Obesity Surgery (2019) 29:3062–3070
https://doi.org/10.1007/s11695-019-04019-8

NEW CONCEPT

One Anastomosis Gastric Bypass–Mini Gastric Bypass with Tailored Biliopancreatic Limb Length Formula Relative to Small Bowel Length: Preliminary Results

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Published online: 18 June 2019

Abstract

Background One Anastomosis Gastric Bypass–Mini Gastric Bypass (OAGB-MGB) is rapidly gaining popularity and is currently being performed by an increasing number of bariatric surgeons worldwide. However, excessive postoperative weight loss and malnutrition still remain a major concern regarding this procedure. The aim of this observational retrospective study was to investigate whether a tailored biliopancreatic limb (BPL) length relative to small bowel length (SBL) is superior to a fixed BPL length of 200 cm in terms of weight loss results and nutritional deficiencies in morbidly obese patients 1 year following OAGB-MGB.

Materials and Methods Sixty-four patients who underwent OAGB-MGB were divided into two consecutive groups depending on the BPL length used: fixed 200-cm BPL and tailored BPL groups. Anthropometric measurements (%EWL, TWL, %TWL) and nutritional parameters (vitamin A, vitamin D_3, vitamin B_{12}, serum iron, serum albumin, total protein) were compared between the two groups at 1-year follow-up.

Results No statistically significant differences were observed between the patients in two groups in terms of %EWL, TWL, %TWL. The number of patients with deficiencies of vitamin A ($p = 0.030$), vitamin D_3 ($p = 0.020$), and albumin ($p = 0.030$) was significantly higher in fixed 200-cm BPL group as compared with tailored BPL group, 1 year following OAGB-MGB. No statistically significant differences were seen between the patients in two groups in terms of vitamin B_{12}, iron, and total protein deficiencies.

Conclusion Tailoring BPL length by bypassing about 40% of the SBL seems to be safe and effective. According to preliminary results of this study, a tailored BPL length relative to SBL is even likely to be superior to the fixed 200-cm BPL as it is associated with less nutritional deficiencies while providing similar weight loss results. Further randomized studies with larger sample sizes and longer follow-up periods are necessary to confirm the primary results of this study.

Keywords One anastomosis gastric bypass–mini gastric bypass (OAGB-MGB) · Biliopancreatic limb (BPL) · Common limb (CL) · Small bowel length (SBL) · Small bowel measurement · Severe malnutrition · Bariatric surgery · Weight loss

Introduction

Currently, surgery is considered the most effective treatment modality for obesity and its related comorbidities. Bariatric surgery not only provides adequate and sustained weight loss but also ameliorates obesity-related diseases and improves the quality of life. Since the mid-twentieth century, many types of bariatric procedures have been introduced, each having its own advantages and disadvantages [1–3].

One Anastomosis Gastric Bypass–Mini Gastric Bypass (OAGB-MGB) was first described by Rutledge in 1997 [4]. Despite unique characteristics and promising weight loss results, the initial controversies surrounding OAGB-MGB have led to a gradual and cautious acceptance of this procedure by bariatric surgeons [5–9]. Nonetheless, the safety and efficacy of this procedure have recently been confirmed by several studies [10–15]. Currently, OAGB-MGB is recognized as a mainstream bariatric procedure and is being practiced by an increasing number of bariatric surgeons around the world [16–18].

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Although the popularity of OAGB-MGB is increasing, excessive postoperative weight loss and malnutrition still remain a major concern regarding this procedure [15, 19, 20]. In OAGB-MGB, maintaining an appropriate ratio between the lengths of biliopancreatic limb (BPL) and common limb (CL) is crucial. As human small bowel length (SBL) has been shown to be highly variable, an unreasonably long BPL in a significantly short small bowel can highly increase the risk of excessive postoperative weight loss and the occurrence of nutritional deficiencies [21–23].

Currently, there are no standard guidelines suggesting the most suitable BPL length for OAGB-MGB that can assure an appropriate balance between weight loss and nutritional deficiency [24]. Though the fixed BPL length of 200 cm, as described by Rutledge, is still the most frequently used, there are significant variations in the BPL lengths used by different surgeons [25]. Moreover, despite recommendations, the majority of bariatric surgeons do not routinely measure the SBL during the procedure due to technical difficulties and high risk of intestinal injury [26, 27]. In the light of new evidence on the variability in SBL and in order to decrease the risk of postoperative malnutrition and mortality, like many other bariatric surgeons around the world, since March 2017, a tailored BPL length formula has been adopted at our surgical unit. We presumed that intraoperative measurement of the SBL and bypassing about 40% of its entire length not only respect the principals of the original Rutledge technique to a high degree but also secure an adequate CL length, long enough to prevent severe postoperative weight loss and malnutrition.

The aim of this observational retrospective study was to investigate whether a tailored BPL length relative to SBL is superior to a fixed BPL length of 200 cm in terms of weight loss results and nutritional deficiencies in morbidly obese patients 1 year following OAGB-MGB.

