Short versus long biliopancreatic limb in Roux-en-Y gastric bypass surgery for treatment of type 2 diabetes mellitus

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Abstract

Introduction: Although laparoscopic Roux-en-Y gastric bypass (RYGB) is still widely accepted as a valid procedure in the treatment of obesity and type 2 diabetes mellitus (T2DM), there continues to be a significant controversy about how long the Roux and biliopancreatic limb should be bypassed for optimum results.

Aim: To assess the effect of a longer biliopancreatic limb (BPL) length on glycemic control after RYGB in T2DM patients.

Material and methods: Eighty-four patients with uncontrolled T2DM who underwent RYGB between May 2010 and April 2017 were collected from the prospectively designed database. Forty patients (S-BPL group) received BPL lengths ≤ 50 cm, including 30 cm (n = 1), 40 cm (n = 1), and 50 cm (n = 38). Forty-four patients (L-BPL group) received 100 cm BPL. Anthropometry, serum glucose and lipid metabolic parameters were measured at baseline and 1, 3, 6, 12, 24 and 36 months after surgery.

Results: Comparing the two groups, there were no significant differences in anthropometric and biochemical measures, except the weight and body mass index, which were higher in the S-BPL group (85.91 ±20.32 vs. 76.25 ±16.99, p = 0.038; 31.87 ±6.61 vs. 28.7 ±4.29, p = 0.005) compared to the L-BPL group. The body weight, glucose and lipid metabolic parameters decreased over time and then remained essentially stable from the first year in both groups. Two years after surgery, the remission (HbA$_{1c}$% ≤ 6%) of T2DM was 31.2% in the S-BPL group and 37.5% in the L-BPL group (p = 0.685).

Conclusions: With consistent total small bowel bypass (AL + BPL) lengths, lengthening of the BPL from 30 to 100 cm did not affect the post-RYGB glycemic control and weight loss.

Key words: Roux-en-Y gastric bypass, type 2 diabetes mellitus, biliopancreatic limb.

Introduction

The Roux-en-Y gastric bypass (RYGB) is currently still the most preferable surgical intervention to treat morbid obesity and type 2 diabetes mellitus (T2DM). The total number of bariatric procedures was approximately 54 490 from 31 countries in the 3 calendar years 2013–2015, of which 49.4% were RYGB procedures [1]. But still, there is no consensus on the ideal gastric bypass limb lengths. Reported lengths of the biliopancreatic limb (BPL) and alimentary limb (AL) varied widely from 10–250 to 35–250 cm, respectively, in a survey of 215 American bariatric surgeons by the American Society for Bariatric Surgery [2].

A number of comparative studies have been performed with variable lengths of the AL, and they show controversy in the effect on weight loss

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[3–16]. A few studies have revealed the relationship between the lengths of the bypassed limb and the remission of T2DM. Pinheiro *et al.* [12] reported that patients with longer AL and BPL achieved greater type 2 diabetes control and lipid disorder improvement. Kaska *et al.* [17] found that a longer BPL can intensify the anti-diabetic effect of RYGB. However, with the extension of AL and BPL length, the common limb (CL) becomes shorter. Many authors also have demonstrated that weight loss and remission of T2DM after RYGB are strongly associated with a short common limb. Unfortunately, the shorter the common limb, the more malnutrition and metabolic complications can be expected [4, 18, 19]. Therefore, how to choose the length of the bypass limb has a vital impact on balancing the efficacy of surgery and nutritional complications in RYGB.

Aim

Generally, an AL length of 100 to 150 cm and a BPL length of 25 to 100 cm with an unmeasured CL length were recommended [2, 20]. In this study, we kept the total bypass (AL + BPL) lengths consistent
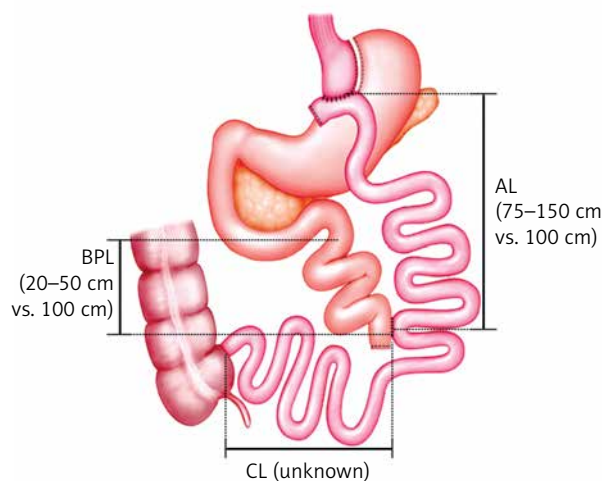

