Nutritional deficiencies after Roux-en-Y gastric bypass for morbid obesity often cannot be prevented by standard multivitamin supplementation\(^1,2\)

**Christoph Gasteyger, Michel Suter, Rolf C Gaillard, and Vittorio Giusti**

**ABSTRACT**

**Background:** Despite the increasing use of Roux-en-Y gastric bypass (RYGBP) in the treatment of morbid obesity, data about postoperative nutritional deficiencies and their treatment remain scarce.

**Objective:** The aim of this study was to evaluate the efficacy of a standard multivitamin preparation in the prevention and treatment of nutritional deficiencies in obese patients after RYGBP.

**Design:** This was a retrospective study of 2 y of follow-up of obese patients after RYGBP surgery. Between the first and the sixth postoperative months, a standardized multivitamin preparation was prescribed for all patients. Specific requirements for additional substitutive treatments were systematically assessed by a biologic workup at 3, 6, 9, 12, 18, and 24 mo.

**Results:** A total of 137 morbidly obese patients (110 women and 27 men) were included. The mean (±SD) age at the time of surgery was 39.9 ± 10.0 y, and the body mass index (in kg/m\(^2\)) was 46.7 ± 6.5. Three months after RYGBP, 34% of these patients required at least one specific supplement in addition to the multivitamin preparation. At 6 and 24 mo, this proportion increased to 59% and 98%, respectively. Two years after RYGBP, a mean amount of 2.9 ± 1.4 specific supplements had been prescribed for each patient, including vitamin B-12, iron, calcium + vitamin D, and folic acid. At that time, the mean monthly cost of the substitutive treatment was $34.83.

**Conclusion:** Nutritional deficiencies are very common after RYGBP and occur despite supplementation with the standard multivitamin preparation. Therefore, careful postoperative follow-up is indicated to detect and treat those deficiencies. *Am J Clin Nutr* 2008;87:1128–33.

**INTRODUCTION**

The growing prevalence of obesity (1), combined with the absence of effective conservative treatment (2) and probably with the development of laparoscopic surgery, has led to a significant increase in the number of bariatric surgical procedures performed each year in most Western countries (3). Bariatric surgery has been shown to produce effective and sustainable weight loss, which in turn results in improvement of obesity-related comorbidities, of quality of life, and of survival (4).

Gastric banding and Roux-en-Y gastric bypass (RYGBP) are currently the most commonly performed surgical procedures for morbid obesity [body mass index (BMI; in kg/m\(^2\)) >40] (3). Laparoscopic gastric banding is a purely restrictive procedure. It has a low operative morbidity but is associated with a substantial rate of late complications and failure (5, 6). Laparoscopic RYGBP is essentially restrictive, but in contrast with gastric banding, it is associated with nutritional deficiencies and has a higher operative morbidity (7). However, it represents the procedure of choice for many surgeons (8, 9) because it induces greater weight loss with better food tolerance.

After RYGBP, careful follow-up is needed to detect and correct nutritional deficiencies. Unfortunately, data about the type and the frequency of these postoperative deficiencies remain scarce (10, 11).

The aims of this retrospective study were 1) to assess the type, frequency, and pattern of development of nutritional deficiencies over the first 24 mo after RYGBP, 2) to determine the amount of supplements prescribed to each patient, and 3) to evaluate the cost of the substitutive treatment.

This information is important to standardize postoperative follow-up and to define which type of nutritional substitution has to be prescribed after RYGBP. It will allow a reduction of the frequency and the consequences of nutritional deficiencies and a decrease in health care–related costs.

**SUBJECTS AND METHODS**

**Screening of medical records and patient selection**

This study was a retrospective analysis of medical records of obese patients who underwent bariatric surgery by RYGBP at our center. Only patients who complied with our follow-up schedule (see below) during the first 2 y after surgery were included. We excluded from our analysis 1) patients who underwent RYGBP secondarily after having previously undergone another bariatric procedure, 2) patients who were lost to follow-up or who attended <4 of the planned medical visits during the first 2 y after RYGBP, 3) patients whose blood analyses were performed in outside laboratories, 4) patients who became pregnant during the first 2 y after RYGBP, and 5) patients who were treated with nutritional supplements before RYGBP.