Materials and Methods

Study Design

An observational retrospective study was undertaken on all morbidly obese patients ($n = 64$) who underwent OAGB-MGB from May 2015 to March 2018 in Surgical Oncology Division of Department of Human Pathology in Adulthood and Childhood "G. Barresi", academic teaching Hospital "G. Martino", University of Messina, Italy. The study was conducted after approval of the Hospital Ethics Committee. Informed written consent was obtained from all patients involved in the study. From May 2015 until March 2017, all OAGB-MGB procedures were performed according to standard Rutledge technique, using a fixed 200-cm BPL, without measurement of the SBL. From March 2017 until March 2018, all procedures were conducted using a tailored BPL length formula, after intraoperative measurement of the SBL and bypassing about 40% of its entire length. This technical change allowed us to retrospectively identify and review two consecutive series of patients: (1) patients who underwent OAGB-MGB with a fixed 200-cm BPL ($n = 32$) and (2) patients who underwent OAGB-MGB with a tailored BPL length relative to SBL ($n = 32$).

The inclusion criteria were age between 18 and 65 years, BMI ≥ 35 kg/m^2, and completion of the 1-year follow-up program. Exclusion criteria were previous gastrointestinal surgery, previous bariatric procedure, and failure of completion of the 1-year follow-up program. All 64 patients included in the study completed their 1-year follow-up.

Preoperative Workup

Preoperative workup included anthropometric measurements (age, gender, height in cm, weight in kg, BMI in kg/m^2, and EBW in kg), blood samples, ECG, echocardiography, chest x-ray, upper gastrointestinal endoscopy with antral biopsy for exclusion of macro- and microscopic gastric lesions, and histologic *Helicobacter pylori* screening, and if requested by anaesthesiologists, spirometry and polysomnography. Psychiatric counseling was conducted in all cases to exclude patients unsuitable for bariatric surgery. All patients with histologically proven *Helicobacter pylori* infection underwent standard eradication therapy preoperatively. Anti-thrombotic prophylaxis with low molecular weight heparin and appropriate antibiotic prophylaxis were administered in all patients prior to surgery.

Operative Technique

All procedures were performed laparoscopically by the same surgeon experienced in laparoscopic bariatric surgery. The consultant surgeon Navarra had performed about 85 laparoscopic biliopancreatic diversion procedures involving SBL measurement and 20 laparoscopic OAGB-MGB procedures prior to the commencement of the present study. Pneumoperitoneum was induced by a Veress needle, introduced at Palmer's point. Five laparoscopic ports were placed. An energy-based device (endo-surgery generator Harmonic®, Ultrasonic or Enseal®, Advanced Bipolar [Ethicon, Somerville, NJ], depending on availability) was used to enter the lesser sac via division of lesser omentum. The lesser curvature-based gastric pouch was created by transversal transection of the stomach starting 2–3 cm below the level of the crow's foot and extending proximally slightly to the angle of His using an endoscopic linear mechanical stapler (Echelon Flex™ Endopath® or Tri-Staple™ stapler [Ethicon], depending on availability). A 36F bougie dilator was used as a template to create the gastric pouch. In the first series of patients, a fixed point on the small bowel, about 200 cm distal to the ligament of Treitz, was selected to create BPL (fixed 200-cm BPL). The SBL was not measured in these patients. In the second series of patients, the SBL measurement was performed carefully on the antimesenteric border, by fully stretching the bowel, using atraumatic laparoscopic forceps marked at 10 cm. The SBL was measured from the ligament of Treitz to the ileocecal valve. Following verification of a CL length equal to or longer than 250 cm, a point about 40% of the total SBL distant to the ligament of Treitz was selected to create the BPL (tailored BPL length). An antecolic 3-cm-wide latero-lateral anastomosis was then created between the pouch and the intestinal loop using linear mechanical staplers. Manual closure and reinforcement of the anastomosis were performed by continuous suturing using V-lock. The anastomosis was tested for integrity by methylene blue dye introduced through the nasogastric tube. A draining tube was placed posteriorly to the site of anastomosis.

Postoperative Follow-up

Postoperatively, patients were managed with *nil* per os, electrolyte and fluid therapy, proton pump inhibitors, and antithrombotic prophylaxis. On the 3rd–4th postoperative day, all patients underwent a gastrografin swallow test to evaluate the integrity of anastomosis and to exclude any leakage. Thereafter, the nasogastric tube and intraperitoneal drain were removed and a liquid diet was initiated. All patients were regularly followed up at the 10th day, and consecutively on 3rd, 6th, and 12th months. Patients were encouraged to take a high protein diet (minimum 1 g/kg body weight daily), daily vitamin supplements (oral multivitamin tablets), and monthly vitamin B_{12} intramuscular injections. During each follow-up, anthropometric parameters were measured and nutritional status (total protein, serum albumin, serum iron, vitamin A, Vitamin D_3, and Vitamin B_{12}) were evaluated.

Statistical Analysis

Statistical analysis was performed using SPSS 20.0 for Windows package. Continuous variables were expressed as the mean ± standard deviation (SD). Baseline comparisons were performed using chi-square tests and *t* tests. A two-sided *p* value of < 0.05 was considered statistically significant. Microsoft Excel 2010 for Windows was used to demonstrate the graphical presentation.