Figure 1. Schematic drawing of operation and limb lengths: In standard BPL group patients, the length of the biliopancreatic limb (distance from the ligament of Treitz to the jejunojejunostomy) is 20–50 cm and the alimentary limb (distance from the gastrojejunostomy to the jejunojejunostomy) is 75–150 cm. In longer BPL group patients, the length of the biliopancreatic limb is 100 cm and the alimentary limb is 100 cm

BPL – biliopancreatic limb, AL – alimentary limb, CL – common limb length.

in two groups, and extended the BPL length in order to evaluate its clinical efficacy in T2DM remission.

Material and methods

Patient selection and follow-up

Eighty-four patients with uncontrolled T2DM who underwent RYGB at our hospital from May 2010 to April 2017 were retrieved from a prospectively designed database. The protocol for this study was approved by the Ethics Committee and institutional review at our hospitals and was compliant with the Helsinki Declaration.

The inclusion criteria were as follows: diagnosis of T2DM or other important co-morbidity based on the criteria of the American Diabetes Association (ADA) [21], from 18 to 60 years of age, body mass index (BMI) > 25 kg/m^2 (based on Chinese obesity and type 2 diabetes surgical treatment guidelines (2014)). A patient would be excluded if he or she had previously undergone bariatric surgery or other complex abdominal surgery, as were those with established diagnoses of type 1 diabetes, latent adult autoimmune diabetes, malignancy, pregnancy, neurologic disease or cardiovascular disease.

Prior to the operation, each patient was assessed by a multidisciplinary team (MDT) comprising a surgeon, endocrinologist, anesthetist, psychiatrist and dietician. Moreover, each patient underwent a routine preoperative workup and counseling in addition to a detailed diabetic workup. Patients were followed up at the outpatient endocrinology clinic with weight registration and metabolic (glucose and lipid) surveillance. The date sets of baseline and 1, 3, 6, and 12 months after surgery and annually thereafter were collected.

Surgical procedure

Laparoscopic RYGB was performed by a single surgeon; the technical aspects of the procedures were the same. For LRYGB, five trocars were used, constructing a 25–30 ml gastric pouch, the gastrojejunostomy was created by a staple technique with an anastomosis 1.5–2.0 cm in diameter, and the integrity of the anastomosis was tested with methylene blue solution infused through an orogastric tube. The length of the biliopancreatic limb was 20–50 cm in the short biliopancreatic limb (S-BPL) group and 100 cm in the long biliopancreatic limb (L-BPL) group,

with alimentary limb values of 75–150 cm and 100 cm in S-BPL and L-BPL respectively (Figure 1). The mesenteric and Petersen defects were closed.

Outcomes

The primary end point was the proportion of patients with a glycated hemoglobin (HbA$_{1c}$) level of 6% or less (with or without diabetes medications) for at least 12 months [22]. Secondary end points included levels of fasting plasma glucose (FPG), 2-hour postprandial glucose (2hPG), fasting C-peptide, HbA$_{1c}$, serum total cholesterol (TC), triglyceride (TG), high-density lipoprotein (HDL), low-density lipoprotein (LDL), arterial blood pressure, BMI and waist circumference.

Statistical analysis

Statistical analysis was performed using SPSS version 17.0 (SPSS Inc, Chicago, IL, USA). Graphs were made using a commercially available software package (GraphPad Prism for Windows). Baseline comparisons were performed using the χ^2 test, paired t test, and one-way ANOVA. Continuous variables were expressed as mean ± standard deviation, continuous variables were compared using Student ANOVA for repeated measurement, and a two-tailed p-value < 0.05 was considered statistically significant.

