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ORIGINAL CONTRIBUTIONS

Micronutrient Supplementation after Biliopancreatic Diversion with Duodenal Switch in the Long Term

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Abstract
Background Malabsorptive bariatric surgery requires life-long micronutrient supplementation. Based on the recommendations, we assessed the number of adjustments of micronutrient supplementation and the prevalence of vitamin and mineral deficiencies at a minimum follow-up of 5 years after biliopancreatic diversion with duodenal switch (BPD-DS).
Methods Between October 2010 and December 2013, a total of 51 patients at a minimum follow-up of 5 years after BPD-DS were invited for a clinical check-up with a nutritional blood screening test for vitamins and minerals.
Results Forty-three of fifty-one patients (84.3 %) completed the blood sampling with a median follow-up of 71.2 (range 60–102) months after BPD-DS. At that time, all patients were supplemented with at least one multivitamin. However, 35 patients (81.4 %) showed either a vitamin or a mineral deficiency or a combination of it. Nineteen patients (44.1 %) were anemic, and 17 patients (39.5 %) had an iron deficiency. High deficiency rates for fat-soluble vitamins were also present in 23.2 % for vitamin A, in 76.7 % for vitamin D, in 7.0 % for vitamin E, and in 11.6 % for vitamin K.
Conclusions The results of our study show that the prevalence of vitamin and mineral deficiencies after BPD-DS is 81.4 % at a minimum follow-up of 5 years. The initial prescription of micronutrient supplementation and further adjustments during the first follow-up were insufficient to avoid long-term micronutrient deficiencies. Life-long monitoring of micronutrients at a specialized bariatric center and possibly a better micronutrient supplementation, is crucial to avoid a deficient micronutrient status at every stage after malabsorptive bariatric surgery.

Keywords Biliopancreatic diversion with duodenal switch · Long-term follow-up · Vitamin deficiency · Mineral deficiency · Micronutrient supplementation

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Introduction

Biliopancreatic diversion with duodenal switch (BPD-DS) is considered to be the most effective bariatric procedure resulting in a sustainable long-term weight loss and a high remission rate of obesity-related comorbidities [1–4]. Besides its excellent long-term outcome, BPD-DS can lead to severe diarrhea and micronutrient deficiencies in the long-term [5–10] based on the malabsorptive character of the procedure [1, 3, 6]. Exclusion of the jejunum from the alimentary tract usually results in poor iron, vitamin B_{12}, and zinc absorption whereas the short common channel of the BPD-DS deteriorates the absorption of fat-soluble vitamins [6, 8, 9, 11].

Despite the recommendations of the American Society of Metabolic and Bariatric Surgery (ASMBS) for micronutrient supplementation after BPD-DS, the exact amount of vitamins and minerals to ensure a sufficient postoperative supplementation is unknown and can be variable among individuals [6–8].

At present, the literature on the nutritional status after BPD-DS mostly reports short-term results and focuses on the most common deficiencies, i.e., iron, vitamin B_{12}, and vitamin D in a small number of patients [9, 12–14]. These deficiencies can be very serious and can lead to readmission and even to additional operations to lengthen the common channel [6, 15]. Most importantly, there is a gap between the supplementation prescribed and what is effectively consumed by the patient over time [6, 9, 11]. Although patients are advised to use life-long multivitamins after malabsorptive surgery, it is unclear if these supplementation regimens adequately prevent micronutrient deficiencies [5, 6, 9].

For this reasons, the purpose of this study was to assess the prevalence of vitamin and mineral deficiencies at a minimum follow-up of 5 years after BPD-DS.

Materials and Methods

Patients

Fifty-one consecutive patients who underwent BPD-DS before October 2005 were retrospectively reviewed with respect to micronutrient supplementation as well as nutritional blood screening tests. To evaluate the overall results after BPD-DS, the bariatric analysis and reporting outcome system (BAROS) was used. Results of the BAROS score were divided into excellent, very good, good, moderate, or poor at 5 years after BPD-DS [16].