Results

A retrospective review of demographic and clinical data of 64 consecutive patients who underwent OAGB-MGB between May 2015 and March 2018 and completed their 1-year follow-up was performed. A total of 79.7% of the patients were female, and the mean age was 43.3 ± 9.4 years (range, 24–65 years). The mean height was 163.8 ± 8.2 cm (range, 150–193 cm). The average preoperative weight and BMI were 119.0 ± 21.1 kg (range, 88.0–175.0 kg) and 44.2 ± 5.8 kg/m^2 (range, 35.2–60.2 kg/m^2), respectively. The mean excess body weight (EBW) was 51.4 ± 16.7 kg (range, 26.0–94.6 kg). No statistically significant differences were observed between the patients in two groups in terms of age, height, weight, BMI, and EBW at the time of surgery. The preoperative demographics of the entire sample and individual groups are summarized in Table 1.

The patients were categorized into two groups based on the BPL length used: the fixed 200-cm BPL and the tailored BPL groups, each comprising 32 patients. Table 2 demonstrates the SBL, BPL, and CL lengths in the tailored BPL group. The average measured SBL of patients in the tailored BPL group was 625.6 ± 110.5 cm, with the shortest and longest SBLs

Table 1 Preoperative demographic in the entire sample, 200-cm BPL group, and tailored BPL group

	Entire sample		200-cm BPL		Tailored BPL		
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	*p* value
Number	64 (100%)	–	32 (50%)	–	32 (50%)	–	–
Gender							
Male	13 (20.3%)	–	6 (18.8%)	–	7 (21.9%)	–	–
Female	51 (79.7%)	–	26 (81.2%)	–	25 (78.1%)	–	–
Age (years)	43.3 ± 9.4	24.0–65.0	42.3 ± 9.7	24.0–65.0	44.4 ± 9.1	28.0–62.0	0.369
Height (cm)	163.8 ± 8.2	150.0–193.0	164.2 ± 9.6	150.0–193.0	163.4 ± 6.8	154.0–182.0	0.685
Weight (kg)	119.0 ± 21.1	88.0–175.0	117.2 ± 18.9	88.0–175.0	120.8 ± 23.4	88.0–172.0	0.497
BMI (kg/m2)	44.2 ± 5.8	35.2–60.2	43.3 ± 4.4	36.5–54.1	45.0 ± 6.9	35.2–60.2	0.234
EBW (kg)	51.4 ± 16.7	26.0–94.6	49.5 ± 13.4	31.6–81.9	53.3 ± 19.4	26.0–94.6	0.364

Table 2 Small bowel length, biliopancreatic limb length, and common limb length in tailored BPL group

Patient	Total small intestine length (cm)	BPL length (cm)	Common limb length (cm)
1	500	200	300
2	620	250	370
3	410	160	250
4	600	240	360
5	720	290	430
6	750	300	450
7	820	330	490
8	570	230	340
9	600	240	360
10	570	230	340
11	630	250	380
12	630	250	380
13	570	230	340
14	550	220	330
15	680	270	410
16	600	240	360
17	720	290	430
18	600	240	360
19	550	220	330
20	550	220	330
21	930	370	560
22	810	320	490
23	550	220	330
24	500	200	300
25	600	240	360
26	650	260	390
27	710	280	430
28	550	220	330
29	540	220	320
30	600	240	360
31	810	320	490
32	530	210	320
	Mean: 625.6 ± 110.5 cm	Mean: 250.0 ± 43.8 cm	Mean: 375.6 ± 66.8 cm
	Range: 410–930 cm	Range: 160–370 cm	Range: 250–560 cm

being 410 and 930 cm, respectively. The mean tailored BPL length was 250.0 ± 43.8 cm, with the shortest and longest BPL lengths used being 160 and 370 cm, respectively. The mean CL length was 375.6 ± 66.8 cm, with the shortest and longest CL lengths being 250 and 560 cm, respectively. The mean intervention time was 97.0 ± 14.0 min in the 200-cm BPL group and 116.0 ± 16.0 min in the tailored BPL group. No intra- and postoperative complications such as hemorrhage, bowel perforation, anastomotic dehiscence, or need for conversion to open surgery were recorded in any of the groups.

One year following the surgery, the average weight was 77.6 ± 13.3 kg in 200-cm BPL group and 80.1 ± 14.9 kg in tailored BPL group. The mean BMI was 28.8 ± 4.1 kg/m^2 in the 200-cm BPL group and 29.9 ± 4.5 kg/m^2 in tailored BPL group. The average %EWL achieved was 66.2 ± 17.1% in 200-cm BPL and 63.3 ± 13.7% tailored BPL groups, while the average TWL was 39.6 ± 12.5 kg for 200-cm BPL and 40.7 ± 13.4 kg for tailored BPL groups. The mean %TWL was 33.4 ± 7.9% and 33.3 ± 6.6%, in 200-cm BPL and tailored BPL groups. No statistically significant differences were observed between the patients in two groups in terms of %EWL, TWL, and %TWL, at 1-year follow-up (Table 3).

