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CLINICAL RESEARCH

The Biliopancreatic Diversion with a Duodenal Switch (BPDDS): How Is It Optimally Performed?

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Abstract
Background The biliopancreatic diversion with duodenal switch can be performed by different combinations of restriction and malabsorption. The aim of this study was to evaluate weight loss and potential side effects for two variants of the procedure.
Methods All patients eligible for a 2-year follow-up (n=182) was included in the study. Thirty-five patients (group A) had a gastric remnant with a volume of approximately 200 ml, an alimentary limb (AL) of 250 cm, and a common channel (CC) of 100 cm, while 147 patients (group B) had a gastric remnant of 100–120 ml, an AL of 40%, and a CC of 10% of the small bowel length. Preoperative variables, such as body mass index (BMI), sex, age, and factors that might influence weight loss, and postoperative weight loss and side effects were registered and compared.
Results Preoperatively, the BMI was 50.6 in group A and 52.1 in group B (ns), with no difference in age, sex, or variables that might influence weight loss. At 2 years, the BMI was 33.1 in group A (n=34) and 28.5 in group B (n=119) with an adjusted difference in weight loss of 5.6 BMI units between the groups (p<0.001). Vitamin D status was also better in group B than in group A at follow-up, while there was no difference in side effects.
Conclusions Patients with a remnant stomach of 100–120 ml, and AL and CC with individually adapted lengths had a larger weight loss and better vitamin D status postoperatively without an increase in side effects.

Keywords Obesity · Bariatric surgery · BPDDS

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Introduction

Bariatric surgery has been shown to save lives, improve health-related quality of life, and resolve metabolic disease. As it is also increasingly recognized that bariatric surgery is the only treatment proven to give sustained weight loss for this patient group, bariatric surgery has gained increased acceptance and popularity [1, 2].

The biliopancreatic diversion with duodenal switch (BPDDS) is known to give a large weight loss and a high remission rate for metabolic disease. It combines a gastric resection (creating gastric volume restriction) with small bowel bypass (creating intestinal malabsorption), but the procedure is not standardized, and different combinations of restriction and malabsorption are being used in different centers [3–5]. In our center, we have used two different combinations of restriction/malabsorption in an attempt to see how well the two approaches are balancing effects and side effects. To our knowledge, this is the first study that has addressed this issue.

Patients and Methods

Our bariatric surgery program started in 2001, and in the time period from April 2001 to February 2008, 182 consecutive patients underwent a primary BPDDS type of operation at our institution. Indications for surgery were a body mass index (BMI) ≥40 or a BMI ≥35 with obesity-related comorbidities. Patients were evaluated at the outpatient clinic preoperatively and at 3, 12, and 24 months after the operation. The program also includes a 5- and 10-year follow-up. Between these check-ups, patients are encouraged to have a yearly visit to their general practitioner. Pre- and postoperative data were collected systematically in a database after having obtained written informed consent from the patients. The database is approved by the Norwegian Data Inspectorate, and the present study is a prospective cohort study with data extracted from the database. As it may be that certain factors such as preoperative weight loss [6, 7], anxiety/depression [8, 9], and type 2 diabetes [10, 11] prior to surgery can influence the degree of short- or intermediate term weight loss, these variables are presented for the two groups.

From April 2001 to December 2003, 35 patients (group A) were operated using a gastric resection which left a gastric volume of approximately 200 ml and a standard total small bowel in function (alimentary limb (AL)) of 250 cm with a common channel (CC) of 100 cm. From December 2003 to February 2008, 147 patients (group B) were operated creating a gastric volume of approximately 100–120 ml, an AL of 40% of the total small bowel length, and a CC of 10% of the total small bowel length. The gastric resection was performed by the Endo-GIA universal (Covidien) using green and blue cartridges and oversewing the staple line. The gastric volume was estimated by filling the stomach with water through a nasogastric tube during the operation and observing how much water was needed to fill the stomach. The bowel lengths were measured using a moistened umbilical tape, while the small bowel was being semi-stretched. In order not to get too many different lengths for CC and AL in group B, the lengths were approximated to the nearest 25 cm so that CC was either 50, 75, or 100 cm and AL 200, 225, 250, 275, or 300 cm, the most common combination for bowel lengths being a CC of 75 cm and an AL of 275 cm. In six patients, the AL was made longer than 300 cm.

All operations were performed through an upper transverse incision. The gallbladder and appendix were removed routinely in all patients. The opening in the small bowel mesentery was closed by non-absorbable suture (Prolene). An abdominal drain was left for 2-3 days and then removed if no sign of leakage or major bleeding was detected. All patients were given a low molecular weight heparin starting from the night before the operation and continued for 2 weeks. An H_2 blocker (cimetidine 300 mg) was given on the night before the operation, and antibiotic prophylaxis started just prior to the operation using 400 mg doxycycline and 1.5 g metronidazole.