All patients were invited for a follow-up at a minimum period of 5 years after BPD-DS. They received a complete nutritional blood screening test which consisted of blood cell count, mean cell volume (MCV), electrolytes with calcium and magnesium, creatinine, ferritin, folate, vitamin B_{12}, 25-hydroxy vitamin D, parathyroid hormone (PTH), albumin, vitamin A, vitamin B_1, vitamin B_6, vitamin E, vitamin K, zinc, selenium, and copper. Deficiencies of vitamins and minerals were defined as serum levels below the hospital internal laboratory standards. For this type of study, formal consent is not required. Informed consent was obtained from all individual participants included in the study.

Surgical Technique

BPD-DS was performed laparoscopically or by laparotomy using standardized techniques previously described [2]. In each patient, the common channel was measured to a length of 80 cm with an alimentary limb of 150 cm resulting in a small bowel length of 230 cm. The length of the biliopancreatic limb was at an individual length of 150 to 280 cm. The sleeve gastrectomy was fashioned over a 40-French stomach tube with an estimated volume of 120 to 150 mL.

Postoperative Management and Follow-up

Controls of the nutritional blood status were repeatedly performed based on the guidelines of the ASMBS either in our outpatient bariatric clinic or by the general practitioner [7]. Early postoperative and life-long recommendations for micronutrient supplementation consisted according to the ASMBS guidelines of a multivitamin-mineral supplementation on a daily base covering 200 % of the daily value. It contained 5000 IU of vitamin A, 2000 IU of vitamin D_3, 300 mg of vitamin K, 2400 mg of calcium, and 16 mg of iron. The need of a life-long multivitamin-mineral supplementation was emphasized at every time point during follow-up. Patients were also advised for a minimal protein intake of 60 g a day and up to 1.5 g/kg ideal body weight. The routine follow-up consisted of visits at our outpatient bariatric clinic including a nutritional blood screening test every 3 months during the first year and every 6 months during the second year after BPD-DS.

Afterwards, nutritional blood screening tests were performed every year including a clinical examination at our outpatient bariatric clinic or the general practitioner. The nutritional blood screening tests included complete blood cell count, MCV, electrolytes with calcium and magnesium, creatinine, ferritin, folate, vitamin B_{12}, 25-hydroxy vitamin D, PTH, albumin, zinc, and selenium. Vitamin A, vitamin B_1, vitamin B_6, vitamin E, vitamin K, and copper were measured every 12 months. After 2 years, patients were invited once a year to have a complete check-up. If a deficiency of micronutrients was diagnosed, the patient received adequate supplementation to treat the deficiency. In addition, these patients received further instructions by the dietary assistant about the importance of the life-long multivitamin-mineral supplementation, and an additional appointment was scheduled for follow-up.

Statistical Analysis

Data were analyzed using Prism 6 (version 6.0d; GraphPad Software). Results are presented as mean values with standard deviation (SD) unless specified otherwise.

Results

Of all 51 patients selected, 43 patients (84.3 %) were available at a minimum follow-up of 5 years after BPD-DS. Two patients were deceased, and six patients were lost in follow-up during the first 5 years after BPD-DS. The characteristics of the remaining patients are shown in Table 1. The mean age of the patients was 41.3 ± 15.2 years (range 28–58), and 31 patients were female (72.1 %). The initial BMI before surgery was 43.1 ± 8.1 kg/m^2 (range 36.3–54.2). After a median follow-up of 71.2 months (range 60–102), the mean weight, BMI, and percentage of excessive weight loss (%EWL) was 98.2 ± 17.7 kg (range 76–138), BMI 31.9 ± 6.2 kg/m^2 (range 24.8–44.2), and %EWL 61.2 ± 15.2 % (range 41.4–123.0). BAROS score at 5 years after BPD-DS was considered good

Table 1 Patient's characteristics at 5 years or longer after BPD-DS

Number of patients ($n = 43$)	n
Female (n)	31 (71.2 %)
Age (years)	41.3 ± 15.2
Weight (kg)	98.2 ± 17.7
BMI (kg/m^2)	31.9 ± 6.2
%EWL (%)	61.2 ± 15.2

n number of patients

to excellent in 35 of 43 patients (81.4 %), moderate in 5 patients (11.6 %), and poor in only 3 patients (7.0 %).

