Original Article

Weight loss after one-anastomosis/mini-gastric bypass – The impact of biliopancreatic limb: A retrospective cohort study

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Background: One-anastomosis/mini-gastric bypass (OAGB/MGB), as a popular bariatric surgery method, has many advantages; however, the biliopancreatic limb length (BPL) in this surgery is under debate. The aim of the study was to evaluate the effect of BPL on weight-loss outcome after OAGB/MGB. **Materials and Methods:** A retrospective cohort study was performed on 653 patients who underwent OAGB/MGB with adjusted BPL based on preoperative body mass index (BMI) and patient's age, between 2010 and 2015 with 12-month follow-ups. Weight-loss outcomes and complications were analyzed in these patients, considering BPL. **Results:** Weight, age, sex, and type 2 diabetes mellitus were the most contributory predictors as independent predictors of 12-month excess weight loss, respectively, and BPL was the least contributory predictor. **Conclusion:** Tailoring BPL in OAGB/MGB based on patient's age and preoperative BMI seems to have acceptable results.

Key words: Biliopancreatic limb, mini-gastric bypass, one-anastomosis gastric bypass, weight loss

How to cite this article: Kermansaravi M, Pishgahroudsari M, Kabir A, Abdolhosseini MR, Pazouki A. Weight loss after one-anastomosis/mini-gastric bypass – The impact of biliopancreatic limb: A retrospective cohort study. J Res Med Sci 2020;25:5.

INTRODUCTION

Bariatric surgery is proven as the most effective and durable treatment of morbid obesity that in addition to weight loss can lead to improving its related comorbidities and decreasing the incidence of some malignancies, improving quality of life, and increasing life expectancy.[1-3]

One very effective method of bariatric surgery that has become popular worldwide is laparoscopic mini-gastric bypass (MGB) that was performed by Rutledge in 1997 and presented in 2001 that contains a long and narrow lesser curvature-based pouch that is cut distal to crow's foot and continues vertically as a tube to the left side of His angle that is finally anastomosed with an omega-shaped jejunal loop, nearly in a distance of 180–220 cm from ligament of Treitz usually in side-to-side fashion.[2,4,5]

Due to durable and good effects, relative simplicity, short duration of surgery, very low and manageable complications, simple reversibility, short learning curve for surgeons, very low weight regain, and only one anastomosis, the one-anastomosis/MGB (OAGB/MGB) is now considered around the world as a recognized bariatric procedure[6] and an alternative method for Roux-en-Y gastric bypass (RYGB), the gold standard bariatric procedure.[2,4,5,7,8]

To perform a more effective and safer operation, all aspects of the method should be known. One of the important debates in OAGB/MGB is identifying the biliopancreatic limb length (BPL), the distance from

Access this article online

Quick Response Code:

Website: www.jmsjournal.net

DOI: 10.4103/jrms.JRMS_117_19

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Received: 18-03-2019; **Revised:** 17-08-2019; **Accepted:** 24-10-2019; **Published:** 20-01-2020

ligament of Treitz. Most of the studies have analyzed the weight-loss outcome of costume OAGB/MGB with constant BPL, but few studies have considered the association between BPL and weight-loss outcomes after it. In fact, some studies recommend tailoring BPL based on some factors as body mass index (BMI) and indicated that BPL has an association with weight-loss outcome, but others emphasize that BPL has no effect on weight loss, especially in nonsuper-obese patients.[9,10]

It is here hypothesize that after OAGB/MGB, there is a correlation between BPL and trends of 1-year weight-loss outcomes.

MATERIALS AND METHODS

This is a retrospective cohort study which includes 653 patients who underwent OAGB/MGB in Rasoul-e-Akram Center of Excellence of European Branch of International Federation for Surgery of Obesity, between October 2010 and August 2015. Patients had 12-month follow-ups at 10 days and 1, 3, 6, and 12 months after the surgery. If any patient did not come for visit, he/she was called or a short message via SMS text or telegram application was sent to him/her to come or send his/her biochemical laboratory data and distinct weight to be registered in database.

The inclusion criteria based on the National Institutes of Health criteria were BMI >40 or BMI >35 with related serious comorbidities[4] and passing at least 12-month follow-ups after the surgery.