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Surgical technique

The surgical technique was described in detail elsewhere (7). The length of the Roux-en-Y limb was determined by the patient’s BMI; it was 100 cm for those with BMI ≤ 48.0 and 150 cm for those with BMI > 48.0. Cholecystectomy was performed if gallstones were present and in many of the remaining patients as prophylaxis against the occurrence of gallstones during rapid weight loss. All patients included in the analysis were operated on between November 1999 and June 2004.

Clinical and biologic follow-up

Every patient met a physician of our team at least once before surgery; after surgery, they were seen every 3 mo during the first postoperative year and at 6-mo intervals during the second year. Height was measured at the preoperative consultation with the use of a stadiometer. At each consultation, body weight was measured using a Detecto scale (Detecto, Webb City, MO), and BMI was calculated. The percentage of excess body weight was calculated according to the ideal body weight (12).

At each postoperative consultation, a nonfasting blood sample was drawn. Measurements included total and corrected calcium, albumin, parathyroid hormone, 25-hydroxyvitamin D, iron, ferritin, folic acid, erythrocytic magnesium, zinc, and vitamin B-1, B-6, and B-12 concentrations and a complete blood count. All biochemical analyses were performed by certified laboratories (ISO CEI 17025) and run in duplicate or triplicate samples. Normal reference ranges and techniques used by our laboratory for the measurement of several vitamins and micronutrients mentioned above are shown in Table 1.

Substitutive treatment

A standardized multivitamin preparation was prescribed for all patients between the first and the sixth postoperative months. It contained the following daily amounts of vitamins and minerals: 800 μg vitamin A, 4.2 mg vitamin B-1, 4.8 mg vitamin B-2, 6 mg vitamin B-6, 3 μg vitamin B-12, 180 mg vitamin C, 5 μg vitamin D-3, 10 mg vitamin E, 30 μg vitamin K, 0.45 mg vitamin H, 0.6 mg folic acid, 54 mg nicotinamide, 18 mg pantothenic acid, 120 mg Ca, 25 μg Cr, 8 mg Fe, 1.5 mg F, 75 μg I, 0.9 mg Cu, 45 mg Mg, 1.8 mg Mn, 45 μg Mo, 126 mg P, 55 μg Se, and 8 mg Zn.

Specific substitutive treatments were prescribed as soon as the value measured in a given patient was below the lower value of the reference range for folic acid, magnesium, vitamin B-1, vitamin B-6, vitamin B-12, and zinc. Calcium and vitamin D-3 were prescribed when corrected calcium or 25-hydroxyvitamin D concentrations were below the lower value of the reference range or when the parathyroid hormone concentration was higher than the higher value of the reference range. Iron was prescribed when either the iron or ferritin concentration was below the lower normal reference value. If a specific substitution was started, the patient was considered deficient in that particular nutrient/hormone for the rest of the follow-up, because discontinuation of the treatment generally leads to reemergence of the deficit.

Nutritional supplements usually were prescribed orally at the following doses: vitamin B-12, 1 mg/mo; iron, 80 mg/d; calcium, 1000 mg/d; vitamin D-3, 0.02 mg/d; folic acid, 1 mg/d; zinc, 5 mg/d; vitamin B-1, 100 mg/d; vitamin B-6, 40 mg/d; and magnesium, 100 mg/d. These doses were then adapted individually according to routine laboratory checks. When no satisfactory response (assessed by laboratory analyses) was obtained, the doses were increased. Vitamin B-12 was always administered intramuscularly, and iron was given intravenously when a satisfactory response to the oral treatment could not be obtained.

Cost of substitutive treatments

Swiss prices as published on the Swiss Compendium website (13) were used to calculate treatment costs, and then converted to US dollars (14). Of note, the cost of intramuscular or intravenous administration was not included in our evaluation.

Statistical analyses

Data are shown as means ± SD. Paired t tests were used for intragroup comparisons, and nonpaired t tests were used for intergroup comparisons. A two-tailed Fisher’s exact test was used for comparison of proportions. Simple bivariate analysis was performed by use of the 2-tailed Pearson correlation coefficient test. The significance level was defined as P < 0.05. SPSS version 15.0 (SSPS, Inc, Chicago, IL) was used for all statistical analyses.