During the entire follow-up, adjustments of micronutrient supplementation were required in 31 of 43 patients (72.1 %). If a deficiency of micronutrients was diagnosed, the patient received at least one additional micronutrient supplementation including iron, vitamin B_{12}, vitamin D, calcium, zinc, selenium, folate, and vitamin A (Table 2). Readjustments of the micronutrient supplementation were necessary mostly within the first year after BPD-DS and included an increase of the initial dosage of about 50 % for folate to about 300 % for vitamin B_{12} (Table 3). Eight patients (18.6 %) required reoperations because of early (2 leaks, 1 bleeding, 1 intra-abdominal abscess) and late complications (3 incisional ventral herniae, 1 small bowel obstruction). Revisional bariatric surgery was performed in one patient (2.3 %) with Barrett's esophagus and a severe hypoalbuminemia that was switched to a Roux-en-Y gastric bypass with an extension of the common channel to 150 cm.

At the time of the follow-up, 17 patients (39.5 %) were under additional micronutrient supplementation based on the previous checkups and nutritional blood screening tests.

Table 2 Use of additional micronutrient supplementation on top of the recommended supplementation by the ASMBS during the 5-year follow-up after BPD-DS

Number of patients ($n = 43$)	n
Additional multivitamin[a]	33 (76.7 %)
Iron	23 (53.5 %)
Vitamin B_{12}	18 (41.9 %)
Vitamin D	16 (37.2 %)
Calcium	16 (37.2 %)
Zinc	11 (25.6 %)
Selen	9 (21.0 %)
Folate	7 (16.3 %)
Vitamin A	5 (11.6 %)

[a] Life-long underlying micronutrient supplementation consisted of a multivitamin-mineral supplementation on a daily base covering 200 % of the daily value containing 5000 IU of vitamin A, 2000 IU of vitamin D_3, 300 mg of vitamin K, 2400 mg of calcium, and 16 mg of iron

n number of patients, $n = 43$

Table 3 Average time after BPD-DS until readjustment for micronutrient supplementation was needed including the increase of vitamins/minerals in percentage compared to the starting dose

Number of patients ($n = 43$)		
Readjustments after BPD-DS[a]	Time (months)	± Dosage (%)
Iron	7.6 ± 3.5	220.1 ± 63.7
Vitamin B_{12}	6.3 ± 4.2	289.3 ± 45.2
Vitamin D	10.2 ± 5.4	134.4 ± 89.1
Calcium	11.1 ± 4.9	89.3 ± 33.2
Zinc	8.3 ± 3.2	230.1 ± 56.3
Selen	13.4 ± 5.0	139.3 ± 47.9
Folate	14.6 ± 4.7	47.2 ± 23.9
Vitamin A	18.5 ± 9.2	122.7 ± 57.5

[a] The initial micronutrient supplementation consisted of a multivitamin-mineral supplementation on a daily base covering 200 % of the daily value containing 5000 IU of vitamin A, 2000 IU of vitamin D_3, 300 mg of vitamin K, 2400 mg of calcium, and 16 mg of iron

n number of patients, $n = 43$

However, 35 of the patients (81.4 %) were diagnosed with a de novo or recurrent micronutrient deficiency including either vitamins, minerals, or both. Nineteen patients (44.1 %) were anemic, and 17 patients (39.5 %) had an iron deficiency and 12 patients (27.9 %) a vitamin B_{12} deficiency. High rates of fat-soluble vitamin deficiencies were present for vitamin A in 10 patients (23.2 %), vitamin D in 33 patients (76.7 %), with 26 patients (60.5 %) with secondary hyperparathyroidism, vitamin E in 3 patients (7.0 %), and vitamin K in 5 patients (11.6 %). Of all patients with secondary hyperparathyroidism, 11 patients (25.6 %) showed a PTH >10 pmol/L combined with a moderate to severe vitamin D deficiency.

Table 4 shows the blood levels and the numbers of deficiencies for each vitamin and mineral. In twelve patients (27.9 %), anemia was due to iron or vitamin B_{12} deficiency of which two patients (4.7 %) were under iron and three patients (7.0 %) under vitamin B_{12} supplementation. There was no patient with folate deficiency. Nineteen patients (44.2 %) were diagnosed with zinc deficiency and twelve patients (27.9 %) with a selenium deficiency.