To investigate weight-loss outcome after OAGB/MGB, the percentage of excess weight loss (EWL%) was calculated based on: ([initial weight] – [postoperative weight])/([initial weight] – [ideal weight]), and ideal weight was calculated based on 25 kg/(m)^2 for BMI.

Moreover, the percentage of total weight loss (TWL%) was calculated as: ([initial weight] – (postoperative weight])/([initial weight]) ×100.[11]

To assess the response to OAGB / MGB, a modification of the Reinhold classification based on Christou *et al*. study was used that postoperative BMI and EWL% were defined as: excellent (BMI <30, EWL%>75%), good (BMI: 30–35, EWL%:5 0–75), and failure (BMI >35, EWL% <50).[12]

All presurgical, surgical, and postsurgical data, such as biochemical data, clinical assessments by physicians, and complications, were registered in the Iran National Obesity Surgery Database (www.obesitysurgery.ir).

For some complaints, such as vomiting, diarrhea, dumping, constipation, and smelly stool, patients' subjection was referred to, and for other complications such as anemia and hypoalbuminemia, the biochemical data were reviewed. Furthermore, the comorbidities and their improvement were evaluated and registered based on the American Society for Metabolic and Bariatric Surgery outcome reporting standards.[11]

All patients signed a written informed consent at the time of preoperative evaluation for using their information on the Iran National Obesity Surgery Database for all studies. The protocol of this study was approved by the ethics committee of Iran University of Medical Sciences with this number: IR.IUMS.REC-1394.94-05-140-27275 at 23 February 2017.

Preoperative assessment

Before the surgery, all patients were evaluated by a multidisciplinary team, and biochemical tests, cardiopulmonary assessment, abdominal sonography, chest radiography, upper gastrointestinal endoscopy, and biopsy for *Helicobacter pylori* (HP) were done, and if HP was positive, eradication was performed.

A low-calorie regimen was started for all the patients, at least for 1 month to reach an at least 10% weight loss. Just before the surgery, in the operating room, all patients received 2 g cefazolin,[13] 40 mg pantoprazole,[13] 5000 unit subcuticular (SC) heparin, and wore antithrombotic stocking.

Surgical technique

In a modified lithotomy position, the surgeon stands between a patient's legs, the cameraman on the left side, and the assistant on the right side of the surgeon. Five trocars were inserted, one 10-mm, one 12-mm, and three 5-mm trocars, and then, the left side of His angle was dissected and the left crus of diaphragm was explored. The stomach is divided transversely through lesser sac, approximately 1 cm distal to crow's foot with linear gold or green stapler 45 mm, according to the thickness of stomach, and along a 36F tube, other 60 mm/3.5 mm linear staplers were fired vertically up to the left side of His angle to create a long and narrow gastric pouch about 18 cm. In some patients with heavy omentum, especially in super-obese patients, the omentum was divided. The BPL was measured by a scaled atraumatic grasper (@ Applied) and mainly adjusted, based on the patient's BMI and age, that we used 180 cm, 200 cm, and 220 cm BPL in BMI of 35–39, 40–50, and above 50, respectively, with a 10 cm reduction in its length in every 5 year age above 45 years old, because before initiating this study, constant 200 cm BPL had been used and there were some cases with severe weight loss and hypoalbuminemia. Antecolic and antegastric side-to-side gastrojejunostomy was performed with 45-mm linear stapler, and then, the enterostomy site was sewn with PDS (polydioxanone) 2–0. Finally, air leak test was performed and the calibration tube was removed and a silicone drain was put. No nasogastric tube or Foley catheter was inserted.

In our opinion, concomitant cholecystectomy prolongs the operation time and can lead to some complications;[14] hence, it was avoided. In asymptomatic or minimally symptomatic patients, we perform cholecystectomy 3–6 months after MGB/OAGB.

Postoperative management and follow-up

The patients must be out of bed 3 h after the surgery. The next morning after performing a methylene blue leak test, a soft liquid regimen was started and the patients were discharged with some recommendations such as doing some exercises and taking medications such as ursodeoxycholic acid (Ursoflor 300 mg/po/Bd) for 6 months, heparin 5000 u/SC/Bd for 5 days, proton pump inhibitors (pantoprazole 400 mg/BD) for at least 6 months, and multivitamin/mineral supplements. The drain was removed depending on the bloody discharge <50 cc/day at the same day or few days after the surgery, and then the patients have regular follow-ups for clinical and biochemical evaluation by the multidisciplinary team, especially for nutrition, in 10 days; 1, 3, 6, 9, and 12 months; and then annually after the surgery.

