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Nutritional Markers following Duodenal Switch for Morbid Obesity

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Background: Laparoscopic duodenal switch with gastric reduction (LapDS) is a minimally invasive hybrid operation combining moderate intake restriction with moderate malabsorption for treatment of morbid obesity. In LapDS, both the quantity of food ingested and the efficiency of digestion are reduced.

Methods: A cohort of 589 sequential LapDS patients had laboratory studies drawn annually. Serum markers for calcium, iron and protein metabolism and for hepatic function were analyzed using SAS statistical software.

Results: There were 95 men and 494 women. Mean age was 44 years, mean BMI 50 kg/m^2 and mean preoperative weight 142 kg. Although mean hemoglobin decreased below reference and mean parathyroid hormone (PTH) increased above reference, similar to abnormal values reported after Roux-en-y gastric bypass, both hemoglobin and calcium in LapDS readily returned to within the reference range following supplementation with iron and calcium respectively. Mean iron, corrected calcium, alkaline phosphatase, albumin, total protein, aspartate aminotransferase (AST), alanine transaminase (ALT), and bilirubin remained within the normal range.

Conclusion: LapDS is not associated with broad nutritional deficiencies. Annual laboratory studies, which are required following any type of bariatric operation, appear to be sufficient to identify unfavorable trends. In selected patients, additional iron and calcium supplementation are effective when indicated.

Key words: Morbid obesity, bariatric surgery, duodenal switch, laparoscopy, serum calcium, parathyroid hormone, serum iron, serum protein, liver functions

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Introduction

The duodenal switch (DS) was first performed by Hess 1988[1] and Marceau et al[2] in 1990, and a laparoscopic approach (LapDS) was first implemented by the author in 1999.[3,4] The DS combines moderate malabsorption with moderate restriction via reduced stomach capacity, yet preserves normal stomach functioning. While quality of life is difficult to study, most postoperative patients report that they continue to be able to ingest normally and enjoy eating.

The DS and the LapDS are identical in internal anatomy and are fashioned as shown in Figure 1. The gastric pouch is constructed after first clearing the greater curvature vessels cephalad to 5 cm proximal to the pylorus. Serial applications of the linear

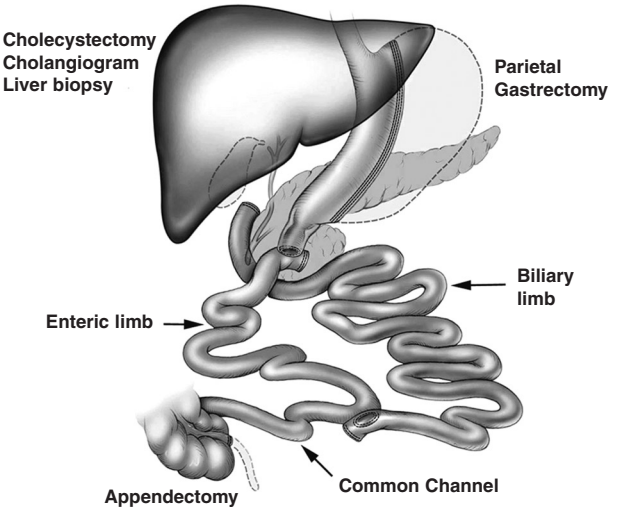


Figure 1. Duodenal switch and concurrent procedures.

stapler achieve a vertical division of the stomach, leaving a lesser curvature sleeve configuration of 120 ml and allowing preservation of the pylorus and intact vagal innervation. The duodenum is divided 4-5 cm distal to the pylorus and anastomosed to the distal 250 cm of ileum, creating a combined enteric and common limb. The remaining proximal biliopancreatic limb is anastomosed to the distal ileum 100 cm proximal to the ileocecal valve, thereby delineating a proximal enteric limb and a distal common channel. Liver biopsy is routine, and cholecystectomy, appendectomy, and operative cholangiogram are performed when the relevant organs are intact.

Sustained weight loss reported after the DS exceeds that reported following the Roux-en-Y gastric bypass.[5-7] Hess has previously reported mean excess weight loss of 73% maintained at 10 years following open DS.[1] A sample of 345 consecutive patients out of our more recent total series exceeding 600 LapDS patients shows a mean excess weight loss of 91% at 24 months (Figure 2).