### Table 1
Normal reference ranges and measurement techniques used by our laboratory

<table>
<thead>
<tr>
<th>Nutrient/Supplement</th>
<th>Reference range</th>
<th>Measurement technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected calcium</td>
<td>2.1–2.5 (mmol/L)</td>
<td>o-Cresolphthaleine</td>
</tr>
<tr>
<td>Parathormone (intact)</td>
<td>10–70 (ng/L)</td>
<td>Chemiluminescence</td>
</tr>
<tr>
<td>25-Hydroxyvitamin D</td>
<td>8.4–52.3 (μg/L)</td>
<td>Radioimmunoassay</td>
</tr>
<tr>
<td>Folic acid</td>
<td>&gt;6.8 (mmol/L)</td>
<td>Chemiluminescence</td>
</tr>
<tr>
<td>Iron</td>
<td>10.7–21.4 (μmol/L; women)</td>
<td>Ferrozine</td>
</tr>
<tr>
<td></td>
<td>12.5–25.1 (μmol/L; men)</td>
<td></td>
</tr>
<tr>
<td>Ferritin</td>
<td>30–300 (μg/L)</td>
<td>Immunoturbidimetry</td>
</tr>
<tr>
<td>Magnesium (erythrocytic)</td>
<td>1.96–2.40 (mmol/L)</td>
<td>Mass spectogram</td>
</tr>
<tr>
<td>Thiamine</td>
<td>6.6–49.9 (mmol/L)</td>
<td>Microbiological method</td>
</tr>
<tr>
<td>Vitamin B-6</td>
<td>17.9–59.8 (mmol/L; women)</td>
<td>Microbiological method</td>
</tr>
<tr>
<td></td>
<td>17.9–197.4 (mmol/L; men)</td>
<td></td>
</tr>
<tr>
<td>Vitamin B-12</td>
<td>133–675 (pmol/L)</td>
<td>Chemiluminescence</td>
</tr>
<tr>
<td>Zinc</td>
<td>10.7–17.5 (μmol/L; women)</td>
<td>Colorimetry</td>
</tr>
<tr>
<td></td>
<td>11.1–19.5 (μmol/L; men)</td>
<td></td>
</tr>
</tbody>
</table>

1 Corrected calcium was calculated according to the following formula: corrected calcium = total calcium − (0.012 × [(albumin/0.9677) − 39.55]).
423 medical records screened

- 129 patients underwent gastric banding
- 26 patients underwent RYGBP as second bariatric procedure because of failure of a previous operation

269 patients operated on primarily by RYGBP

- 68 patients operated on after June 2004
- 3 patients treated by nutritional supplementation before surgery
- 38 patients dropped out during follow-up
- 19 patients had blood analyses performed in an external laboratory
- 3 patients became pregnant during the 2 first postoperative years

137 patients included in analysis

FIGURE 1. Patient selection and screening procedures.

RESULTS

Records from 423 patients were screened; 137 (110 women and 27 men) of them were included in the final analysis. Details of the screening procedure are shown in Figure 1.

Anthropometric parameters

Age at surgery was 39.9 ± 10.0 y (range: 19–64 y), and BMI was 46.7 ± 6.5 (range: 38.0–69.7). Ninety patients had a preoperative BMI ≤48.0 (later defined as group 1), and therefore the length of their Roux-en-Y-limb was 100 cm; 47 patients had a BMI >48.0 (later defined as group 2), and consequently the length of their Roux-en-Y-limb was 150 cm.

At 3 mo after the operation, weight loss was already statistically significant in all patients (as shown in Table 2). Two years after surgery, the overall absolute weight loss was 46.2 ± 13.9 kg; it was significantly larger for group 2 than for group 1 patients [54.0 ± 14.3 and 41.8 ± 11.6 kg, respectively, P < 0.0001]. In terms of relative weight loss, the difference between the 2 groups was not significant, as group 1 lost 35.3 ± 7.8% and group 2 lost 36.1 ± 8.4% of their initial body weight (P = 0.59). Overall, the relative weight loss was 35.6 (8.0)%.

When we stratified by sex but not by weight group, absolute weight loss was the same in women and men [45.6 ± 13.2 and 48.9 ± 16.4 kg, respectively, P = 0.30]. The relative weight loss was higher in women than in men [36.4 ± 7.4% and 31.9 ± 9.2%, respectively, P = 0.01].