Statistical analysis

Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences, V 11.5) software. Data were first tested for normal distribution with the Kolmogorov–Smirnov test. Mean ± standard deviation or median (interquartile range [IQR]) was calculated for quantitative and frequency (%) for qualitative variables. One-way ANOVA or Kruskal–Wallis H-test was used to determine if there are significant differences between complications and other outcomes between three groups of BPL or EWL%. Tukey's test was used as a *post hoc* test. The Friedman test was used to analyze related dependent variables that represent different measurements of the same attribute such as weight-loss outcomes. Predictor factors for 12-month EWL% were determined by a forward multiple linear regression analysis. Spearman's correlation coefficient was applied to assess the association between variables. $P < 0.05$ was accepted as an indicating statistical significance.

RESULTS

The sample included 653 patients who underwent OAGB/MGB and completed 12-month follow-ups, with a median (IQR) age of 37 (31, 46) years. Most of the patients (81.60%) were female. The median (IQR) preoperative BMI was 44.35 (41.14, 49.09) kg/m^2, and the median (IQR) preoperative excess weight (EW) was 51.23 (42.87, 65.03) Kg. The postoperative BMI response rate was as follows: 96.93% at 1 month, 93% at 3 months, 95.40% at 6 months, 90.80% at 9 months, and 100% at 12 months. Complication declaration response rate was 93.1% at 12 months. The two most common comorbidities were dyslipidemia in 38.30% and type 2 diabetes mellitus (T2DM) in 17% of the cases. Table 1 shows the demographic and clinical characteristics, comorbidities, and operative data of the patients.

According to Reinhold's classification, 12-month results showed poor for 2.90%, good for 28.80%, and excellent EWL% for 68.30% of the patients [Table 2].

Table 3 shows the trends of weight-loss outcomes (TWL%, WL, EWL%, BMI, and change in BMI) during a 12-month postoperative period. During 12 months postoperative, weight, BMI, and EW have significant decreasing trends, whereas WL, TWL%, EWL%, and BMI loss had significant increasing trends ($P < 0.001$ for all).

Percentage of total weight loss, weight loss, and percentage of excess weight loss

There were significant weakly positive correlations between 12-month TWL% and preoperative weight (r = 0.142) and BMI (r = 0.201) and negative correlation between 12-month TWL% and age (r= −0.151) ($P < 0.001$ for all), but analysis did not reveal any significant association between TWL% and BPL at this period of time ($P = 0.544$).

Older age was significantly associated with lower WL at the 12-month follow-up ($r = -0.248$, $P < 0.001$), the inverse

Table 1: Demographic and clinical characteristics of all patients who underwent mini-gastric bypass surgery with 12-month follow-up data (*n*=653)

Variables	*N*=653
Age (years), median (IQR)	37.00 (31.00, 46.00)
Female, *n* (%)	532 (81.6)
Weight (kg), median (IQR)	120.00 (108, 135)
BMI class (kg/m^2), *n* (%)	
35-40	102 (15.6)
40-50	410 (62.9)
>50	140 (21.5)
T2DM, *n* (%)	111 (17)
Hypertension, *n* (%)	106 (16.3)
Dyslipidemia, *n* (%)	250 (38.3)
Sleep apnea, *n* (%)	17 (11.8)
BPL (cm), median (IQR)	200 (180, 200)
BPL group (cm), *n* (%)	
150-179	36 (5.5)
180-200	601 (92.2)
201-220	15 (2.3)

BMI=Body mass index; IQR=Interquartile range; T2DM=Type 2 diabetes mellitus; BPL=Biliopancreatic limb length

Table 2: Demographic and clinical characteristics of all patients who underwent mini-gastric bypass surgery with 12-month follow-up data for excess weight loss percentage groups