Regarding the nutritional deficiencies, vitamin A deficiency was noted in 31.2% and 9.4%, and vitamin D_3 deficiency was present in 28.1% and 6.2% of the patients in 200-cm BPL and tailored BPL groups, respectively.

Table 3 Weight loss results in 200-cm BPL and tailored BPL groups at 1-year postoperative period

	200-cm BPL		Tailored BPL		*p* value
	Mean ± SD	Range	Mean ± SD	Range	
Weight (kg)	77.6 ± 13.3	61.0–120.0	80.1 ± 14.9	54.0–116.0	0.476
BMI (kg/m2)	28.8 ± 4.1	20.7–38.0	29.9 ± 4.5	21.1–39.7	0.289
%EWL	66.2 ± 17.1	28.3–112.7	63.3 ± 13.7	31.2–95.7	0.467
TWL (kg)	39.6 ± 12.5	14.0–71.0	40.7 ± 13.4	15.0–80.0	0.756
%TWL	33.4 ± 7.9	14.5–51.4	33.3 ± 6.6	15.6–50.0	0.929

Vitamin B_{12} deficiency was seen in 12.5% of the patients in the 200-cm BPL group and 6.2% of the patients in the tailored BPL group. Statistically significant differences were observed between the patients in two groups in terms of vitamin A deficiency ($p = 0.030$) and vitamin D_3 deficiency ($p = 0.020$), whereas the difference between the two groups in terms of vitamin B_{12} deficiency was not statistically significant ($p = 0.391$).

In the 200-cm BPL group, 18.7% of the patients had iron deficiency, while 12.5% of the patients in the tailored BPL group presented with iron deficiency. The difference between the number of patients having iron deficiency in the two groups was not statistically significant ($p = 0.491$). Hypoalbuminemia was seen in 31.2% and 9.4% of the patients in 200-cm BPL and tailored BPL groups, respectively. The difference between the patients in two groups in terms of albumin deficiency was statistically significant ($p = 0.030$). Total protein deficiency was observed in 21.9% and 12.5% of the patients in 200-cm BPL and tailored BPL groups, respectively; however, this difference was not statistically significant ($p = 0.320$). Figure 1 summarizes the percentage of patients with nutritional deficiencies in 200-cm BPL and tailored BPL length groups.

During the 1-year follow-up, 25.0% of the patients in the 200-cm BPL group and 6.2% of the patients in the tailored BPL group complained of frequently occurring diarrhea. The difference between patients in two groups complaining of frequent diarrhea was statistically significant ($p = 0.039$).

Three patients were readmitted during the first postoperative year. One female patient was readmitted 11 months after surgery with severe anemia (Hb = 5.6 g%) and treated conservatively with blood transfusions and intravenous iron supplementation. The other two patients were readmitted at 9th and 10th months, respectively, for weakness and profuse diarrhea. Both patients were managed conservatively with parenteral nutrition and intravenous vitamin supplementation. All three patients belonged to the first group and had undergone OAGB-MGB with a fixed 200-cm BPL length. None of the patients presented with severe malnutrition, requiring re-admission for revisional surgery.

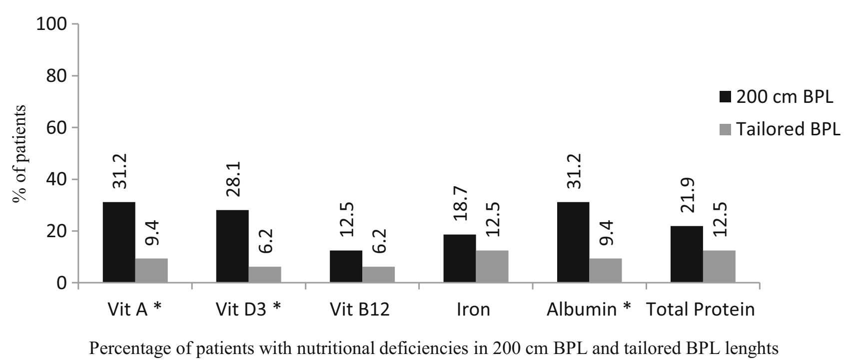

Fig. 1 Percentage of patients with nutritional deficiencies in 200-cm BPL and tailored BPL length groups. *Significance defined as $p < 0.05$. Vitamin A deficiency was seen in 31.2% of the patients in the 200-cm BPL group and 9.4% of patients in the tailored BPL group ($p = 0.030$). Vitamin D_3 deficiency was seen in 28.1% of the patients in the 200-cm BPL group and 6.2% of the patients in the tailored BPL group ($p = 0.020$). Vitamin B_{12} deficiency was seen in 12.5% of the patients in the 200-cm BPL group and 6.2% of the patients in the tailored BPL group ($p = 0.391$). Iron deficiency was seen in 18.7% of the patients in the 200-cm BPL group and 12.5% of the patients in the tailored BPL group ($p = 0.491$). Albumin deficiency was seen in 31.2% of the patients in the 200-cm BPL group and 9.4% of the patients in the tailored BPL group ($p = 0.030$). Total protein deficiency was seen in 21.9% of the patients in the 200-cm BPL group and 12.5% of the patients in the tailored BPL group ($p = 0.320$)

Discussion

OAGB-MGB is rapidly gaining popularity owing to multiple advantages such as rather technical simplicity, short operative time, and excellent weight loss and comorbidity resolution results [15, 28]. Despite the earlier controversies surrounding OAGB-MGB, the safety and efficacy of this procedure in terms of weight loss and metabolic improvements have lately been approved by many authors [16, 29]. Nevertheless, the excessive postoperative weight loss and protein-calorie malnutrition following OAGB-MGB still remain a major concern [30–32], with a reported range up to 0.9–1.2% [33, 34], requiring revisional surgery in around 0.7% of the cases [35].

