	M1 ($n = 28$)	M3 ($n = 20$)	M6 ($n = 25$)	M12 ($n = 28$)	p value
Vitamin B_1 (nmol/l)	122.9 ± 40.5	99.4 ± 28.3	117 ± 34.6	118 ± 21.5	128.9 ± 39.2	0.033
< 66.5 nmol/l, *N* (%)	1 (3.8)	0 (0)	0 (0)	0 (0)	1 (3.6)	
Vitamin B_6 (nmol/l)	45.2 ± 36.1	35.3 ± 23.7	45.4 ± 35.6	70.5 ± 85.3	50.2 ± 19.9	0.134
< 20 nmol/l, *N* (%)	3 (11.5)	8 (30.8)	3 (15)	3 (12)	1 (3.6)	
Folic acid (ng/ml)	8.4 ± 8.3	7.2 ± 4.7	5.1 ± 2.5	6.4 ± 5.3	6.5 ± 3.17	0.025
< 3 ng/ml, *N* (%)	0 (0)	1 (4)	2 (10.5)	2 (8.3)	1 (3.6)	
Vitamin B_{12} (ng/ml)	370.7 ± 170	390 ± 144	329 ± 137	295 ± 135	327 ± 169	0.0045
< 180 ng/ml, *N* (%)	1 (4.3)	0 (0)	2 (10.5)	2 (8.3)	4 (14.3)	
Vitamin A (μmol/l)	1.78 ± 0.43	1.49 ± 0.41	1.53 ± 0.48	1.48 ± 0.36	1.66 ± 0.41	0.0099
< 1.2 μmol/l, *N* (%)	2 (7.7)	6 (24)	3 (17.6)	6 (24)	3 (11.1)	
Vitamin E (μmol/l)	29.7 ± 6.7	23.8 ± 5.6	27.5 ± 5.9	27.1 ± 4.92	27.2 ± 5.6	0.196
< 10 μmol/l, *N* (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Vitamin D (ng/ml)	22.4 ± 10.9	25.1 ± 9	32.3 ± 13.9	31.4 ± 10.4	25.7 ± 5.7	0.0116
< 30 ng/ml, *N* (%)	19 (73)	20 (74.1)	10 (50)	13 (52)	18 (66.7)	
PTH (pg/ml)	55.6 ± 26.6	57.7 ± 26.5	49 ± 20.5	46.5 ± 19.0	51.3 ± 22.7	0.149
> 88 pg/ml, *N* (%)	2 (7.7)	4 (14.8)	1 (5)	1 (4)	2 (7.4)	
Magnesium (nmol/l)	0.8 ± 0.07	0.82 ± 0.076	0.84 ± 0.07	0.83 ± 0.066	0.83 ± 0.05	0.11
< 0.65 nmol/l, *N* (%)	0 (0)	1 (3.7)	0 (0)	0 (0)	0 (0)	
Iron (μmol/l)	13.4 ± 5.2	12 ± 4.1	12.8 ± 3.8	14.5 ± 5.9	16.9 ± 7.15	0.65
< 8 μmol/l, *N* (%)	4 (16.7)	3 (11.1)	1 (5.3)	3 (12.5)	1 (3.6)	
Ferritin (μg/l)	120.4 ± 123.8	128.9 ± 105.7	57.9 ± 57	96.5 ± 98.4	73.2 ± 64.4	0.0001
< 24 μg/l, *N* (%)	3 (11.5)	2 (7.4)	7 (36.8)	3 (12.5)	8 (28.6)	
Zinc (μmol/l)	13.5 ± 1.68	14.6 ± 4.7	13.2 ± 1.78	11.9 ± 1.24	13.1 ± 1.69	0.47
< 12 μmol/l, *N* (%)	3 (11.5)	3 (11.5)	2 (10)	8 (32)	7 (25)	
Selenium (μmol/l)	1.05 ± 0.18	0.87 ± 0.17	0.94 ± 0.14	0.89 ± 0.15	0.94 ± 0.15	0.0064
< 0.75 μmol/l, *N* (%)	2 (7.7)	4 (15.4)	1 (5)	3 (12.5)	2 (7.1)	

dumping syndrome could explain the higher intake of fat. The increase in fat intake reported in patients that have been through RYGB may lead to weight regain after bariatric surgery. Therefore, it is really mandatory to recognize symptoms of dumping syndrome and to make the patients aware of these symptoms. The main dietary modifications to manage dumping syndrome like reducing the amount of food consumed at each meal, have to be explained to patients in order to avoid that they develop strategies that could induce weight regain [29].

As previously reported, our patients were already suffering from several vitamin deficiencies before bariatric surgery with a huge percentage of patients (82%) suffering vitamin D deficiency [30]. 25OH vitamin D deficiency is known to be 35% more frequent in obese compared with normal weight subjects [31, 32]. Indeed, obese people do usually have low solar exposition, and metabolites of vitamin D are trapped in adipose tissue [31].

Vitamin B_6 and B_{12} and iron deficiencies were also present before surgery. The notion that despite excess of fat mass, obese patients have often vitamin deficiencies is now well known [33]. The underlying mechanisms of vitamin deficiencies in patients with obesity are multiple. Patients with obesity usually have low fruit and vegetable intake, and they are more prone to eat food with high caloric density, especially in the context of poor dental status [33].

After bariatric surgery, vitamin deficiencies were still diagnosed despite polyvitamin supplementation. Vitamin D deficiency was still highly prevalent. This might be related to an imperfect compliance. However, the quality of the evidence for the dosing and regimens of vitamin D deficiency recommended is still limited [34]. Of note, in the context of vitamin D deficiency poorly corrected, adequate hydration is one more time mandatory to minimize the risk of stone precipitation. Iron and zinc deficiencies were also frequent after both types of surgery. Serious neurological complications [35, 36] and malnutrition requiring artificial nutrition have been described after SG [37]. Aron-Wisnewsky et al. even described vitamin deficiencies after AGA [8].

Although some degrees of error in food records are known from long time ago, these results emphasize the fact that regular follow-ups of patients after BS are mandatory whatever the type of procedure [38]. In addition, none of the patients of the series were affected by serious complications or morbidities that could have affected food intake after BS. In addition, all of the patients had a dental evaluation before BS to be sure that mastication was correct to prevent malnutrition as much as possible.

Although our series was small, adhesion to follow-up was quite good. Therefore, among the 57 patients included, 53 came at M1, 45 at M3, 50 at M6, and 54 at M12. Consequently, there were a low number of patients lost at follow-up compared with previous studies [8]. The creation of CSO has allowed building specialized teams to take care of these patients all along the process before and after surgery and to create a strong link between patients and staff that may decrease the risk of lost at follow-up [39].

Our results confirm that calories intake is really low after BS, whatever the type of the procedure. In addition, the prevalence of vitamin deficiency is high after BS despite supplementation. Lastly, oral hydration is strongly decreased after BS and this can lead to complications. Therefore, oral hydration really needs to be included in the usual monitoring after BS.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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