Variables	Poor EWL % (*n*=19)	Good EWL % (*n*=188)	Excellent EWL % (*n*=445)	*P*
Age (years), median (IQR)	40 (34, 52)	39 (32, 47)	36 (30, 45)[a,b]	0.025
Female, *n* (%)	16 (84.2)	147 (78.2)	369 (82.9)	0.357
Preoperative weight (kg), median (IQR)	128 (104, 150)	130 (115, 143)	115 (105.25, 130)[b]	<0.001
Preoperative BMI (kg/m^2), median (IQR)	46.60 (42.46, 49.22)	48.57 (43.68, 52.80)	43.03 (40.55, 46.96)[a,b]	<0.001
BPL (cm), median (IQR)	200 (180, 200)	200 (200, 200)	200 (180, 200)[a,b]	<0.001
T2DM, *n* (%)	6 (31.6)	39 (20.7)	66 (14.8)[a]	0.045
Gall stone, *n* (%)	0	0	3 (0.90)	0.515
Vomiting, *n* (%)	1 (5.60)	11 (6.20)	15 (3.60)	0.372
Diarrhea, *n* (%)	0	7 (3.9)	18 (4.30)	0.657
Dumping, *n* (%)	0	5 (2.80)	15 (3.60)	0.645
Constipation, *n* (%)	0	3 (1.70)	14 (3.40)	0.396
Smelly stool, *n* (%)	6 (33.30)	27 (15.20)	83 (20)	0.113
Albumin (g/dL), median (IQR)	4 (3.70, 4.20)	4.10 (3.90, 4.40)	4.10 (3.90, 4.40)	0.344
Hb (mg/dL), median (IQR)	11.85 (11.02, 13.12)	12.95 (11.90, 14)	12.90 (12, 13.80)	0.324

[a]Compared with poor EWL% group, *P*<0.05, [b]Compared with good EWL% group, *P*<0.05. Poor EWL%=EWL% ≤50; Good EWL%=50<EWL% ≤75; Excellent EWL %=EWL% >75. BMI=Body mass index, BPL=Biliopancreatic limb length; EWL=Excess weight loss; IQR=Interquartile range; T2DM=Type 2 diabetes mellitus; Hb=Hemoglobin

Table 3: Trends of weight-loss outcomes (weight, absolute weight loss, weight loss, excess weight loss, body mass index, and change in body mass index) during 12-month postoperative follow-up

Variables*	Before surgery (*n*=652)	One month (*n*=632)	Three months (*n*=626)	Six months (*n*=622)	Nine months (*n*=592)	12 months (*n*=652)	*P*
Weight (kg), median (IQR)	120 (108, 136)	105.9 (95, 120)	94 (84, 107)	85 (75.7, 96)	79 (70, 89)	75.5 (67, 85)	<0.001
BMI (kg/m^2), median (IQR)	44.5 (41.10, 49.30)	39.41 (36.14, 43.50)	35.1 (31.95, 39.98)	31.51 (28.60, 35)	29.13 (26.64, 32.53)	28.03 (25.39, 31.41)	<0.001
BMI loss (kg/m^2), median (IQR)	-	5.12 (4.25, 6.23)	9.55 (8.32, 10.95)	13.22 (11.42, 15.06)	15.43 (13.3, 17.58)	16.88 (14.15, 19.34)	<0.001
EW (kg), median (IQR)	51.23 (42.87, 65.03)	38.34 (29.79, 50.31)	26.61 (18.76, 37.33)	17.29 (9.57, 26.37)	10.98 (4.52, 20.24)	7.98 (1.0, 17.28)	<0.001
WL (kg), median (IQR)	-	14 (11, 17)	26 (22, 30)	35 (30, 41)	41 (35, 47.5)	45 (37, 52)	<0.001
TWL %, median (IQR)	-	11.48 (9.73, 13.46)	21.3 (18.60, 24.31)	29.26 (26.05, 32.79)	34.31 (30.52, 38.09)	36.92 (32.98, 41.67)	<0.001
EWL %, median (IQR)	-	26.5 (21.28, 32.72)	48.76 (40.74, 58.10)	66.89 (56.37, 77.90)	78.34 (67.09, 90.58)	84.94 (71.40, 97.65)	<0.001

*Data are given as median (IQR). IQR=Interquartile range; BMI=Body mass index; EW=Excess weight; WL=Weight loss; EWL=Excess WL; TWL=Total WL

of the significant and fairly strong positive correlation between WL with preoperative weight (r = 0.701), preoperative BMI (r = 0.612), and BPL (r = 0.210) at 12-month follow-up (P < 0.001 for all); furthermore, there were significant negative correlations between 12-month EWL% and age (r = −0.310), preoperative weight (r = −0.386), BMI (r = −0.501), and BPL (r = −0.216) (P < 0.001 for all) [Table 4]. Other correlations in other months are shown in Table 4.