Results

Patients

We retrospectively evaluated the results of 84 patients with T2DM who underwent laparoscopic RYGB, including 38 (45.2%) women and 46 (54.8%) men. They were divided into two groups based on the length of BPL. Forty patients were enrolled in the S-BPL group, including 30 cm (n = 1), 40 cm (n = 1), and 50 cm (n = 38). The L-BPL group consisted of 44 patients who received 100-cm limbs. The number of follow-up patients was 51 (60.7%) at 1 year, 40 (47.6%) at 2 years, 13 (15.5%) at 3 years. The baseline patient characteristics are shown in Table I. Comparing the two groups, there were no significant differences in age, duration of diabetes, blood pressure, or glucolipid metabolism. However, the patients of the S-BPL group had significantly greater weight (85.91 ±20.32 vs. 76.25 ±16.99 kg, p = 0.038), higher BMI (31.87 ±6.61 vs. 28.7 ±4.29 kg/m^2,

p = 0.005) and higher C-peptide level (2.01 ±2 vs. 1.08 ±0.66 ng/ml, p = 0.01).

Complications

All procedures were successfully performed by laparoscopic techniques. There was no early or late mortality. Eight (9.5%) patients developed early or late complications, including 1 patient with gastrojejunal anastomotic leakage, 2 patients with gastrojejunal anastomotic stenosis, 2 patients with anastomotic ulcer, 2 patients with anemia and 1 patient with severe malnutrition. All such complications were cured through conservative treatment.

Glycemic control

In both groups, the FPG, 2hPG, HbA$_{1c}$% and C-peptide levels steadily decreased in the first 6 months (p < 0.05), and remained stable during follow-up (Figure 2). Although a trend of better glucose metabolic control was observed in the L-BPL group, there was no significant difference at any point between the S-BPL and L-BPL groups (Figures 2 A–C). In 1-year follow-up after surgery, C-peptide in the S-BPL group was higher than that of the L-BPL group (p < 0.05) (Figure 2 D).

The remission of T2DM at one year is shown in Table II. Eleven (52.3%) patients in the S-BPL group and 17 (56.7%) patients in the L-BPL group achieved complete remission of diabetes mellitus with HbA$_{1c}$ < 6.0% (p = 0.762), and 18 (85.7%) patients in the S-BPL group and 26 (86.7%) patients in the L-BPL group achieving improvement of diabetes mellitus with HbA$_{1c}$ < 7.0% (p = 0.923).

The remission of T2DM at 2 years is shown in Table III. Five (31.2%) patients in the S-BPL group and 9 (37.5%) patients in the L-BPL group achieved complete remission of diabetes mellitus with HbA$_{1c}$ < 6.0% (p = 0.685), and 13 (81.2%) patients in the S-BPL group and 26 (79.2%) patients in the L-BPL group achieved improvement of diabetes mellitus with HbA$_{1c}$ < 7.0% (p = 0.872).

Weight loss

Patients in both groups showed a significant mean weight, BMI and waist circumference reduction. Three years after surgery, the mean weight had declined from 85.91 ±20.32 to 59.36 ±10.94 (p = 0.007), BMI had declined from 31.87 ±6.61 to 23.23 ±2.02 (p = 0.01), and waist circumference had decreased from 102.21 ±12.65 to 80 ±6.55 (p < 0.001) in

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Table I. Baseline patient characteristics

Characteristic	BPL group (n = 40)	BPL group (n = 44)	P-value
Male/female	23/17	23/21	0.631
Age [years]	42.7 ±11.7	44.77 ±9.4	0.065
Duration of diabetes [years]	3.13 ±3.55	6.01 ±4.22	0.152
Weight [kg]	85.91 ±20.32	76.25 ±16.99	0.038*
BMI [kg/m^2]	31.87 ±6.61	28.7 ±4.29	0.005*
Waist circumference [cm]	102.21 ±12.65	95.85 ±11.14	0.099
SBP [mm Hg]	132.38 ±15.7	131.86 ±15.5	0.841
DBP [mm Hg]	81.15 ±11.3	80.8 ±11	0.976
FPG [mmol/l]	8.12 ±3.31	8.59 ±3.07	0.93
2hPG [mmol/l]	14.53 ±5.12	17.1 ±4.27	0.321
HbA$_{1c}$ (%)	8.01 ±2.31	8.35 ±1.77	0.169
C-peptide [ng/ml]	2.01 ±2	1.08 ±0.66	0.01*
TC [mmol/l]	4.65 ±1.1	5.18 ±1.37	0.51
TG [mmol/l]	2.73 ±2.21	2.96 ±2.49	0.867
HDL [mmol/l]	1.17 ±0.81	1.26 ±0.96	0.552
LDL [mmol/l]	2.5 ±0.61	2.97 ±0.91	0.194

