The role of alimentary and biliopancreatic limb length in outcomes of Roux-en-Y gastric bypass

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Abstract

Introduction: *Roux-en-Y gastric bypass (RYGB) is one of the safe and easily reproducible bariatric procedures.*
Aim: *To evaluate the effect of biliopancreatic limb (BPL) and alimentary limb (AL) length on weight loss outcomes after RYGB.*
Material and methods: *This retrospective cohort study included 313 morbidly obese patients who underwent primary laparoscopic RYGB 2009–2015. Patients' BPL and AL lengths were categorized into three groups: group 1 (BPL: 50 cm and AL: 150 cm), group 2 (BPL: 150 cm and AL: 50 cm), and group 3 (BPL: 100 cm and AL: 100 cm). Data were provided from the Iranian National Obesity Surgery Database. The generalized estimating equations method was used to assess the effect of limbs length on %excess weight loss (%EWL).*
Results: *Mean ± standard deviation age and body mass index (BMI) of 252 patients were 38.55 ±10.24 years and 45.8 ±4.77 kg/m², respectively. Totally, 172 (68.3%, BMI of 46 ±5 kg/m²), 48 (19%, BMI of 45.12 ±4.26 kg/m²), and 32 (12.7%, BMI of 45.43 ±4.23 kg/m²) were in group 1, 2, and 3, respectively (p = 0.44). The results showed that the choice of different limb lengths had no significant effect on %EWL over 12 months follow-up (p = 0.625) adjusted for baseline BMI (p = 0.25). Mean %EWL in the patients with longer BPL and shorter AL was 5.43% (1.91, 8.95) higher in comparison to the patients with shorter BPL and longer AL during 36 months postoperatively adjusted for baseline BMI (p = 0.002).*
Conclusions: *During 12 months after RYGB, %EWL was not associated with BPL or AL length. However, during 36 months postoperatively, the patients with longer BPL had a significantly higher %EWL in comparison to the patients with shorter BPL.*

Key words: *weight loss, Roux-en-y gastric bypass, biliopancreatic limb, alimentary limb, generalized estimating equations.*

Introduction

Morbid obesity and its related comorbidities are increasing universally [1]. Bariatric surgery is now the most effective and durable method in weight loss and resolution of obesity-related comorbidities in the morbidly obese population. Roux-en-Y gastric bypass (RYGB) is the second most common procedure among bariatric operations worldwide [2–5], with excellent results in excess weight loss (70–80%) and resolution of weight-related comorbidities within the first 2 postoperative years [6].

Different findings have been obtained about the effect of biliopancreatic limb (BPL) and alimentary

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limb (AL) length on the outcomes of RYGB patients [6–11], and there is not yet any consensus on the appropriate length of the BPL, AL, and common limb. Previous studies have reported contradictory results in efficacy of these limb lengths to achieve the best results in weight loss outcomes and the prevention of nutritional complications.

Aim

The aim of this study is to determine the effect of BPL and AL lengths on the trend of excess weight loss and body mass index (BMI) change at short- and medium-term (12 and 36 months, respectively) follow-up after RYGB. Finally, the proportion of complications is compared between various limb length groups.

Material and methods

Studied sample

This retrospective cohort study included 313 morbidly obese patients who underwent primary laparoscopic RYGB surgery, between January 2009 and March 2015. All of the procedures were performed by a single surgery team. Note that from 2013, the team had a tendency to bypass a longer BPL due to the experience of weight regain in patients. We included only patients older than 18 years old, with BMI > 40 kg/m² or BMI > 35 kg/m² along with at least one major comorbidity, with at least 12 months follow-up after surgery. Patients who had re-operation including conversion, reversal, and revision due to weight loss failure, and female patients who became pregnant after the surgery were excluded from the study. Data were provided from the National Obesity Surgery Database, Iran. Written informed consent was obtained from all patients before the surgery. The ethics committee of Iran University of Medical Sciences approved the study (code: IR.IUMS.REC 95-02-140-27472).