The major known function of the small intestine is the absorption of macro- and micronutrients [24]. Like other malabsorptive bariatric procedures, OAGB-MGB involves bypassing the proximal segment of the small bowel. Clearly, the longer the length of the bypassed small intestine, the better the weight loss results, but at the same time, the higher the risk of occurrence of nutritional deficiencies. On the contrary, an insufficient bypassing of the small intestine might result in unsatisfactory weight loss and comorbidity resolution results [36–39].

Despite the various consensus and continuous attempts, still, there are no standard guidelines regarding the most suitable BPL length in OAGB-MGB that would yield a counterbalance between weight loss and nutritional deficiency. Various limb lengths have been used and reported by several authors, from 150 [40] to 200 cm [13, 14, 41, 42], to a tailored BPL length formula according to BMI [43]. However, a BPL length of about 200 cm from the ligament of Treitz is still the one used most frequently [25, 44]. Moreover, although due to variations in SBL in humans, the measurement of the entire small bowel is recommended to guarantee an adequate length of the CL [33, 45], only around 25% of the surgeons routinely do so [25]. Technical challenges associated with laparoscopic measurement of SBL, risk of intestinal and neighboring organ injury, and prolongation of the operative time are possible explanations for the surgeon's hesitancy on SBL measurements [26, 27]. Additionally, there is no consensus regarding the best method for laparoscopic SBL measurement. Animal studies performed laparoscopically have demonstrated an overestimation of the SBL by more than 30% [46].

According to original OAGB-MGB described by Rutledge, a fixed point about 200 cm distal to the ligament of Treitz is to be used to construct the gastro-entero anastomosis in OAGB-MGB [4], hence bypassing around 30–40% of the proximal segment of the small intestine of about 5- to 6-m long. The selection of a fixed 200-cm BPL has shown to be suitable for most, but not for all patients as the variation in SBL in humans is a conflicting subject. The average length of the small intestine has been reported to vary from 3 to 10 m [47]. Therefore, measurement of the SBL prior to the creation of gastro-entero anastomosis appears to be a wise approach as it secures an adequate length of the CL. A too short or too long CL can increase the risk of postoperative malnutrition or inadequate weight loss, respectively. In our series, the shortest measured SBL was 410 cm; using a 200-cm BPL would have left a CL of about 210-cm long with an increased risk of postoperative protein-calorie malnutrition. On the contrary, the longest measured SBL was 930 cm; therefore, a fixed BPL length of 200 cm would have left a CL of about 730-cm long which would have probably resulted in unsatisfactory weight loss results.

Over the last decade, the concept of tailored BPL in OAGB-MGB has been introduced. Lee et al. [43] reported a tailored BPL approach incorporating different bypass limb length according to the patient's BMI. However, Tacchino [47] reported that weight is not a determinant of bowel length and found no correlation between obesity and SBL. Although the correlation of SBL variability with some anthropometrical factors (age, gender, weight, and height) has been previously studied, only height has been reported to be an independent predictor of increased SBL [48]. Nevertheless, height has shown to be a poor predictor of the SBL variability with low reliability [47, 49]. Moreover, in Teitelbaum's study, height correlated with increased SBL in men, whereas in women it did not [49]. In our study, 79.7% of the sample comprised of women, which coincides with the majority of the published studies observing a predominance of women subjected to bariatric surgery [24, 50, 51]. Overall, the evidence on the correlation of SBL and anthropometric parameters such as height is still very weak and the topic is subjected to further research. The prediction of SBL based on the anthropometric factors alone and increasing BPL length without intraoperative SBL measurement might lead to catastrophic nutritional consequences.

The current study aimed to demonstrate the effects of the fixed 200-cm BPL versus the tailored BPL length formula according to SBL in two consecutive series of patients in terms of weight loss results and nutritional deficiencies. Both groups had satisfactory weight loss results 1 year following the surgery. The %EWL was 66.2% and 63.3% in 200-cm and tailored BPL groups, respectively. The reported TWL in the 200 cm group was 39.6 kg, while in the tailored BPL group was 40.7 kg. The %TWL was 33.4% and 33.3% in 200-cm and tailored BPL groups, respectively. No statistically significant differences were observed in weight loss results between the two groups at 1-year follow-up.