Nutritional parameters

The proportions of patients at 3, 6, 12, 18, and 24 mo after RYGBP who were receiving at least one specific nutritional supplement are displayed in Figure 2, which shows that only 2% of patients were free of supplement use 2 y after surgery. A detailed analysis of the number of supplements prescribed at the end of the follow-up is provided in Figure 3. This figure shows that 59.8% of patients were receiving at least 3 and 37.2% were receiving 4 or more types of supplements. The mean amount of supplements per patient was 2.9 ± 1.4 and was similar between groups 1 and 2. There was no difference between men and women, and we found no correlation between the number of prescribed supplements and the absolute (r = 0.07, P = 0.46) or relative (r = 0.08, P = 0.39) weight loss.

The proportions of patients receiving specific supplements at 3, 6, 12, 18, and 24 mo after RYGBP are shown in Figure 4. Vitamin B-12 was the most frequently prescribed supplement (80% at 2 y), followed by iron (60%), calcium + vitamin D-3 (60%), and folic acid (45%). We found no significant differences in these proportions when we compared groups according to their initial body weight and sex, except for calcium and vitamin D-3 supplementation. In group 2, the proportion of patients who needed calcium and vitamin D-3 supplementation at 2 y after surgery was significantly higher than that in group 1 (74% compared with 52%, respectively; P = 0.02).

Cost of the substitutive treatment

An estimate of the average cost of nutritional supplementation 2 y after RYGBP is shown in Table 3. According to this table, the mean yearly expenses would be $417.96.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Anthropometric parameters before and 3, 6, 12, 18, and 24 mo after RYGBP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before surgery</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>117.7 ± 15.6</td>
</tr>
<tr>
<td>Group 2</td>
<td>150.1 ± 20.0</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>42.9 ± 2.7</td>
</tr>
<tr>
<td>Group 2</td>
<td>54.2 ± 4.9</td>
</tr>
<tr>
<td>EBW (%)</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>99.7 ± 12.4</td>
</tr>
<tr>
<td>Group 2</td>
<td>152.1 ± 23.5</td>
</tr>
</tbody>
</table>

1 Data are shown as x ± SD. Group 1 refers to patients with a preoperative BMI ≤48.0 and Group 2 to patients with a preoperative BMI >48.0. P < 0.001 for all values when compared with the “before surgery” values of the corresponding value and patient group (paired t test).
DISCUSSION

RYGBP has become one of the most common bariatric procedures. However, long-term nutritional outcome data remain scarce, and, aside from a few published expert recommendations (15–17), there are no guidelines regarding the optimal postoperative nutritional follow-up. The aim of this study was to improve our knowledge of the nutritional consequences of RYGBP, because of potential complications related to development of nutritional deficiencies such as neurologic dysfunction for vitamin B-12 deficiency (18).

Our main observations are as follows. 1) Standard multivitamin supplementation is not sufficient to prevent nutritional deficiencies after RYGBP. Indeed, almost 60% of our patients required one or more nutritional supplements 6 mo after surgery, with virtually all patients needing them after 2 y. 2) The prevalence of vitamin D and calcium deficiency increases significantly with the length of the Roux-en-Y limb. 3) Proper postoperative nutritional substitution can become a burdensome and expensive treatment, which may challenge a patient’s compliance considerably.

The reported incidence of specific deficiencies after RYGBP varies widely in the current literature: between 10% and 50% for vitamin B-12 and iron (10, 11, 19) and between 0 and 40% for folic acid (17). Hypovitaminosis D with secondary hyperparathyroidism was found in up to 80% of patients both pre- and postoperatively (20). No data are available for vitamins B-1 and B-6, magnesium, and zinc. However, most authors report the incidence of specific deficiencies at different time points after surgery, without considering the number of patients who will require any substitutive treatment during follow-up. In addition, some authors prescribe a multivitamin supplement immediately after RYGBP and others do not, potentially confounding the data. Finally, the time points at which patients are studied vary among studies, and yet, as exemplified by the present data, the prevalence of nutritional deficiencies increases with time. We chose here to report the proportion over time of patients receiving one or more nutritional supplements. Because these supplements were prescribed according to strict guidelines on the basis of regular biologic measurements, we believe that these data provide an accurate picture of the clinical importance of this problem over the period under study. By reporting the mean number of supplements prescribed for each patient, our study is also the first to illustrate the burden of nutritional substitution.