Variables

The included variables were sex, age, height, preoperative weight and BMI, comorbidities (hypertension, type 2 diabetes mellitus (T2DM), impaired glucose tolerance (100 < FBS ≤ 125), dyslipidemia, hypothyroidism, musculoskeletal pain (low-back and knee), sleep apnea, cardiovascular disease), complications, and the time of follow-up postop-

eratively. The patients' weight were registered at 10 days and 1, 3, 6, 9, 12, 18, 24 and 36 months after surgery.

Patients' BPL and AL lengths were measured by marked graspers with 5 cm by 5 cm measurement and categorized into three groups as follows: group 1 (BPL: 40–60 cm and AL: 120–150 cm); group 2 (BPL: 120–150 cm and AL: 40–60 cm); and group 3 (BPL: 95–105 cm and AL: 95–105 cm) for convenience.

The main outcomes of the study were %excess weight loss (%EWL) and change in BMI (ΔBMI) calculated from %EWL = ((initial weight) − (postoperative weight)) × 100/((initial weight) − (ideal weight)) where ideal weight is defined by the weight corresponding to a BMI of 25 kg/m², and ΔBMI = initial BMI − postoperative BMI, respectively [12]. Weight loss failure was defined as %EWL < 50% at 18 months postoperatively [13]. Leak, bleeding, hypoalbuminemia (defined as at least one occurrence of albumin < 3.5 mg/dl), and death were reported as complications. Complications were reported according to early (≤ 30 days) and late (> 30 days) occurrence. Ursodeoxycholic acid 300 mg was routinely prescribed twice daily for 6 months after the surgery. In order to look for gallstones, sonography was performed at the 6th month and annually postoperatively.

Statistical analysis

Qualitative and quantitative variables were reported as number (%) and mean ± standard deviation (SD), respectively. ANOVA and independent sample *t*-test were used to compare the quantitative variables between the groups. The χ^2 and Fisher exact tests were performed to compare the categorical variables between the groups. The generalized estimating equation method was used to assess the effect of the factors on weight loss outcome [14]. The results were reported using mean difference (95% confidence interval) adjusted for baseline measurement and time as the concomitant variable. The data were analyzed using SPSS software v. 16.0 (IBM Corp., Armonk, NY, USA). *P*-values less than 0.05 were considered as significant.

Results

Twelve patients who became pregnant after the surgery were excluded from the study. Forty-nine

patients with BPL and AL lengths out of prespecified groups were excluded from the study. Then, 252 morbidly obese patients were included in the analysis. The mean ± SD age of the patients was 38.55 ±10.24 years and 209 (83%) patients were female. The numbers (%) of patients in groups 1, 2, and 3 were 172 (68.3%), 48 (19%), and 32 (12.7%), respectively. Patients' mean ± SD weight and BMI were 124.03 ±19 kg and 45.81 ±4.77 kg/m², respectively.

Table I shows that the mean ± SD age of the patients was homogeneous between the three groups (p = 0.96). No significant difference was found in preoperative mean ± SD BMI between the groups (p = 0.44, Table I). Median (interquartile range) for follow-up time was 59.55 (50.62–68.4), 19.75 (15.86–25.81), and 14.01 (13.36–15.63) months for groups 1, 2, and 3, respectively.

Patients' reported comorbidities at first visit were homogeneous between the groups except T2DM (p = 0.012) and sleep apnea (p = 0.035), which were more common in group 1. Follow-up rates were 90%, 88%, 88%, 88%, 84%, 86%, 70%, 66%, and 62% at

10 days and 1, 3, 6, 9, 12,18, 24, and 36 months after the surgery, respectively. Group 3 was excluded from the 36-month analysis.

Sensitivity analysis revealed that the characteristics including baseline weight and BMI, sex, comorbidities, and follow-up time of the patients who were excluded from and included in the study were not significantly different (results not shown).

%EWL

Figure 1 shows that the trend of mean %EWL of the patients with longer BPL is higher compared to the patients with shorter BPL. This difference was not statistically significant, except at 3 and 6 months after the surgery (Table II).