Both the quantities of food ingested and the efficiency of absorption are affected by the DS. The bypassed duodenum and jejunum are active in fat-soluble vitamin and mineral absorption. Consequently, routine laboratory studies are employed to identify trends revealing progression to out-of-range values and to allow the physician to be proactive with respect to those deficiencies. The bariatric surgical team works in conjunction with the primary care physician; patient compliance is essential in facilitating recognition of potential deficiencies and enabling successful resolution of potential or actual problems as identified.

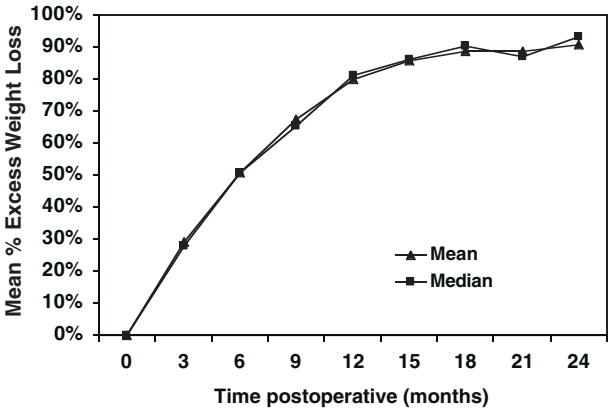


Figure 2. % excess weight loss over time.

Methods

As summarized in Table 1, 589 sequential LapDS patients were operated on over 43 months from September 1999 to May 2003. There were 95 men and 494 women, with mean age 44 years (median 44, range 18-69 years). The average body mass index (BMI) was 50 kg/m^2 (median 49, range 35-118), with an average preoperative weight of 142 kg (median 137, range 91-284 kg) and an average height of 168 cm (median 168, range 147-201 cm). The average patient was 74 kg or 209% above his/her ideal weight, calculated at an ideal BMI of 24 kg/m^2 (medians 69 kg or 203%, ranges 31-284 kg or 145-492%, respectively). The heaviest patient was a woman weighing 284 kg and standing 155 cm.

Hemoglobin, iron, and chemistries measuring protein and calcium metabolism and hepatic function were averaged preoperatively and at 1, 2, and 3 years. Calcium is corrected for normal albumin using the following formula:

corrected calcium = calcium level + 0.8(4.0-albumin level).

Our sample size was insufficient to report fractionated alkaline phosphatase results.

A mean, range, and SEM are provided for each time interval; each metabolic deficiency documents a case study of treatment and subsequent results. Means between the preoperative period and the postoperative testing intervals taken as a whole and means between all periods were compared using Welch's methodology for a General Linear Model (GLM) for unbalanced designs, expressed as *P1* and *P2*, respectively. We employed a standard GLM when the data met the assumption of homogeneity

Table 1. Preoperative data on the 589 consecutive laparoscopic duodenal switch operations September 1999 - May 2003

Demographic	Mean	Median	Range
Sex (M/F)			95/494
Age (years)	44	44	18-69
BMI (kg/m^2)	50	49	35-118
Height (cm)	168	168	147-201
Preoperative weight (kg)	142	137	91-284
Excess weight (kg)*	74	69	31-226
%Excess weight	209	203	145-492

*Ideal weight calculated at BMI = 24 kg/m^2

of variance. Outliers were cut beyond 2 standard deviations from the mean. The SAS program (The SAS Institute, Cary, NC, USA) was utilized for statistical analysis.

Results

Iron Metabolism

Two values relating to iron metabolism were tested: hemoglobin and serum iron. The normal range for hemoglobin is 12-16 g/dl. Average hemoglobin levels decreased from 13.3 ± 0.05 (range 10-16.7) g/dl pre-operatively to 12.4 ± 0.10 (range 10-16.7) g/dl, 11.6 ± 0.17 (range 5-15.7) g/dl, and 11.8 ± 0.34 (range 9.1-14.4) g/dl at 1, 2, and 3 years, respectively, with *P1* <0.0001 and *P2* <0.0001 (Figure 3). Within a normal range of 26-170 µg/ml, iron averages decreased slightly from 69.4 ± 1.12 (range 20-124) µg/ml preoperatively to 65.1 ± 1.68 (range 9-123) µg/ml, to 61.6 ± 2.90 (range 7-118) µg/ml in the 1st and 2nd years, and then rebounded from 2nd-year lows to 65.2 ± 8.764 (range 20-126) µg/ml by the 3rd year, with *P1* = 0.0050 and *P2* = 0.0373 (Figure 4).