Despite some limitations inherent to the retrospective design of this study, our data stress the fact that oral and/or parenteral nutritional supplementation can become a potential problem for patients. Indeed, they demonstrate that a standardized multivitamin supplement with a single pill per day will probably not meet the needs of the vast majority of patients. Taking several...
the given supplement). The lack of effectiveness of multivitamin supplementation, and the high cost of the above-mentioned postoperative follow-up, an achievable alternative to our follow-up schedule and treatment plan would be to prescribe vitamin B-12, iron, calcium + vitamin D-3, and folic acid supplements in sufficient amounts to all patients after RYGBP. A pragmatic approach of prescribing a double dose of a multivitamin is sometimes used; however, the effectiveness of this approach has not yet been fully demonstrated. Therefore, the development of a single “multi-pill” or injection containing appropriate doses of vitamin B-12, iron, calcium + vitamin D-3, and folic acid would facilitate compliance and reduce costs; research to determine the proper dosage and route of administration of this type of medication should be encouraged. With such a regimen, our data suggest that nutritional assessments performed every 6 mo would be adequate to both detect less frequent deficiencies such as those of vitamins B-1 and B-6, zinc, or magnesium and monitor the efficacy of treatment.

RYGBP has become one of the most commonly performed bariatric procedures. Our data demonstrate that after surgery routine supplementation with a standardized multivitamin preparation alone does not prevent the frequent occurrence of nutritional deficiencies. We therefore suggest that rigorous postoperative follow-up should be implemented in all patients to detect the most frequent of these deficiencies, which include deficiencies of vitamin B-12, iron, calcium, 25-hydroxyvitamin D, and folic acid. Given the prevalence and clinical importance of this problem, prospective studies should be performed to establish formal guidelines for the nutritional care of these patients.

We express our deep gratitude to François Pralong, who offered his help by revising the manuscript. The author’s responsibilities were as follows—CG: collected and analyzed data, interpreted results, and wrote the manuscript; MS: participated in data collection and revised the manuscript; RG: revised the manuscript; and VG: participated in data collection, interpreted results, and wrote the manuscript. None of the authors had a personal or financial conflict of interest.

## REFERENCES


### TABLE 3

<table>
<thead>
<tr>
<th>Nutritional supplement</th>
<th>Monthly cost per patient</th>
<th>Proportion of patients receiving supplementation</th>
<th>Predictable cost 2 y after RYGBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin B-12</td>
<td>12</td>
<td>0.80</td>
<td>9.60</td>
</tr>
<tr>
<td>Iron</td>
<td>10</td>
<td>0.60</td>
<td>6.00</td>
</tr>
<tr>
<td>Calcium inferior + vitamin D₃</td>
<td>20</td>
<td>0.60</td>
<td>12.00</td>
</tr>
<tr>
<td>Folic acid</td>
<td>8</td>
<td>0.45</td>
<td>3.60</td>
</tr>
<tr>
<td>Vitamin B-6</td>
<td>2</td>
<td>0.13</td>
<td>0.26</td>
</tr>
<tr>
<td>Zinc</td>
<td>16</td>
<td>0.12</td>
<td>1.92</td>
</tr>
<tr>
<td>Magnesium</td>
<td>11</td>
<td>0.13</td>
<td>1.43</td>
</tr>
<tr>
<td>Thiamine</td>
<td>7</td>
<td>0.04</td>
<td>0.28</td>
</tr>
<tr>
<td>Total</td>
<td>NA¹</td>
<td>0.98⁴</td>
<td>34.8³</td>
</tr>
</tbody>
</table>

¹ All costs are expressed in US Dollars.
² The predictable cost for each given supplement was calculated with the following formula: (cost of a 1-mo treatment × proportion of patients receiving the given supplement).
³ NA, not applicable.
⁴ Proportion of patients receiving at least one nutritional supplement 2 y after RYGBP.
⁵ Total cost calculation was made by adding the predictable costs of all supplements.