Subgroup analysis based on biliopancreatic limb categories

The patients were divided into three groups based on BPL: <180 cm in 36 patients (5.5%), 180–200 cm in 601 cases (92.2%), and >200 cm in 15 patients (2.3%). The three groups of BPL were similar age (P = 0.926) and sex (P = 0.758).

The most common subjective complication was smelly stool (17.8%), followed by vomiting (4.1%) [Table 5]. Twelve-month complication and weight-loss outcomes and hemoglobin (Hb) and albumin levels were compared between the groups. There were no significant differences between the groups in complications except for vomiting; the prevalence of vomiting was higher in group with 201 ≤ BPL ≤ 220 compared with group with 180 ≤ BPL ≤ 200 (P = 0.010); 12-month albumin (P = 0.370) and Hb levels (P = 0.506) were the same in the groups. There were significant differences between EWL% (P < 0.001) and WL (P < 0.001) in the three groups of BPL; EWL% in the groups with less BPL was significantly higher and WL is the reverse of EWL% (P < 0.001 for all); TWL (P = 0.408) was the same in the groups [Table 5].

Albumin level and serum hemoglobin

The median (IQR) albumin level and serum Hb had significant reductions at 12-month follow up, 4.00 (4.00, 4.6) vs. 4.10 (3.9, 4.4) and 12.90 (12.00, 13.80) vs. 13.90 (13.00, 14.70), respectively ($P > 0.001$ for all). There were no correlations between albumin level and EWL% ($P = 0.674$) and BPL ($P = 0.598$) at 12-month follow up, after controlling for baseline albumin; the same result was found for Hb level and EWL% ($P = 0.468$) and BPL ($P = 0.161$) at this period of time, after controlling for baseline Hb.

Table 4: Correlation between weight loss and biliopancreatic limb length, age, weight, and body mass index

Parameter	Age (years)	Preoperative weight (kg)	Preoperative BMI (kg/m^2)	BPL (cm)
TWL%				
10 days	−0.061	−0.076	−0.066	−0.064
1 month	−0.048	−0.014	−0.058	0.024
3 months	−0.126**	−0.027	−0.047	−0.036
6 months	−0.125**	0.006	−0.015	−0.027
9 months	−0.113**	0.063	0.109**	0.010
1 year	−0.151**	0.142**	0.201**	0.019
WL				
10 days	−0.153**	0.355**	0.256**	0.091*
1 month	−0.165**	0.487**	0.334**	0.176**
3 months	−0.249**	0.600**	0.438**	0.163**
6 months	−0.248**	0.649**	0.479**	0.187**
9 months	−0.235**	0.680**	0.566**	0.221**
1 year	−0.248**	0.701**	0.612**	0.210**
EWL%				
10 days	−0.054	−0.365**	−0.438**	−0.191**
1 month	−0.041	−0.372**	−0.525**	−0.144**
3 months	−0.101*	−0.459**	−0.622**	−0.227**
6 months	−0.111**	−0.461**	−0.640**	−0.250**
9 months	−0.104*	−0.451**	−0.586**	−0.217**
1 year	−0.130**	−0.386**	−0.501**	−0.216**

*Correlation is significant at the 0.050 level (two-tailed); **Correlation is significant at the 0.01 level (two-tailed). BMI=Body mass index; BPL=Biliopancreatic limb length; WL=Weight loss; EWL=Excess WL; TWL=Total weight loss

All patients with mild hypoalbuminemia improved to normal level of albumin. Of the patients who had normal level of albumin preoperatively, 16 (7.1%) were worsened to mild hypoalbuminemia; however, it was no statistically significant ($P = 0.078$). None of the patients had pre- and postoperative severe hypoalbuminemia.