Case Report

D.W., a 54-year-old female, first presented with a BMI of 54 at 171 kg and 178 cm. At the time of her May 2002 surgery, she displayed a hemoglobin level of 10.8 g/dl. Her level increased to 11.6 g/dl after the 1st postoperative month, yet decreased below preoperative levels to 10.2 g/dl by the 6th postoperative month. Ten weeks following this diagnosis, the patient was prescribed oral iron, which resulted in a 1st postoperative year hemoglobin of 12.3 g/dl, substantially higher than the preoperative value.

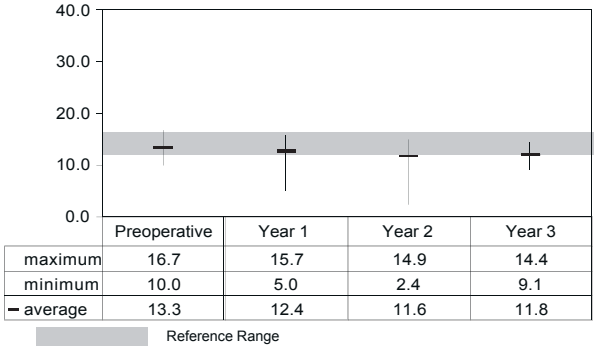


Figure 3. Average, minimum, and maximum hemoglobin over time.

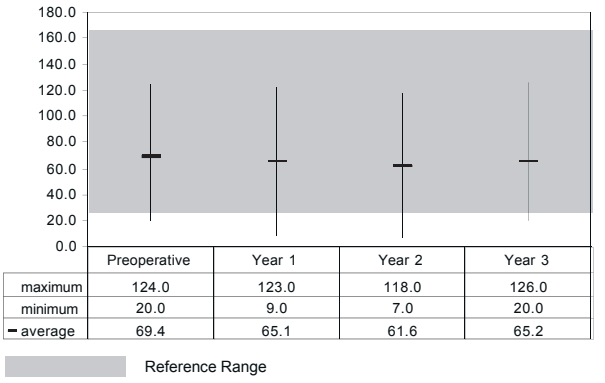


Figure 4. Average, minimum, and maximum iron over time.

Calcium Metabolism

Three measures indicating calcium metabolic status were tested: adjusted calcium; parathyroid hormone, intact (PTH); and alkaline phosphatase. The normal range for calcium is 8.5-10.0 mg/dl. As illustrated in Figure 5, preoperative mean values of 9.2 ± 0.02 (range 8.1-11.2) µg/dl decreased to 9.0 ± 0.03 (range 7.9-10.5) µg/dl in the 1st postoperative year, and then to 8.8 ± 0.04 (range 7.8-10.1) µg/dl and 8.7 ± 0.12 (range 7.9-9.5) µg/dl by the 2nd and 3rd years, with *P1* <0.0001 and *P2* <0.0001. PTH levels increased from a preoperative mean of 41.5 ± 1.31 (range 11-93) pg/mL to 69.2 ± 2.63 (range 8.3-180.0) pg/mL in the 1st year and 74.5 ± 5.20 (range 16-204) pg/mL in the 2nd year, with *P1* <0.0001, *P2*

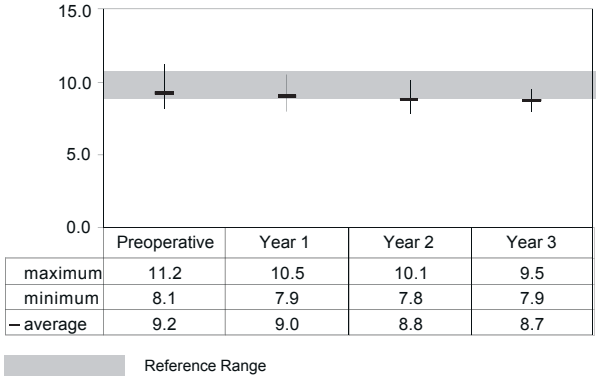


Figure 5. Average, minimum, and maximum corrected calcium over time.

<0.0001 and a reference range of 8-78 pg/mL (Figure 6). The sample size at year 3 was not sufficient for reporting purposes. The normal range for alkaline phosphatase is 39-117 IU/L (Figure 7). Alkaline phosphatase averages increased from 84.5 ± 0.96 (range 41-135) IU/L preoperatively to 95 ± 1.48 (range 38.0-163) IU/L, 97.8 ± 2.91 (range 45-178) IU/L, and 114 ± 10.10 (range 53-250) IU/L in the 1st, 2nd, and 3rd postoperative years, with *P1* <0.0001 and *P2* <0.0001. The high value of 250 IU/L in the 3rd year is derived from a patient who had obesity-related renal failure preoperatively.