*BMI – body mass index, SBP – systolic blood pressure, DBP – diastolic blood pressure, FPG – fasting plasma glucose, 2hPG – 2-hour postprandial blood glucose, HbA$_{1c}$ – glycated hemoglobin A$_{1c}$, TC – total cholesterol, TG – triglyceride, HDL – high-density lipoprotein, LDL – low-density lipoprotein, *p < 0.05.*

the S-BPL group. In the L-BPL group, the mean weight decreased significantly from 76.25 ±16.99 to 55.65 ±6.48 ($p < 0.001$), BMI decreased from 28.7 ±4.29 to 22.21 ±1.33 ($p < 0.001$), and HbA$_{1c}$ decreased from 95.85 ±11.14 to 81.42 ±6.6 ($p < 0.001$). The changes in weight, BMI and waist circumferences among the subjects in both groups are shown in Figures 3 A–C. The changes in weight, BMI and waist circumference were not different at any point between the S-BPL and L-BPL groups, except in the 1-month post-surgery follow-up, when BMI was higher in the S-BPL group than the L-BPL group ($p < 0.05$).

Lipid levels and blood pressure

Post-operative serum total cholesterol (TC) and triglyceride (TG) showed a sharp fall in the first month in both groups, recovered slightly at 1 year and remained stable in the following years (Figures 4 A, B). The serum HDL and LDL cholesterol remained stable in the follow-up period (Figures 4 C, D). The serum levels of TC, TG, HDL, and LDL were similar at each time point for both groups ($p > 0.05$).

The systolic and diastolic blood pressure decreased from baseline to 3 years in both groups,

albeit not significantly (Figures 5 A, B), and there were no differences at any point between groups ($p > 0.05$).

Discussion

RYGB is considered to be a restrictive and malabsorptive procedure, creating a small gastric pouch (usually 15–30 ml) which limits the amount of food that can be ingested, and bypassing of the duodenum and part of the small bowel provides a degree of malabsorption, together resulting in weight loss and glycemic control. Particularly, the "foregut and hindgut hypotheses" described by Rubino and Cummings explain the hormonal and metabolic benefits of bypassing the duodenum and part of the proximal jejunum and accelerating the undigested food to the distal intestine [23–25], which plays an important role in the treatment of T2DM.