On comparing vitamin deficiencies, more patients with 200-cm BPL length had deficiencies of vitamins A, D_3, and B_{12} as compared with patients with a tailored BPL length. These differences were statistically significant in cases of vitamins A ($p = 0.030$) and D_3 ($p = 0.020$) deficiencies. The lack of a statistically significant difference in vitamin B_{12} deficiency between the two groups ($p = 0.391$) can be explained by the fact that all patients were prescribed monthly intramuscular vitamin B_{12} injections in addition to oral multivitamin supplements.

In terms of iron deficiency, no statistically significant difference was seen between the two groups ($p = 0.491$). One female patient with 200-cm BPL was readmitted with severe anemia (Hb = 5.6 g%) and generalized weakness 11 months after surgery. The patient was not taking supplements as prescribed and referred abundant bleedings during menstrual cycles. The patient was treated conservatively with blood transfusions and intravenous iron supplementation and was referred to the gynecology department for further investigations. Iron deficiency in patients with OAGB-MGB is the result of bypassing the acidic environment of the stomach and the absorptive surface of the duodenum and proximal jejunum, the major sites of iron absorption. Therefore, no real benefits regarding serum iron levels should be expected by alterations in BPL length, as the proximal small intestine is excluded in all cases of OAGB-MGB. The iron deficiency is more pronounced in the presence of chronic blood loss or in woman in reproductive age, as well as a vegetarian diet with reduced intake of organic (heme) iron [24].

Regarding albumin deficiency, 31.2% of the patients in the 200-cm BPL group and 9.4% of the patients in the tailored BPL group presented with subclinical hypoalbuminemia. The difference between the two groups was statistically significant ($p = 0.030$). Total protein deficiency was observed in 21.9% and 12.5% of the patients in 200-cm BPL and tailored BPL groups, respectively. The difference between the patients with total protein deficiency in the two groups was not statistically significant ($p = 0.320$). Lately, the reported cases of death of two patients due to severe protein deficiency and hepatic failure following OAGB-MGB utilizing 200-cm BPL length have raised significant concerns [52, 53]. Kruschitz et al. [54] reported significantly poorer liver function in patients undergoing OAGB-MGB as compared with RYGB in the first year not associated with weight loss, requiring a more careful postoperative follow-up.

During the periodic follow-ups, 25.0% of the patients in the 200-cm BPL group and 6.2% of the patients in the tailored BPL group complained of frequently occurring diarrhea. The difference between the two groups was statistically significant ($p = 0.039$). Two patients were readmitted at 9th and 10th months, respectively for generalized weakness and profuse diarrhea. Both patients were managed conservatively with parenteral nutrition and intravenous vitamin supplementation.

To the best of our knowledge, the current single-center study tends to be the first in the literature to report the preliminary results of tailored BPL length formula relative to SBL in OAGB-MGB. The aims of our study design were twofold: to have optimal weight loss results, while limiting excessive postoperative weight loss and malnutrition. As a consequence, it was decided to tailor the BPL length relative to the SBL, following verification of a CL length equal to or longer than 250 cm, hence long enough to minimize the risk of postoperative malnutrition.

We observed that intraoperative measurement of the SBL and bypassing about 40% of its length result in less nutritional deficiencies compared with standard fixed 200-cm BPL length while providing similar weight loss results. Although the information regarding SBL in the 200-cm BPL group is lacking, significant nutritional differences between the two groups could have probably been either due to (1) higher number of patients in the 200-cm BPL group with significantly short SBL (< 500 cm) or (2) shorter mean SBL of the patients in the 200-cm BPL group. Nonetheless, these observations actually highlight the importance of intraoperative SBL measurement and tailored BPL length formula according to SBL in OAGB-MGB. In the current study, the measurement of the SBL increased the intervention time by around 19 min. However, considering the highly variable SBL, and huge risk associated with nutritional consequences, it is wise to measure the SBL, even at the expense of increasing the intervention time.

Limitations

This study had some limitations. Firstly, the sample size of 64 patients is small and follow-up program of 1 year is short. Secondly, the mean SBL length in the 200-cm BPL group is not clear or could be estimated based on anthropometric factors alone. Finally, this is an observational retrospective analysis of the data; instead, a randomized control trial would have been more useful.

Conclusion

OAGB-MGB is rapidly gaining popularity among bariatric surgeons all around the world. Measuring the entire length of the small bowel and a reasonable BPL length relative to SBL is crucial to prevent postoperative nutritional deficiencies or unsatisfactory weight loss results. Tailoring BPL length by bypassing about 40% of the SBL seems to be safe and effective. According to preliminary results of this study, a tailored BPL length relative to SBL is even likely to be superior to the fixed 200-cm BPL as it is associated with less nutritional deficiencies, but with similar weight loss results. Further randomized studies with larger sample sizes and longer follow-up periods are necessary to confirm the primary results of this study.