Case Report

P.S., a 51-year-old female weighing 103 kg with a height of 160 cm (BMI 40 kg/m^2) underwent the DS in March, 2001. Preoperatively, her calcium measured 8.5 µg/dl. PTH values were not available. Her calcium tests remained stable until 12 months postoperatively, when she presented with a calcium of 8.0 mg/dl, below the recommended range, and PTH of 171.4 pg/mL, well above the reference ceiling of 117 pg/mL. Calcium citrate at a dose of 600 mg elemental calcium q.i.d. was prescribed, and by the 18th postoperative month, her calcium had increased above her preoperative marker to 8.7 mg/dl and her PTH decreased to 84 pg/mL. At 20 months, her calcium measured 8.9 mg/dL and her PTH, N-Terminal Specific was 20 pg/mL (normal range 8-24 pg/mL).

Protein Metabolism

Albumin and total protein were measured to indicate protein metabolism following the DS. The normal range for albumin is 3.5-5.0 g/dl. Averages decreased slightly from 4.0 ± 0.01 (range 3.3-4.8) g/dl pre-operatively to 3.9 ± 0.03 (range 1.7-6.8) g/dl, 3.8 ± 0.06 (range 1.8-6.7) gm/dl, and 3.9 ± 0.09 (range 2.9-4.7 g/dl) in the 1st, 2nd, and 3rd postoperative years, with *P1* <0.0001 and *P2* <0.0001 (Figure 8). Total protein, shown in Figure 9 and with a reference range of 6.0-8.3 g/dl, decreased from 7.4 ± 0.02 (range 5.4-9.0) g/dl preoperatively to 6.7 ± 0.04 (range 3.6-8.3) gm/dl in the 1st year, then stabilizing at a mean of 6.6 ± 0.05 g/dl in years 2 and 3, with minimums increasing to 5.1 and 5.6 gm/dl respectively (*P1* <0.0001 and *P2* <0.0001).

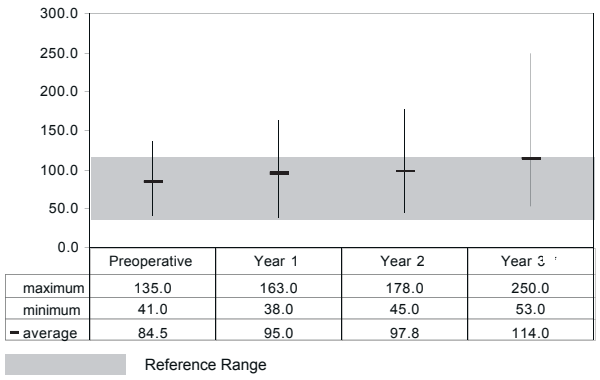


Figure 7. Average, minimum, and maximum alkaline phosphatase over time.

Case Report

J.M., a 34-year-old male with BMI 54 (weight 235 kg, height 191 cm), underwent LapDS in May 2002. Preoperatively, his total protein measured 7.4 g/dl and his albumin 3.2 g/dl. After 6 months, however, his total protein level decreased to 5.9 g/dl and his

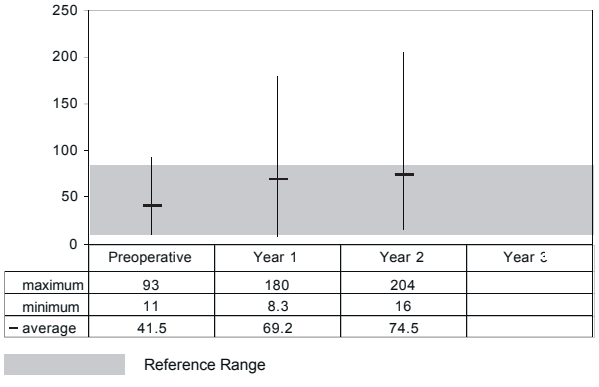


Figure 6. Average, minimum, and maximum intact parathormone, over time.