Linear regression model

Linear regression results for EWL% at 12 months postoperative including sex, age, preoperative weight, BPL, and T2DM in Table 6 showed that EWL% decreased as the preoperative weight ($\beta = -0.511$), age ($\beta = -0.193$), and BPL ($\beta = -0.082$) increased. In addition, males ($\beta = -0.164$) and the patients who were suffering from T2DM ($\beta = -0.114$) had a significantly lower EWL% at 12-month postoperative period.

According to the standardized β-coefficients, weight, age, sex, and T2DM were the most contributory predictors, respectively, and BPL was the least contributory predictor of EWL%.

Reinhold's classification of percentage of excess weight loss

Table 2 shows the comparison of demographic and clinical characteristics of patients in Reinhold's classification of 12-month EWL%. The differences between the three groups of EWL% in terms of preoperative weight ($P < 0.001$), preoperative BMI ($P < 0.001$), age ($P = 0.025$), BPL ($P < 0.001$), and T2DM ($P = 0.045$) were significant. *Post hoc* test indicated that the excellent EWL% group had significantly lower age and lower BMI compared with poor EWL% ($P = 0.052$ and $P = 0.020$, respectively) and good EWL% ($P = 0.035$ and $P < 0.001$, respectively). Furthermore, the excellent EWL% group had a significant difference with good EWL% in

Table 5: Twelve-month weight loss and complications after mini-gastric bypass surgery for the biliopancreatic limb length groups

Variables	BPL groups			*P*
	150-179 cm (*n*=36)	180-200 cm (*n*=601)	201-220 cm (*n*=15)	
Vomiting, *n* (%)	0	24 (4.3)[b]	3 (20)[a]	0.006
Diarrhea, *n* (%)	0	24 (4.2)	1 (6.7)	0.437
Dumping, *n* (%)	2 (6.3)	17 (3)	1 (6.7)	0.457
Constipation, *n* (%)	0	17 (3)	0	0.482
Smelly stool, *n* (%)	5 (15.6)	109 (19.3)	2 (13.3)	0.748
Leakage	0	2	0	—
Bleeding	0	8	1	0.166
Mortality	0	0	0	—
Albumin (g/dL), median (IQR)	4.35 (4, 4.92)	4 (4, 4.70)	4 (4, 4.62)	0.370
Hb (mg/dL), median (IQR)	12.30 (11, 13.85)	12.90 (12, 13.85)	13.20 (11.87, 13.72)	0.506
EWL % (kg), mean±SD	96±32.58	84.63±18.10[a,b]	68.37±12.34[a]	<0.001
WL (kg), median (IQR)	38 (34.1, 44.50)	45 (37.65, 52)[a,b]	59 (50, 63)[a]	<0.001
TWL % (kg), median (IQR)	35.60 (31.14, 41.41)	37.19 (32.79, 41.67)	36.76 (34.48, 42.65)	0.408

[a]Compared with 150≤BPL≤179 group, *P*<0.010; [b]Compared with 201≤BPL≤220 group, *P*<0.010. BPL=Biliopancreatic limb length; WL=Weight loss; EWL=Excess WL; TWL=Total Weight Loss; SD=Standard deviation; Hb=Hemoglobin; IQR=Interquartile range

Table 6: Multiple linear regression equation for excess weight loss percentage at 12-month follow-up

Predictors	Standardized coefficients (β)	*P*
Preoperative weight (kg)	−0.511	<0.001
Age (year)	−0.193	<0.001
Sex (male vs. female)	−0.164	<0.001
T2DM (yes vs. no)	−0.114	0.002
BPL (cm)	−0.082	0.024

Adjusted R^2=0.232. Adjusted for preoperative weight, age, sex, BPL, and T2DM. Dependent variable: EWL% at 12 months postoperative. For regression analysis, forward selection method was used. BPL=Biliopancreatic limb length; EWL=Excess weight loss; T2DM=Type 2 diabetes mellitus

weight, BMI, T2DM, and BPL ($P < 0.001$ for all). The excellent and poor EWL% groups were found to be similar in terms of preoperative weight ($P = 0.106$) and BPL ($P = 0.603$).

The number of comorbidities changed from 0 (36.7%) to 4 (2.3%) in our patients. However, there was no significant association between the number of comorbidities and the BPL ($P = 0.682$).