Compliance with Ethical Standards

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

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

Statement of Human and Animal Rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

1. Buchwald H, Estok R, Fahrbach K, et al. Weight and type 2 diabetes after bariatric surgery: a systematic review and meta-analysis. Am J Med. 2009;122:248–56.
2. De Luca M, Angrisani L, Himpens J, et al. Indications for surgery for obesity and weight-related diseases: position statements from the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO). Obes Surg. 2016;26:1659–96.
3. Sjöström L, Narbo K, Sjöström CD, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. N Engl J Med. 2007;357:741–52.
4. Rutledge R. The mini gastric bypass: experience with the first 1,274 cases. Obes Surg. 2001;11:276–80.
5. Fisher BL, Buchwald H, Clark W, et al. Mini-gastric bypass controversy. Obes Surg. 2001;11:773–7.
6. Olchowski S, Timms MR, O'Brien P, et al. More on mini gastric bypass controversy. Obes Surg. 2001;11:532.
7. Mahawar KK, Carr WR, Balupuri S, et al. Controversy surrounding "mini" gastric bypass. Obes Surg. 2014;24:324–33.
8. Madhok B, Mahawar KK, Boyle M, et al. Management of super-super obese patients: comparison between mini (one anastomosis) gastric bypass and sleeve gastrectomy. Obes Surg. 2016;26:1646–9.
9. Parmar C, Abdelhalim MA, Mahawar KK, et al. Management of super-super obese patients: comparison between one anastomosis (mini) gastric bypass and Roux-en-Y gastric bypass. Surg Endosc. 2017;31:3504–9.
10. Lee WJ, Ser KH, Lee YC, et al. Laparoscopic Roux-en-Y vs. mini-gastric bypass for the treatment of morbid obesity: a 10-year experience. Obes Surg. 2012;22:1827–34.
11. Noun R, Skaff J, Riachi E, et al. One thousand consecutive mini-gastric bypass: short- and long-term outcome. Obes Surg. 2012;22: 697–703.
12. Musella M, Susa A, Greco F, et al. The laparoscopic mini-gastric bypass: the Italian experience: outcomes from 974 consecutive cases in a multicenter review. Surg Endosc. 2014;28:156–63.
13. Kular KS, manchanda N, Rutledge R. A 6-year experience with 1, 054 mini-gastric bypasses-first study from Indian subcontinent. Obes Surg. 2014;24:1430–5.
14. Chevallier JM, Arman GA, Guenzi M, et al. One thousand single anastomosis (omega loop) gastric bypasses to treat morbid obesity in a 7-year period: outcomes show few complications and good efficacy. Obes Surg. 2015;25:951–8.
15. Mahawar KK, Jennings N, Brown J, et al. "Mini" gastric bypass: systematic review of a controversial procedure. Obes Surg. 2013;23:1890–8.
16. De Luca M, Tie T, Ooi G, et al. Mini gastric bypass-one anastomosis gastric bypass (MGB-OAGB)-IFSO position statement. Obes Surg. 2018;28:1188–206.
17. Deitel M. Letter to the editor: bariatric surgery worldwide 2013 reveals a rise in mini gastric bypass. Obes Surg. 2015;25:2165.
18. Angrisani L, Santonicola A, Iovino P, et al. Bariatric surgery worldwide 2013 reveals a rise in mini gastric bypass. Obes Surg. 2015;25:2165.
19. Mahawar KK, Parmar C, Carr WEJ, et al. Impact of biliopancreatic limb length on severe protein-calorie malnutrition requiring revisional surgery after one anastomosis (mini) gastric bypass. JMAS. 2018;14:37–43.
20. Genser L, Soprani A, Tabbara M, et al. Laparoscopic reversal of mini-gastric bypass to original anatomy for severe postoperative malnutrition. Langenbeck's Arch Surg. 2017;402:1263–70.
21. Lee S, Sahagian KG, Schriver JP. Relationship between varying Roux limb lengths and weight loss in gastric bypass. Curr Surg. 2006;63:259–63.
22. Brolin RE, LaMarca LB, Kenler HA, et al. Malabsoptive gastric bypass in patients with superobesity. J Gastrointest Surg. 2002;6: 195–203.
23. Nelson WK, Fatima J, Houghton SG, et al. The malbsorptive very, very long limb Roux-en-Y gastric bypass for super obesity: results in 257 patients. Surgery. 2006;140:517–22.
24. Ahuja A, Tantia O, Goyal G, et al. MGB-OAGB: effect of biliopancreatic limb length on nutritional deficiency, weight loss, and comorbidity resolution. Obes Surg. 2018;28:3439–45.
25. Mahawar KK, Kular KS, Parmar C, et al. Perioperative practices concerning one anastomosis (mini) gastric bypass: a survey of 210 surgeons. Obes Surg. 2018;28:204–11.
26. Van der Voort M, Heijnsdijk EAM, Gouma DJ. Bowel injury as a complication of laparoscopy. Br J Surg. 2004;91:1253–8.
27. Bishoff JT, Allaf ME, Kirkels W, et al. Laparoscopic bowel injury: incidence and clinical presentation. J Urol. 1999;161:887–90.
28. Georgiadou D, Sergentanis TN, Nixon A, et al. Efficacy and safety of laparoscopic mini-gastric bypass. A systematic review. Surg Obes Relat Dis. 2014;10:984–91.
29. Deitel M. Mini-gastric (one-anastomosis) bypass becoming a mainstream operation. Bariatric News. 2013;(18)13.
30. Cavin JB, Voitellier E, Cluzeaud F, et al. Malabsorption and intestinal adaptation after one anastomosis gastric bypass compared with Roux-en-Y gastric bypass in rats. Am J Physiol Gastrointest Liver Physiol. 2016;311:492–500.
31. Bètry C, Disse E, Chambrier C, et al. Need for intensive nutrition care after bariatric surgery: is mini gastric bypass at fault? JPEN J Parenter Enteral Nutr. 2016;41:258–62.
32. Jammu GS, Sharma R. A 7-year clinical audit of 1107 cases comparing sleeve gastrectomy, Roux-En-Y gastric bypass, and mini gastric bypass, to determine an effective and safe bariatric and metabolic procedure. Obes Surg. 2016;26:926–32.
33. Carbajo MA, Luque-de-León E, Jiménez JM, et al. Laparoscopic one-anastomosis gastric bypass: technique, results, and long-term follow-up in 1200 patients. Obes Surg. 2017;27:1153–67.
34. Rutledge R, Walsh W. Continued excellent results with the mini-gastric bypass: six-year study in 2410 patients. Obes Surg. 2005;15: 1304–8.
35. Lee WJ, Lee YC, Ser KH, et al. Revisional surgery for laparoscopic minigastric bypass. Surg Obes Relat Dis. 2011;7:486–91.
36. Scopinaro N, Gianetta E, Civalleri D, et al. Bilio-pancreatic bypass for obesity: initial experience in man. Br J Surg. 1979;66:618–20.
37. Sugerman HJ, Kellum JM, DeMaria EJ. Conversion of proximal to distal bypass for failed gastric bypass for superobesity. J Gastrointest Surg. 1997;1:517–26.
38. Brolin RE, Cody RP. Adding malabsorption for weigh loss failure after gastric bypass. Surg Endosc. 2007;21:1924–6.