After the operation, all patients were given standard vitamin and mineral supplements; one multivitamin, 30,000 IE vitamin D2 (25(OH)D), and 2 g of calcium carbonate daily (calcium citrate is not readily available in Norway). Serum levels were monitored, and we aimed to keep 25(OH)D above 30 nmol/l, PTH below 10 pmol/l, ALP below 105 U/l, ferritin >10 μg/l, and vitamin B 12 and folate at reference levels [12]. Extra supplements were given if these serum levels were not obtained. Patients were encouraged to have a diet rich in proteins. If hypoalbuminemia (serum albumin below 30 g/l) occurred, the patient was given 2 weeks of supplemental parenteral nutrition. This treatment would be attempted at a maximum of two times; if hypoalbuminemia occurred for a third time, surgical revision was performed.

Weight loss was evaluated as change in BMI, percent excess weight loss (%EWL), and percent excess BMI loss (%EBMIL) [13]. "Failures" in terms of inadequate weight loss was defined as an EWL <50%. Statistical analysis between group A and B was performed using the chi-square test or Fisher's exact test as appropriate for categorical variables, and unpaired *t* test for continuous variables. Since the number of patients in group A was rather low (with increased risk for a statistical type II error), a summary score for the side effects at 2 years was made. Multivariate analysis adjusting for preoperative variables was used to evaluate the change in BMI and the difference in side effect score for the two groups 2 years after surgery. A *p* value of ≤0.05 was considered statistically significant.

Table 1 Preoperative characteristics of the 182 patients

	Group A	Group B	*p* value
Patients (*n*)	35	147	
Age (years)	37.3±1.3	39.5±0.8	0.21
Sex (F/M)	20/15	80/67	0.92
BMI	50.6±1.3	52.1±0.6	0.28
Preoperative weight change (kg)	2.6±1.3	−0.6±1.2	0.21
Anxiety or depression (*n*)	10 (29%)	59 (40%)	0.28
Type 2 DM (*n*)	11 (31%)	57 (39%)	0.54

Table 2 Surgical complications

	Group A	Group B
Patients (*n*)	35	147
Reoperations within 30 days (*n*)		
Leaks (gastric tube)	1	0
Bleeding	0	2
Bile leak	1	0
Intra-abdominal abscess	0	1
Mortality	0	0
Reoperations within 24 months (pts, *n*)	34	119
Protein malnutrition	0	4
Ileus	2	2
Recognized incisional hernias (*n*)	2	5

The GraphPad Prism and SPSS version 11 statistical package were used for statistics and graphics.

Results

There were no significant differences in preoperative characteristics between the two groups (Table 1). The average length of time between the preoperative evaluation and the operation was 3 months, and although weight loss was recommended in this period, most patients' weight was stable. Of special notice is the high number of patients receiving treatment for anxiety and/or depression, and the low level of vitamin D with approximately three fourths of the patients having a serum level of 25(OH)D below 50 nmol/l.

There was no 30 (or 90)-day mortality (Table 2). One patient was reoperated due to a leak at the top of the fundus. In this case, too much fundus had been left behind, so the top of the fundus could be restapled and oversewed without further events. Two patients were reoperated due to bleeding and one due to bile leak, but in none of these, the source could be found at relaparotomy, and the situations subsided spontaneously. In group A, one patient was treated successfully for protein malnutrition without surgical intervention, while in group B, four of five patients with protein malnutrition had surgical revision. Revisions were performed by anastomosing the AL cephalad on BPL thereby lengthening both the CC and AL. Limb lengths for the patients who had revisions were 50/225, 75/250, 75/300, and 75/300. A low rate of incisional hernias was observed.

The weight loss was significantly higher, and the fraction of patients with an EWL <50% significantly lower in group B than in group A both at 1 (3.5% versus 15%, $p=0.035$) and 2 years (3.4% versus 20%, $p<0.001$), without any significant difference in side effects (Table 3). In group B, there were 11 combinations of CC and AL. At 2 years, the loss in BMI units and the number of stools per day were very similar for all these combinations, with both variables being within ±1.5 SD for the mean in group B (20.3–26.9 BMI units; 2.4–4.0 stools per day), except for a lower weight loss in the group with CC=100 cm and AL>300 cm (13.9 BMI units (SD, 8.4; $n=3$)). The failure rate for patients with an AL longer than 300 cm was as high as 33%.