DISCUSSION

OAGB/MGB is a good alternative for the gold standard classic RYGB, due to significant effects on weight loss, obesity-related comorbidities and lifestyle, simplicity to do and reversal, low rates of complications, and acting with both restrictive and malabsorptive mechanisms.[4,7] It seems that the higher malabsorption effect in OAGB/MGB in contrast to RYGB is due to longer BPL and elimination of potential mechanisms of absorption in the alimentary limb (AL) of RYGB.[15,16]

There has been a debate on bypassed limb length and its effects, both in OAGB/MGB and RYGB.[6,9,12,13,17-26]

In this study, the BPL was routinely adjusted based on preoperative BMI and patient's age that has been described earlier. Our analysis showed that the number of comorbidities is not an important factor for BPL adjustment. Consequently, there were three groups of BPL. There was a significant negative correlation between BPL and EWL% but a positive correlation between BPL and WL. These correlations were in all follow-up times, as a trend of all weight-loss outcomes, such as BMI loss, EW, WL, TWL%, and EWL%. A Rutledge's study on 3309 patients who underwent OAGB/MGB showed that in every 1 foot BPL, the patient will have a 7.7-kg increase in 1 year WL.[9] Lee *et al*. adjusted the BPL in OAGB/MGB, according to the preoperative BMI, that used a 150-cm BPL for BMI 35 and a 10-cm increase in every one-point BMI increase till 350 cm. They showed a linear correlation between adjusted BPL and BMI loss after the surgery and concluded that tailoring of BPL based on BMI is feasible.[10] Ahuja *et al*. showed that adjusted BPL based on preoperative BMI in three groups had no statistically significant difference in 1 year %EWL but better WL in longer BPL due to higher preoperative BMI and weight.[27] Nergaard *et al*. showed a statistically significant effect on WL and excess body mass index loss (EBMIL), in 7-year follow-ups after laparoscopic Roux-en-Y gastric bypass (LRYGB), in a group of patients with long BPL and short AL (200 cm and 60 cm), in comparison with a group of patients with short BPL and long AL (60 cm and 150 cm) in both BMI >50 and <50, and concluded that 2-m BP limb is more effective for long-term weight loss in comparison with a 150-cm AL.[20]

These studies confirmed our results about positive association between adjusted BPL and postoperative BMI and weight loss, at least in short-term follow-ups.

Some other studies in RYGB also recommended that the lengths of BPL, Roux limb (RL) and Common limb (CL), have no significant statistical effect on weight-loss outcomes in morbidly obese patients.[18,24,26,28,29] These studies do not support the present study, probably due to some confounding factors, especially RYGB that has two limbs instead of only one BP limb in OAGB/MGB and other factors such as different duration of follow-ups, higher BMI patients, and lower sample sizes.

In the present study in contrast to WL, EWL% had a statistically significant negative correlation with BPL at the same time. The study of Lee *et al*. which OAGB/MGB was performed with modified BPL based on BMI showed better EWL% in lower BMI patients with shorter BPL (150 cm vs. 250 cm and 350 cm) but better WL% in higher BMI patients with longer BPL, in 2-year follow-ups, that were statistically significant.[10] Some studies reported the correlation between higher preoperative BMI and less EWL%.[30] The present study is in line with these studies, as here longer BPL was used in patients with higher preoperative BMI. On the other hand, according to the formula of EWL, it is reasonable that higher preoperative BMI (which is in denominator) leads to less EWL.

Another finding of this study was the lower levels of Hb in patients with lower BMI which we used a tailored shorter BPL; however, it was not statistically significant; meanwhile, it warns that patients with lower BMI are more at risk for anemia due to micronutrients and essential elements deficiency, and we must use shorter BPL in bypass or use other bariatric procedures such as sleeve gastrectomy that has lower malabsorptive component. Lee *et al*. showed that patients with lower BMI are more prone to nutritional deficiencies and will have more severe anemia in contrast to patients with higher BMI and recommended that it may be better to perform restrictive procedures in order to do malabsorptive procedures in these patients.[10] In Ahuja *et al*. study, the incidence of iron and ferritin deficiency was higher in 250-cm versus 150-cm BPL that were statistically significant.[27] Other studies have reported the incidence of IDA after OAGB/MGB to vary from 3.9% to 9.7%.[2,7,8,31-33] It seems that care should be taken about the prevention of IDA by choosing shorter BPL, especially in lower BMI patients, by tailoring the limb.