Discussion

To our knowledge, this is the first study showing a prevalence of vitamin and mineral deficiency after BPD-DS of 81.4 % at a minimum follow-up of 5 years. We conclude, that the initial prescription of micronutrient supplementation and further adjustments during the follow-up were insufficient to avoid long-term micronutrient deficiencies. Therefore, a better vitamin and mineral supplementation could possibly ensure a sufficient life-long supply after BPD-DS.

Table 4 Vitamin and mineral blood levels 5 years or longer after BPD-DS

	Normal limits	Normal ranges		Deficiency	
		Blood levels	*n*	Blood levels	*n*
Hemoglobin (mmol/L)	M: 8.5–11.0	10.8 ± 2.3	9	7.5 ± 1.9	3
	F: 7.6–10.1	9.8 ± 1.9	15	6.8 ± 0.9	16
Ferritin (μg/L)	30–300	103.3 ± 31.8	26	24.3 ± 12.6	17
Vitamin B_{12} (pmol/L)	200–650	364.7 ± 65.2	31	123.8 ± 63.0	12
Folate (nmol/L)	9.0–36.0	21.2 ± 9.3	43	–	0
Vitamin D (nmol/L)	<50	87.8 ± 21.9	10	23.8 ± 9.9	33
Calcium (mmol/L)	2.19–2.63	2.78 ± 0.19	31	2.04 ± 0.21	12
PTH (pmol/L)	1.5–7.0	3.3 ± 2.3	17	10.2 ± 2.9	26
Magnesium (mmol/L)	0.8–1.15	1.11 ± 0.09	39	0.78 ± 0.12	4
Zinc (μmol/L)	9.7–12.4	11.0 ± 2.4	24	11.0 ± 2.4	19
Selenium (μmol/L)	0.8–1.5	1.09 ± 0.23	31	0.56 ± 0.21	12
Vitamin A (μmol/L)	1.08–2.75	1.78 ± 0.354	33	0.82 ± 0.28	10
Vitamin E (μmol/L)	13.0–44.8	31.2 ± 6.8	40	11.5 ± 5.2	3
Vitamin K (nmol/L)	0.29–3.50	1.87 ± 0.89	38	0.19 ± 0.09	5
Albumin (g/L)	36–50	39.2 ± 5.23	36	29.1 ± 4.9	7

n number of patients, *n* = 43

Nutritional deficiencies are common after bariatric surgery and are related to a decreased food intake and the malabsorptive character of the procedure [5, 6, 8, 9, 12, 13, 15, 17, 18]. Any bariatric procedure with a malabsorptive effect may lead to an increased risk of nutritional deficiencies during the postoperative period [6, 10, 11]. Additionally, all types of bariatric surgery lead to an important decrease of ingested calories, especially during the first half year after the procedure [9].

Besides its excellent long-term results in terms of weight loss [2, 4], BPD-DS can lead to severe diarrhea and micronutrient deficiencies [5, 10, 12, 15] based on the malabsorptive and malnutritional character of the procedure [9, 11]. Malnutrition even can result in rehospitalization and revisional bariatric surgery with an extension of the common channel in some patients [12, 15]. In one patient, a switch to a Roux-en-Y gastric bypass with an extension of the common channel to 150 cm was necessary. Exclusion of the jejunum from the alimentary tract usually results in poor iron, vitamin B_{12}, and zinc absorption whereas the short common channel of the BPD-DS deteriorates the absorption of fat-soluble vitamins [6, 11, 14, 19]. These mechanisms result in considerable negative side effects that should not be underestimated [15]. Historically, the BPD-DS was created with a small segment of attached duodenum to overcome the poor iron, vitamin B_{12}, and zinc absorption of the Scopinaro procedure, but long-term reports show no significant benefits [4].

We report a rate of over 80 % in micronutrient deficiencies at a minimum follow-up of 5 years after BPD-DS. The readjustments of the micronutrient supplementation were necessary mostly within the first year after BPD-DS. Due to the significant malabsorption of the BPD-DS, the increase of the specific vitamin and mineral supplementation was about 50 to 300 % (R#2.1). Furthermore, 25.6 % of the patients showed a secondary hyperparathyroidism with a PTH >10 pmol/L combined with a moderate to severe vitamin D deficiency.