Table III demonstrates that there is no significant difference in %EWL in group 1 (p = 0.625) and group 2 (p = 0.250) in comparison to group 3 over 12 months follow-up controlling for baseline BMI. Table III shows that the patients with lower BMI at baseline had a significantly higher %EWL (p < 0.001).

Table I. Patients' reported comorbidities at first visit and other characteristics of the patients in terms of limb length groups

Characteristics	Group 1[†] (n = 172)	Group 2[‡] (n = 48)	Group 3[§] (n = 32)	P-value
Age, mean ± SD [years]	38.44 ±10.50	38.73 ±9.54	38.90 ±10.200	0.96
Preoperative weight, mean ± SD [kg]	125.70 ±19.9	119.67 ±16.11	121.50 ±17.20	0.11
Preoperative BMI, mean ± SD [kg/m²]	46.00 ±5.00	45.12 ±4.26	45.43 ±4.23	0.44
Sex (female), n (%)	144 (57.1)	39 (15.5)	26 (10.3)	0.88
Preoperative BMI, n (%):				
< 50 kg/m²	134 (53.2)	41 (16.3)	28 (11.1)	0.289
≥ 50 kg/m²	38 (15.1)	7 (2.8)	4 (1.6)	
Comorbidities, n (%):				
Hypertension	37 (21.5)	8 (16.7)	5 (15.6)	
T2DM	25 (16.3)	1 (4)	8 (2.4)	0.012
IGT[¶]	41 (23.8)	10 (20.8)	6 (18.8)	0.776
Dyslipidemia	84 (80.5)	20 (22.5)	14 (15)	0.633
Hypothyroidism	42 (39)	10 (11)	5 (7.2)	0.522
Pain (low-back and knee)	182 (72.2)	64 (25.5)	31 (9.3)	0.112
Sleep apnea	18 (7)	10 (4)	8 (3.2)	0.035
Cardiovascular disease	8 (3.2)	1 (0.4)	4 (1.6)	0.097

[†]BPL – 50 cm and AL – 150 cm, [‡]BPL – 150 cm and AL – 50 cm, [§]BPL – 100 cm and AL– 100 cm, T2DM – type 2 diabetes mellitus, [¶]100 < FBS ≤ 125.

Mean %EWL was not statistically significant between the groups 36 months postoperatively (Table II, $p = 0.076$). Table IV shows that %EWL mean in the patients in group 1 was 5.43% lower in comparison to the patients in group 2 over 36 months after the surgery adjusted for baseline BMI ($p = 0.002$). Mean %EWL was 8.25% higher in the patients with preoperative BMI < 50 kg/m^2 compared to the patients with preoperative BMI ≥ 50 kg/m^2, a significant difference ($p < 0.001$, Table IV).

ΔBMI

All the patients' mean ± SD ΔBMI reached 15.41 ±4.01 at the 12th month after the surgery and remained relatively without change afterward (results not shown). Patients' BMI change was not significantly different between groups in various follow-up times (Table II).

The different limb length groups had no significant effect on ΔBMI during 12 months postoperatively, adjusted for baseline BMI ($p = 0.42$, $p = 0.68$, Table II). Patients with lower baseline BMI had a significantly lower change in BMI (–2.65 kg/m^2, $p < 0.001$, Table III).

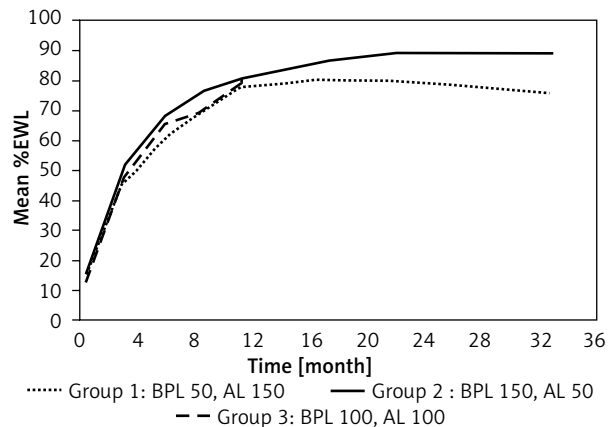At 36 months postoperatively, the mean ΔBMI of the patients was not statistically significant be-