Jammu *et al*. reported 13.1% hypoalbuminemia in OAGB/MGB, especially with BPL >230 cm, and hypothesized that the maximum length of BPL must be 200 cm to prevent hypoalbuminemia.[2] Lee *et al*. showed that there was no correlation between RL and changes in serum albumin in RYGB,[13] but Noun *et al*. concluded that modification of BPL based on patient's BMI can usually prevent malnutrition.[34] In our study, the albumin levels had a significant reduction after surgery, but only mild hypoalbuminemia was seen, and no correlation was found between hypoalbuminemia and BPL; this might be related to adjustment of BPL and also some missed follow-ups in laboratory data.

Despite the adjustment of BPL based on preoperative BMI and patient's age, the 1-year poor EWL (≤50%), based on Reinhold's classification, was 2.9%. Lee *et al*. reported poor EWL in 5% of patients, 2 years after OAGB/MGB.[35] Furthermore, Noun *et al*. obtained 95% and 89.8% EWL >50% in 1.5 years and 5 years, respectively.[34] The results of this study about good EWL are approximately comparable with the results of these studies.

In the present study, it was found that in addition to BPL, preoperative weight, age, and male gender have a statistically significant negative effect on EWL%. Chevallier *et al*. showed that MO patients younger than 40 years old have better weight loss and excess BMI loss after OAGB/MGB in 5-year follow-ups.[36] Barhouch *et al*. concluded that some factors, such as surgical approach, preoperative BMI and waist circumference, age, T2DM, hypertension, and gender, have the most effects on %EWL after RYGB with 5-year follow-ups.[30] Furthermore, another study reported some factors of poor weight loss after gastric bypass, such as older age, male gender, higher preoperative BMI, T2DM, marriage, black race, postoperative immobility, and non-efficient follow-ups.[37] These studies confirm our findings about contributing factors in weight loss after OAGB/MGB.

The strengths of the present study were relatively good sample size compared with other studies,[12,13,17-21,23-25,28,29,34,35] also evaluating some factors affecting weight-loss outcomes, such as age, sex, and T2DM, which could act as confounding factors. Hence, these factors were considered in the analyses. Another point of strength was registry-based data collection despite the retrospective nature of the study.

The limitations of this study were retrospective evaluation, loss of long-term follow-ups, and some missing data, especially biochemical data of patients. Another limitation was unequal numbers of patients in groups which was inevitable according to retrospective form of the study and adjusting the BPL based on preoperative BMI. In addition, whole small bowel length was not measured although it has a large variation in patients and can have a significant effect on weight loss and nutritional outcomes. Most of the other similar studies did not measure the whole small bowel length, especially in OAGB/MGB.

CONCLUSION

Tailoring BPL in OAGB/MGB, based on patient's age and preoperative BMI, seems to have good-to-excellent results in weight-loss outcomes in short term with minimal complications. Hence, it must be performed, especially in lower BMI patients who are more prone to nutritional complications. Before the initiation of this study and the 1st years that we started to perform OAGB/MGB, we used to use a constant 200 cm BPL and few cases with severe weight loss and severe hypoalbuminemia were observed, so we changed our method to use an adjusted BPL instead of a constant BPL. However, more trial studies with larger sample size (especially for detecting complications which have lower prevalence), equal group patient numbers and finally determining total length of small bowel for prevention of short common limb and longer follow-ups are essential, and thitherto, it is reasonable to continue adjusting BPL based on BMI and age.

Acknowledgments

We used data from the Iran National Obesity Surgery Database. We would like to express our gratitude to the Iranian National Obesity Surgery Database team who provided useful data for us. The authors would like to appreciate the presence of Prof. A. Khalaj, Dr. MA Pakaneh, and Dr. P. Alibeigi as participating surgeons in this study and also thank Dr. S. Darabi and Dr. F. Eghbali for their precious help in drafting this manuscript.

Financial support and sponsorship

This work was funded and supported by the Iran University of Medical Sciences (IUMS) Grant number 94-05-140-27275).

Conflicts of interest

There are no conflicts of interest.

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