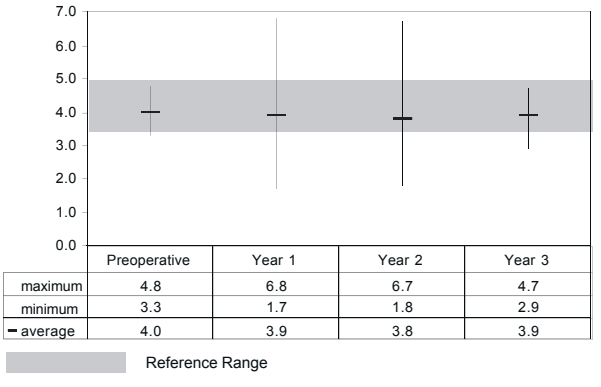
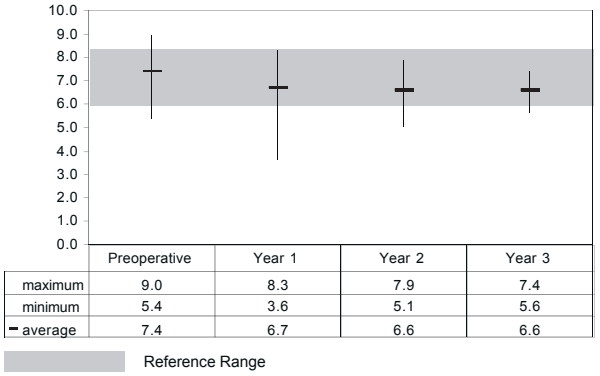


Figure 8. Average, minimum, and maximum albumin over time.



	Preoperative	Year 1	Year 2	Year 3
maximum	9.0	8.3	7.9	7.4
minimum	5.4	3.6	5.1	5.6
average	7.4	6.7	6.6	6.6

Figure 9. Average, minimum, and maximum total protein over time.

albumin level to 3.1 g/dl. The patient was prescribed a high protein diet with supplements that increased his protein intake to 60-80 grams per day. By the end of the 1st postoperative year, measures of protein metabolism had re-established themselves within the normal range with 6.2 g/dl total protein and 3.3 g/dl albumin. He was directed to continue his diet and protein supplements.

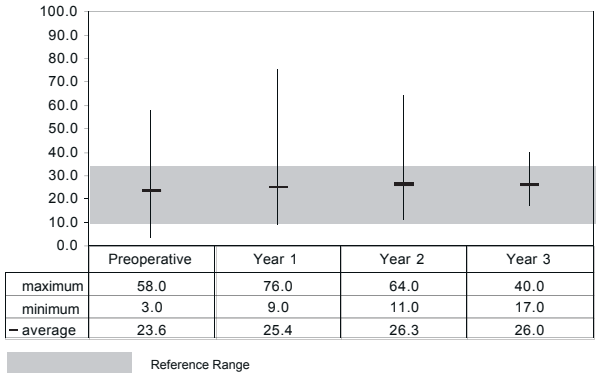
Hepatic Function

Three measures were each averaged to deduce hepatic changes following the DS: aspartate aminotransferase (AST), alanine transaminase (ALT), and bilirubin. The normal range for AST is 10-34 IU/L (Figure 10). Preoperative averages were 23.6 ± 0.41 (range 3-58) IU/L, which increased to 25.4 ± 0.54 (range 9-76) IU/L, 26.3 ± 0.96 (range 11-64) IU/L, and 26.0 ± 1.51 (range 17-40) IU/L during the 1st, 2nd, and 3rd postoperative years, with *P1* = 0.0380 and *P2* = 0.0066. ALT averages remained within the reference range of 7-31 IU/L, with a pre-operative average of 26.1 ± 0.67 (range 1-80) IU/L and an increase to 27.8 ± 0.72 (range 5-76) IU/L, 28.1 ± 1.23 (range 3-74) IU/L, and 30.5 ± 2.81 (range 12-56) IU/L in the following postoperative years, where *P1* = 0.0007 and *P2* = 0.164 (Figure 11). The normal range for bilirubin is 0.1-1.5 µg/dl. Preoperative values averaged 0.4 ± 0.01 (range 0.10-0.70) µg/dl, with postoperative means of 0.60 ± 0.02 (range 0.10-1.70) µg/dl in the 1st year, 0.52 ± 0.02 (range 0.20-1.30) µg/dl in the 2nd, and 0.40 ± 0.04 (range 0.10-0.90) µg/dl in the 3rd year, with *P1* <0.0001 and *P2* <0.0001 (Figure 12).