39. McConnell DB, O'Rourke RW, Deveney CW. Common channel length predicts outcomes of biliopancreatic diversion alone and with the duodenal switch surgery. Am J Surg. 2005;189:536–40.
40. Himpens JM, Vilallonga R, Cadière GB, et al. Metabolic consequences of the incorporation of a roux limb in an omega loop (mini) gastric bypass: evaluation by a glucose tolerance test at mid-term follow-up. Surg Endosc. 2016;30:2935–45.
41. Carbajo M, García-caballero M, Toledano M, et al. One-anastomosis gastric bypass by laparoscopy: results of the first 209 patients. Obes Surg. 2005;15:398–404.
42. Parmar CD, Mahawar KK, Boyle M, et al. Mini gastric bypass: first report of 125 consecutive cases from United Kingdom. Clin Obes. 2016;6:61–7.
43. Lee WJ, Wang YC, Lee MT, et al. Laparoscopic mini-gastric bypass: experience with tailored bypass limb according to body weight. Obes Surg. 2008;18:294–9.
44. Mahawar KK, Himpens J, Shikora SA, et al. The first consensus statement on one anastomosis/mini gastric bypass (OAGB/MGB) using a modified Delphi approach. Obes Surg. 2018;28:303–12.
45. Madan AK, Harper JL, Tichansky DS. Techniques of laparoscopic gastric bypass: on-line survey of American Society for Bariatric Surgery practicing surgeons. Surg Obes Relat Dis. 2008;4:166–72.
46. Gazer B, Rosin D, Bar-Zakai B, et al. Accuracy and inter-operator variability of small bowel length measurement at laparoscopy. Surg Endosc. 2017;31:4697–704.
47. Tacchino RM. Bowel length: measurement, predictors, and impact on bariatric and metabolic surgery. Surg Obes Relat Dis. 2015;11:328–34.
48. Marie L, Nacache R, Scemama U, et al. Preoperative prediction of small bowel length using CT scan and tridimensional reconstructions: a new tool in bariatric surgery? Obes Surg. 2018;28:1217–24.
49. Teitelbaum EN, Vaziri K, Zettervall S, et al. Intraoperative small bowel length measurements and analysis of demographic predictors of increased length. Clin Anat. 2013;26:827–32.
50. AbdullGaffar B, Raman L, Khamas A, et al. Should we abandon routine microscopic examination in bariatric sleeve gastrectomy specimens? Obes Surg. 2016;26:105–10.
51. Raess PW, Baird-Howell M, Aggarwal R, et al. Vertical sleeve gastrectomy specimens have a high prevalence of unexpected histopathologic findings requiring additional clinical management. Surg Obes Relat Dis. 2015;11:1020–3.
52. Kermansaravi M, Abdolhosseini MR, Kabir A, et al. Severe hypoalbuminemia and steatohepatitis leading to death in a young vegetarian female, 8 months after mini gastric bypass: a case report. Int J Surg Case Rep. 2017;31:17–9.
53. Motamedi MAK, Barzin M, Ebrahimi M, et al. Severe fatal protein malnutrition and liver failure in a morbidly obese patient after mini-gastric bypass surgery: case report. Int J Surg Case Rep. 2017;33:71–4.
54. Kruschitz R, Luger M, Kienbacher M. The effect of Roux-en-Y vs omega-loop gastric bypass on liver, metabolic parameters, and weight loss. Obes Surg. 2016;26:2204–12.