Although routine follow-up at our outpatient bariatric clinic included a nutritional blood screening test every 3 months during the first year, and every 6 months during the second year after BPD-DS, the prevalence was very high. Afterwards, nutritional blood screening tests were performed every year including a clinical examination at our outpatient bariatric clinic or the general practitioner. Comparable rates for micronutrient deficiencies were also found by other authors [5, 12, 14, 15, 18]. These findings are supported by a recent study of Risstad et al. and a review of Gietsu-Miller et al. [11, 18], but are in contrast with the results of Marceau et al. who concluded that BPD-DS resulted in fewer nutritional deficiencies [2].

At present, the literature on nutritional status after BPD-DS mostly reports short-term results [5, 13, 15, 17]. It focuses on the most common deficiencies, i.e., iron, vitamin B_{12}, and vitamin D in a small number of patients [8, 14]. Although Marceaux reports a negligible rate of micronutrient deficiencies 20 years after BPD-DS [2], other authors reported that the prevalence varies between 50 and 80 % [5, 12, 15, 18]. In the report of Marcaux, vitamin A, hemoglobin, and calcium levels were slightly decreased. For all other nutritional markers, the reported prevalence of deficiency remained below 2 % over a follow-up of 20 years [2]. Other than that, PTH was correlated in 22 % of patients to lower calcium, but not with vitamin D [2]. The differences found in the literature might be explained by the differences of lengths of the common channel, varying from 50 to 100 cm for BPD-DS, respectively, and by the weight loss, where a higher %EWL naturally leads to a higher rate of micronutrient deficiencies [3, 15]. In our study, BPD-DS resulted in a long-term weight loss of 61.2 % EWL after a mean follow-up of 71.2 months with some patients with weight regain [4, 5, 12, 14] (R#2.7). Nevertheless, the BAROS score showed good to excellent results in more than 80 % of the patients at 5 years after BPD-DS.

In bariatric procedures with less malabsorptive effect such as sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB), Gehrer et al. reported a lower number of micronutrient deficiencies in SG compared to RYGB, especially for iron, folate, vitamin D, vitamin B_{12}, and zinc [13].

In reality, there is a gap between the supplementation regimen prescribed and what is effectively consumed by the patient over time [6, 9, 11]. Although patients are advised to use life-long multivitamins especially after malabsorptive bariatric surgery, it is unclear if these supplementation regimens adequately prevent micronutrient deficiencies. Despite existing recommendations by the ASMBS for micronutrient supplementation after BPD-DS, the exact amount of vitamins and minerals to ensure a sufficient postoperative supplementation is unknown and can be variable among individuals [14, 20].

One of the most commonly reported micronutrient deficiencies is iron deficiency, which is the main cause of developing anemia after bariatric surgery [6, 8, 10]. In our study, 19 patients (44.1 %) were anemic, and 17 patients (39.5 %) had an iron deficiency. Other causes of anemia are folate and vitamin B_{12} deficiencies [8, 12]. Interestingly, no folate deficiency was found in our series, but 12 patients (27.9 %) had a vitamin B_{12} deficiency. Bariatric procedures also lead to reduced delivery of calcium and vitamin D. These nutrients are fundamental to the bone metabolism. A vitamin D deficiency was the most frequently diagnosed deficiency in the present study. A total of 33 (76.7 %) patients were diagnosed with vitamin D deficiency and 26 patients (60.5 %) with secondary hyperparathyroidism.

Conclusion

Our study shows a high rate of micronutrient deficiencies of over 80 % at a minimum follow-up of 5 years after BPD-DS. From this standpoint, initial prescription and supplementation of micronutrients and further adjustments during the follow-up was insufficient to meet the demand of vitamins and minerals in the long-term. A high number of readjustments during the first year after BPD-DS were necessary by adding a significant amount of vitamin A, vitamin D, vitamin B_{12}, as well as calcium, zinc, and iron.

We conclude that repeated and life-long monitoring at a specialized bariatric center is needed to detect and treat deficiencies at every stage after malabsorptive bariatric surgery. When deficiencies are found, a better micronutrient supplementation and a more frequent follow-up is necessary—at least on an annual basis—to prevent patients from developing vitamin and mineral deficiencies.

Compliance with Ethical Standards

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

Ethical Approval For this type of study, formal consent is not required.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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