Discussion

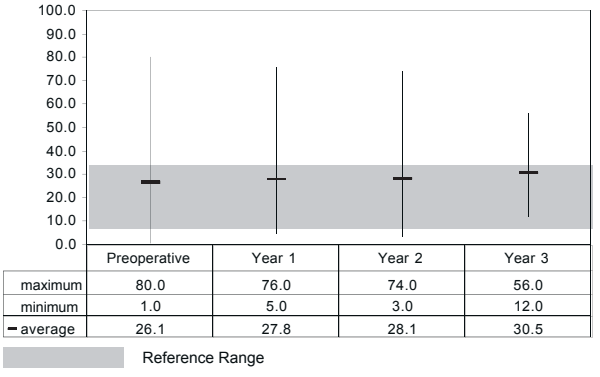
Unlike pure malabsorptive operations such as the jejunoileal bypass (JIB) operation, the DS is not associated with electrolyte imbalances or broad nutritional deficiencies. In our LapDS patients, the mean values demonstrate that the vast majority of nutritional markers – mean iron, mean corrected calcium, mean alkaline phosphatase, mean albumin, mean total protein, mean AST, ALT, and bilirubin – remain within the normal range. Only mean hemoglobin and mean PTH depart from the normal range.

Out-of-range values indicating iron deficiency are more prevalent among menstruating women, while reduced calcium absorption is associated with secondary elevated PTH levels. Decreases in the mechanical ability to absorb protein may call for dietary increases. As demonstrated in the case studies, iron and calcium supplementation offer success-



	Preoperative	Year 1	Year 2	Year 3
maximum	58.0	76.0	64.0	40.0
minimum	3.0	9.0	11.0	17.0
average	23.6	25.4	26.3	26.0

Figure 10. Average, minimum, and maximum aspartate aminotransferase over time.



	Preoperative	Year 1	Year 2	Year 3
maximum	80.0	76.0	74.0	56.0
minimum	1.0	5.0	3.0	12.0
average	26.1	27.8	28.1	30.5

Figure 11. Average, minimum, and maximum alanine transaminase over time.

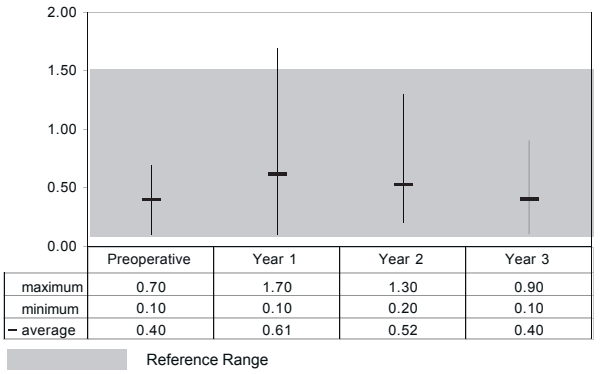


Figure 12. Average, minimum, and maximum bilirubin over time.

ful restorative treatment. However, these therapies necessitate patient compliance.

Elevations in AST and bilirubin stabilize or decrease by the 3rd postoperative year, as is to be expected following the stress attendant to any abdominal surgery. Elevations in ALT were significant between the pre- and postoperative periods but not significant when all time intervals were compared.

Diet-induced weight loss by itself is known to be associated with reversible bone loss.[8] Metabolic bone disease is associated with Crohn's disease and the other severe malabsorptive states such as following JIB.[9] Available studies of nutrition following biliopancreatic diversion (BPD), an woperation combining a limited gastrectomy with a short common channel, differ on the short- and long-term instances of morbidities such as metabolic bone disease. Compston et al[10] found a high incidence of metabolic bone disease after standard BPD with a 50-cm common channel, although vitamin D levels were normal in all patients. Marceau et al[11] found that bone itself was relatively tolerant to the metabolic changes due to BPD performed with a 100-cm common channel, and that bone loss at the hip depended upon albumin levels and protein nutrition. Hamoui et al[12] found that the length of the common channel in the DS influences hyperparathyroidism and out-of-range calcium metabolism values. Parada et al[13] reported 53% abnormally elevated PTH at 18 months following Roux-en-y gastric bypass, indicating that the alterations in calcium metabolism after LapDS are not unique to the DS. Instead, clinically significant calcium deficiency seen after both procedures may derive from the duodenal exclusion from the food stream, as well as the overall reduction in dietary calories and nutrients, common to both procedures. In contrast to calcium, Vanderhoof et al[14] found that zinc absorption is not impaired in the absence of pancreatic exocrine secretions. Since the DS entails a longer common channel than the BPD, bone changes after the BPD may be more pronounced when compared with the DS.

Conclusion

Laparoscopic duodenal switch for morbid obesity affords the absence of general electrolyte or nutritional deficiencies, available effective correction via oral supplementation if indicated, and superior sustained weight loss and quality of life.

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