Table 3 Changes in weight and potential side effects after BPDDS (mean, SEM)

	Preoperative			12 months			24 months		
	Group A	Group B	*p* value	Group A	Group B	*p* value	Group A	Group B	*p* value
Patients (*n*)	35	147		34	141		34	119	
Effect									
BMI	50.6±1.3	52.1±0.6	0.28	33.9±0.9	29.6±0.5	<0.001	33.1±0.8	28.5±0.5	<0.001
%EWL				62.0±2.8	79.1±1.2	<0.001	63.8±3.0	82.3±1.4	<0.001
"Failures" (*n*, def: EWL<50%)				5	5	0.035	7	4	0.002
%EBMIL				68.0±3.7	85.8±1.4	<0.001	69.7±4.0	89.1±1.5	<0.001
Potential side-effects									
Stools per day	2.2±0.1	1.9±0.1	0.04	3.5±0.4	3.1±0.1	0.25	3.3±0.3	3.2±0.2	0.64
Continuous anti-diarrheal medication (*n*)	0	0	1.0	0	0	1.0	0	1	0.59
Serum albumin (g/l)	40±0.5	39±0.3	0.23	39±0.5	38±0.4	0.19	40.2±0.7	39.9±0.4	0.76
Protein malnutrition (*n*, def: albumin<30 g/l)	0	0	1.0	1	5	0.86	0	4	0.65
Vomiting weekly (*n*)	1	6	0.73	3	16	0.9	0	10	0.20
Hyperparathyroidism (*n*, def: PTH>10 pmol/l)	5	8	0.15	9	20	0.14	15	40	0.36
Hypovitaminosis D (*n*, def: 25(OH)D<50 nmol/l)	25	118	0.36	13	22	0.007	15	22	0.004

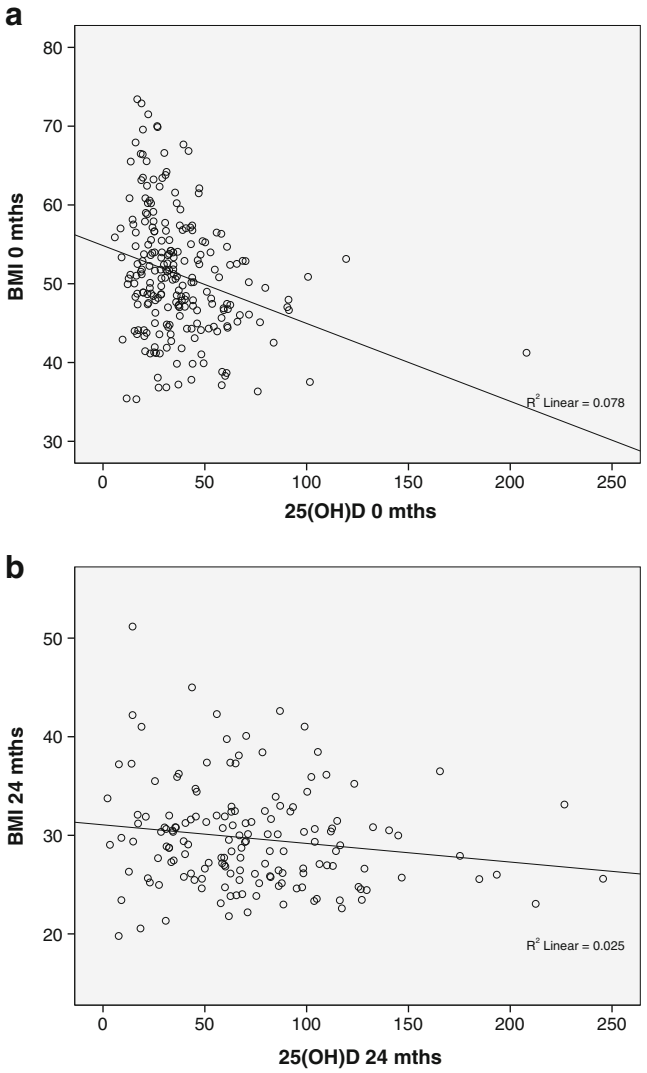

Fig. 1 The relationship between BMI and 25(OH)D preoperatively (r=−0.28, p<0.001) and at 24 months (r=−0.17, p=0.047)

Preoperatively, the patients in group A had slightly more stools per day than patients in group B. At follow-up, the number of stools per day was similar for the two groups, and the increase in number of stools per day from preoperatively to postoperatively (24 months) was 1.1± 0.3 in group A and 1.4±0.2 in group B (p=0.45), indicating no difference in the change of stool frequency between the two groups. The vitamin D and PTH status was better in group B than in group A at follow-up, and we found an inverse relationship between BMI and vitamin D level both pre- and postoperatively (Fig. 1). Although not significant, there was a tendency to vomit more in group B. In the multivariate analysis, having adjusted for preoperative data, a greater weight loss in group B without difference in side effect score was confirmed (Table 4).