Figure 1. The trend of %EWL of the patients in three groups during 36 months follow-up

tween the groups ($p = 0.167$, Table II). In addition, Table IV reveals that ΔBMI was significantly lower in group 1 in comparison to group 2 controlling for baseline BMI (–0.8 kg/m^2, $p = 0.007$). Patients who had preoperative BMI < 50 kg/m^2 experienced a lower ΔBMI (–3.07 kg/m^2, $p = 0.001$, Table IV).

Complications

Table V shows that 2 (0.8%) patients died early: one patient due to sepsis because of a leak from

Table II. %EWL and ΔBMI of patients in limb length groups at different time points postoperatively

Time point	%EWL, mean ± SD				ΔBMI, mean ± SD			
	Group 1[†]	Group 2[‡]	Group 3[§]	P-value	Group 1	Group 2	Group 3	P-value
10 D	14.91 ±6.61 (N = 156)	16.2 ±4.2 (N = 46)	12.48 ±5.8 (N = 25)	0.052	3.06 ±1.51	3.21 ±0.93	2.5 ±1.11	0.106
1 M	24.99 ±9.5 (N = 155)	27.38 ±7.34 (N = 45)	23.02 ±9.25 (N = 23)	0.139	5.02 ±1.73	5.26 ±1.3	4.67 ±1.94	0.391
3 M	44.02 ±12.73 (N = 157)	50.13 ±11.8 (N = 45)	47.7 ±8.62 (N = 20)	0.01	8.98 ±2.6	9.61 ±1.92	9.81 ±2.37	0.155
6 M	59.12 ±14.12 (N = 153)	65.84 ±15.17 (N = 45)	64.72 ±16.19 (N = 24)	0.012	12.09 ±3.31	12.66 ±2.7	12.53 ±3.44	0.529
9 M	68.57 ±16 (N = 155)	75.32 ±17.07 (N = 43)	69.85 ±20 (N = 13)	0.063	14.03 ±3.65	14.59 ±3.55	13.41 ±4.72	0.537
12 M	75.4 ±18.13 (N = 160)	79.66 ±20.4 (N = 44)	79.13 ±18.34 (N = 12)	0.359	15.45 ±3.98	15.39 ±4.12	15 ±3.94	0.928
18 M	77.92 ±18.44 (N = 155)	84.54 ±20.09 (N = 23)	–	0.114	16.08 ±4.3	15.95 ±3.55	–	0.888
24 M	77.6 ±19.87 (N = 155)	88.61 ±15.75 (N = 11)	–	0.074	15.9 ±4.3	16.64 ±4.44	–	0.587
36 M	73.11 ±21.07 (N = 149)	87.45 ±9.88 (N = 7)	–	0.076	15.06 ±4.58	17.49 ±2.31	–	0.167

[†]BPL – 50 cm and AL – 150 cm, [‡]BPL – 150 cm and AL – 50 cm, [§]BPL – 100 cm and AL – 100 cm, D – day, M – month, ANOVA was used for comparisons ≤ 12 months and independent sample t-test was used for comparisons afterwards; none of the Ps were significant.