Discussion

The ideal bariatric operation should carry a low risk and give an optimal, sustained weight loss without side effects. None of the operations available fulfills these criteria. Our study is part of our continuous surveillance of own practice, which includes evaluation of the surgical technique in order to optimize the results. After becoming aware of some differences in how the BPDDS technique is being performed between different centers, we have tried two different approaches in our program and found that by reducing the residual gastric volume and individualizing the length of small bowel in function, weight loss was improved without causing more side effects.

The optimal weight loss after bariatric surgery has yet to be determined. In the SOS study, the patients' health-related quality of life several years after surgery was linked to the degree of sustained weight loss [14], and it is also likely that the degree of resolution of metabolic disease at least to some extent is dependent on weight loss [15]. If the weight loss is too large, however, this may reduce the patient satisfaction due to prominent bones and redundant skin [16]. In our clinical experience, it is important for the patient to look "normal," that is not to be recognized or glared at for being obese. As weight regain may be a

Table 4 Change in body mass index from baseline to 2-year follow-up and side-effect summary score 2 years after surgery

Variable	Group A (n=34)	Group B (n=119)	Difference, 95% CI	p value
	Change (SD)[a]			
Body mass index	−17.4 (7.2)	−23.6 (6.6)	−5.6 [−7.3, −3.8][b]	<0.001
	Mean (SD)			
Side effect score	0.91 (0.80)	0.67 (0.73)	−0.25 [−0.55, 0.05][c]	0.10

Side effect score (0–5). Anti-diarrheal medication: yes=1, no=0; protein malnutrition: yes=1, no=0; vomiting: greater than or equal to once weekly=1, less than weekly=0; hypovitaminosis D: yes=1, no=0; hyperparathyroidism: yes=1, no=0

[a] Crude changes

[b] Adjusted for age, gender, baseline body mass index and preoperative weight loss, anxiety, depression, and type 2 diabetes mellitus

[c] Adjusted for age, gender, baseline body mass index, and preoperative serum albumin, 25(OH)D, and PTH

potential problem also after the BPDDS; it will be interesting to reevaluate the results for group A and group B in future years [4].

With malabsorptive surgery, there is a question of how much of the small bowel should be excluded and how much should remain in function. Already with the jejunoileal bypass, it was suggested that the length of the small bowel left in function should be individualized [17, 18]. As the length of the small bowel in general, and also in our patients, varied between 5 and 10 m, this suggestion is somewhat logic. If too much small bowel is excluded, however, there is the risk for protein malnutrition. Proteins are being absorbed throughout the AL and to some extent in the colon after adaptive changes [17]. The length of the CC may be of importance for weight loss and maintenance of weight loss, but the shorter the CC, the higher the risk for diarrhea and possibly also for protein malnutrition. In group B, the CC was significantly shorter than in group A, but on the other hand, the AL was significantly longer (both $p<0.001$), and this may have counteracted the effect of the shorter CC as far as the proteins are concerned.

A high frequency of vitamin D deficiency among patients with morbid obesity is well known, and the mechanism is thought to be a reduced vitamin D availability in serum because the fat act as a reservoir for vitamin D [19, 20]. In our study, we found an inverse relationship between the BMI and the serum level of 25(OH)D both pre- and postoperatively, and in accordance with this, the frequency of vitamin D deficiency was significantly higher in group A than in group B both at 1 and 2 years after surgery. As patients in group A remained significantly heavier than patients in group B, this support the hypothesis of fat acting as a reservoir for vitamin D. In clinical practice, this should mean that the heavier the patient remains after surgery, the larger the dose of vitamin D substitution is required to obtain the recommended serum level. A similar approach is suggested for obese patients in general [21].

In this study, we have only evaluated weight loss against the most important side effects, and changes in for instance health-related quality of life or deficiencies in other vitamins than vitamin D and trace minerals have not been evaluated. Studies on health-related quality of life will have a key position in our future research on bariatric surgery [22]. Concerning vitamin and mineral deficiencies, it is unlikely that these should be significantly different between the two groups, and there is also a question on how important such deficiencies are. In a 25-year follow-up study on jejunoileal bypass patients, who in general were not administered vitamin and mineral substitution, we found no clinical relevant disease due to such deficiencies [23]. Further limitations of this study are that it is not a randomized control trial, and also the relatively short follow-up time. Strengths are the high follow-up rate and the ability to control for possible confounders at baseline.

In conclusion, our data shows that the BPDDS can be performed safely through an upper transverse incision and gives excellent weight loss results at 2 years. Based on our data, we will continue to perform the procedure by leaving a stomach volume of 100–120 ml, and individualize the length of the AL between 200 and 300 cm and the CC between 50 and 100 cm.

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