Table III. The effect of three limb length groups on outcomes over 12 months follow-up

Variable	%EWL		ΔBMI	
	Mean difference[||] (95% CI)	*P*-value	Mean difference (95% CI)	*P*-value
Limb length group:				
Group 1[†]	−1.05 (−5.3, 3.19)	0.625	−0.37 (−1.28, 0.53)	0.42
Group 2[‡]	2.85 (−2.01, 7.71)	0.25	0.2 (−0.8, 1.2)	0.68
Group 3[§]	−		−	
Time	5.13 (4.92, 5.34)	< 0.001	1.04 (0.99, 1.08)	< 0.001
Baseline BMI (< 50 vs. ≥ 50)	6.85 (3.83, 9.88)	< 0.001	−2.65 (−3.41, −1.88)	< 0.001

[†]*BPL − 50 cm and AL − 150 cm,* [‡]*BPL − 150 cm and AL − 50 cm,* [§]*BPL − 100 cm and AL − 100 cm,* [||]*If 95% confidence interval excludes the value of 0 it is statistically significant.*

Table IV. The effect of two limb length groups with outcomes over 36 months follow-up

Factor	%EWL		ΔBMI	
	Mean difference[§] (95% CI[§])	*P*-value	Mean difference (95% CI)	*P*-value
Limb length group:				
Group 1[†]	−5.43 (−8.95, −1.91)	0.002	−0.88 (−1.52, −0.24)	0.007
Group 2[‡]	−		−	
Time	1.6 (1.5, 1.7)	< 0.001	0.32 (0.3, 0.34)	< 0.001
Baseline BMI (< 50 vs. ≥ 50)	8.25 (4.59, 11.93)	< 0.001	−3.07 (−3.97, −2.17)	< 0.001

[†]*BPL − 50 cm and AL − 150 cm,* [‡]*BPL − 150 cm and AL − 50 cm,* [§]*If 95% confidence interval excludes the value of 0 it is statistically significant.*

gastrojejunostomy three days after the surgery and one patient due to fulminant hemolysis which led to multi-organ failure (due to anaphylaxis reaction to cephalosporins). Four patients experienced a leak; 5 (2%) patients had obstruction which resulted in readmission and were treated with surgery.

Two (0.8%) patients died late due to non-surgery related reasons. Hypoalbuminemia was observed in 8 (3.2%) cases. Gallstone and intolerance of the bariatric surgery were not reported. Patients' complaints of smelly stool, constipation, dry skin, and hair loss were significantly different between the limb length groups. Weight loss failure was observed in 11 (4.4%) cases.

Discussion

Despite the invention of new bariatric surgical procedures, RYGB has been considered as a gold standard procedure which is malabsorptive and restrictive [10, 15]. The impact of BPL and AL lengths on RYGB outcomes is still controversial regarding appropriate limb lengths [6, 8, 10, 11, 15–18], de-

spite the established relationship between patients' height and total small bowel length [15].

In our study, there was no significant difference in weight loss outcomes between different limb length groups over 12 months after RYGB. However, %EWL was significantly higher in the patients with longer BPL and shorter AL during 36 months postoperatively. Feng *et al.* found that long and short Roux limbs had no significant effect on %EWL and %BMI loss, one year after RYGB in morbidly obese patients with BMI < 50 kg/m² [16]. Inabnet *et al.* found that the mean %EWL in 2 years follow-up did not have a significant association with longer BPL (100 cm vs. 50 cm) and only internal herniation was more common in the group with longer BPL [9]. A report by Kaska *et al.* revealed that there was no significant difference in BMI in RYGB patients with long BPL (100–150 cm) and short BPL (50–75 cm) 2 years after the surgery [8]. Another study also showed the non-significant effect of BPL and AL on total weight loss 12 months after RYGB [11]. These studies had a compatible finding with our unadjusted and ad-

Table V. *N* (%) of early and late complications in three limb length groups up to 36 months

Complications	Group 1[†] (n = 172)	Group 2[‡] (n = 48)	Group 3[§] (n = 32)	*P*-value
Early (≤ 30 days):				
Death	2 (0.8)	0	0	1
Leak	3 (1.2)	1 (0.4)	0	1
Bleeding	5 (2)	0	0	0.63
ICU required (postoperative)	11(0.44)	3 (1.2)	0	0.39
Obstruction[‖]	5 (2)	0	0	0.63
Pouch dilatation	2 (0.8)	0	0	1
Wound infection	1 (0.4)	0	0	1
Intra-abdominal abscess	1 (0.4)	0	0	1
Late (> 30 days):				
Death	2 (0.8)	0	0	1
Hypoalbuminemia[¶]	6 (2.4)	2 (0.8)	0	0.64
Dumping	36 (14.4)	5 (2)	8 (3.2)	0.18
Smelly stool	57 (22.8)	25 (10)	16 (12.4)	0.023
Stricture	1 (0.4)	0	0	1
Stomal ulcer	1 (0.4)	0	0	1
GERD	0	1 (0.4)	1 (0.4)	0.1
Hernia	1 (0.4)	0	0	1
Vomiting	28 (11.2)	6 (12.5)	8 (0.25)	0.32
Constipation	5 (2)	12 (4.8)	14 (5.6)	< 0.001
Diarrhea	13 (5.2)	8 (3.2)	6 (2.4)	0.057
Dry skin	5 (2)	16 (12.4)	16 (12.4)	< 0.001
Hair loss	5 (2)	25 (10)	21 (8.4)	< 0.001

[†]BPL – 50 cm and AL – 150 cm, [‡]BPL – 150 cm and AL – 50 cm, [§]BPL – 100 cm and AL – 100 cm, [‖]Obstruction that resulted in readmission and treated by surgery, [¶]Albumin < 3.5 mg/dl, GERD – gastroesophageal reflux disease.

justed (for time and baseline BMI) results, demonstrating no significant association between limb length and either %EWL or BMI change.

On the other hand, similar to our findings in 36 months postoperatively, Nergaard *et al.* observed that long BPL (200 cm) had more significant weight loss in comparison to short BPL (60 cm), 18 months after RYGB, which was persistent in follow-ups for 7 years [6]. It is also reported that %EWL at 18 months was greater in patients with a shorter AL (100 cm) in BMI < 50 kg/m² compared with a longer AL (150 cm) in patients with BMI > 50 kg/m²; however, %EWL did not differ after 24 months follow-up [10], which may be related to the BMI difference in morbidly obese and super-obese patients. In our study, the direction of association between limb length and %EWL as well as BMI change was similar to both studies. The findings of the present study showed that the association between %EWL and limb length was not significant over a short-term follow-up, whereas it was significant over a mid-term follow-up. Moreover, we have incorporated the effect of time as well as patient's BMI at the baseline in the analysis.

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Another study by Gleysteen *et al.* compared three different lengths of AL limb groups (41–61 cm, 130–160 cm, 115–250 cm about one third of total bowel length) with five years follow-up. They found that longer AL has better weight loss outcomes only in super-obese (BMI > 50 kg/m²) patients, not in morbidly obese patients, and also concluded that there is no need to measure whole small bowel length [7]. Moreover, Ciovica *et al.* found that longer AL (150 cm) had a greater effect on weight loss and %EWL in the 1st year after RYGB compared to shorter AL (100 cm) [18]. The findings of these studies are completely different from our study. In most of these studies, small bowel length was not measured like in our study. So, this controversy between different studies should be interpreted with caution because of the essential role of common channel limb length on weight regain, which has been ignored.

Similar studies concluded that the length of AL and BPL has no significant impact on complications and nutritional deficiencies after RYGB [9, 16, 17]. The reason for these different results may be the wide variety in choice of limb length, the number of patients, the method of data analysis, and follow-up duration. The lack of difference between the three groups in %EWL (at 12 months) was likely due to type II error which occurred because of the small sample size in group 2. Limited follow-up in the group 3 patients, limb length variety within the groups (which could have resulted in residual confounder), small sample size at 36 months follow-up, and lack of measurement of the entire small bowel length, which is quite variable among people, are limitations of this study.

Conclusions

There was no significant relationship between the length of BPL and AL and weight loss outcomes over short-term follow-up (12 months); however, the patients with longer BPL and shorter AL length had a greater weight loss regarding %EWL and BMI change over mid-term follow-up (36 months) after RYGB.

Acknowledgments

Conflict of interest

The authors declare no conflict of interest.

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