Over the past decades, researchers have sought to achieve greater weight loss by reducing the pouch size and lengthening the limb length. A number of studies have focused on the effect of the AL length and weight loss [26, 27], while less research has been performed to explore the effect of various BPL on
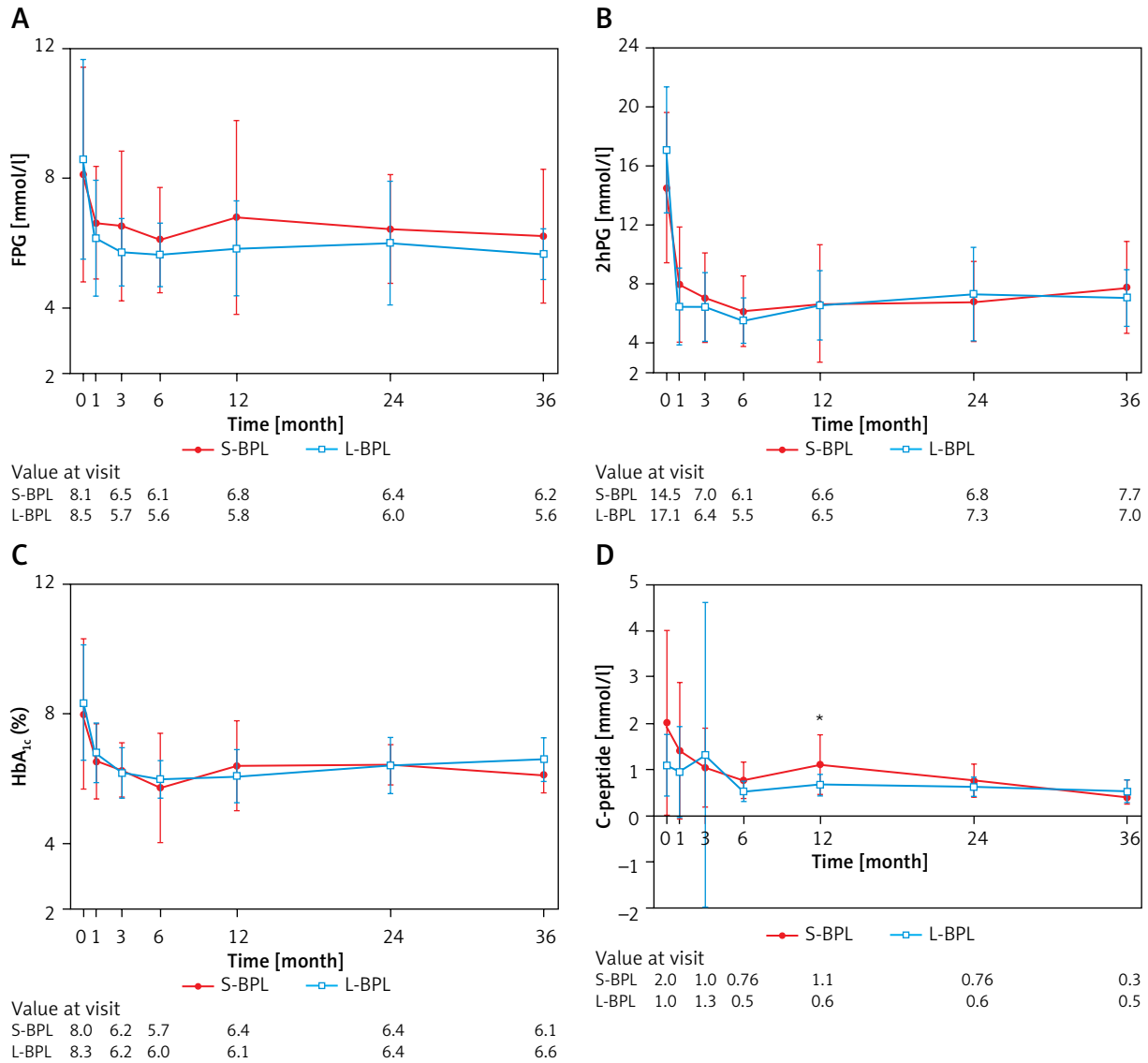
Figure 2. Mean changes in measures of diabetes control from baseline to 3 years between the two groups. **A** – Fasting plasma glucose (FPG). **B** – 2-hour postprandial blood glucose (2hPG). **C** – Glycated hemoglobin A$_{1c}$ (HbA$_{1c}$). **D** – C-peptide

*p < 0.05.

Table II. Remission of type 2 diabetes mellitus in group of S-BPL and L-BPL at 1 year

Glycated hemoglobin	S-BPL (n = 21)	L-BPL (n = 30)	P-value
≤ 6.0%, n (%)	11 (52.3)	17 (56.7)	0.762
≤ 6.5%, n (%)	13 (61.9)	25 (83.3)	0.084
≤ 7.0%, n (%)	18 (85.7)	26 (86.7)	0.923

S-BPL – short biliopancreatic limb, L-BPL – long biliopancreatic limb.

Table III. Remission of type 2 diabetes mellitus in group of S-BPL and L-BPL at 2 years

Glycated hemoglobin	S-BPL (n = 16)	L-BPL (n = 24)	P-value
≤ 6.0%, n (%)	5 (31.2)	9 (37.5)	0.685
≤ 6.5%, n (%)	8 (50)	15 (62.5)	0.433
≤ 7.0%, n (%)	13 (81.2)	19 (79.2)	0.872

S-BPL – short biliopancreatic limb, L-BPL – long biliopancreatic limb.

weight loss and T2DM remission [12, 17]. In the study by Dallegrave Marchesini [28] and Stefanidis *et al.* [29], a better anti-diabetic effect and a higher T2DM remission rate were demonstrated in patients with a longer BPL, not with a longer AL. An editorial comment indicated that manipulating BP limb length may hold a key in optimizing the effect of RYGB [30].

There is a case reported by Kao *et al.* [31], a woman (BMI: 34.4 kg/m^2) with T2DM, who had undergone RYGB three times. For the first RYGB, BPL was set at 150 cm, and AL was 100 cm, after 18 months, her BMI and HbA$_{1c}$ were 25.2 kg/m^2 and 4.6%, but frequent diarrhea occurred and medical treatment for this was unsuccessful. So she underwent a laparoscopic
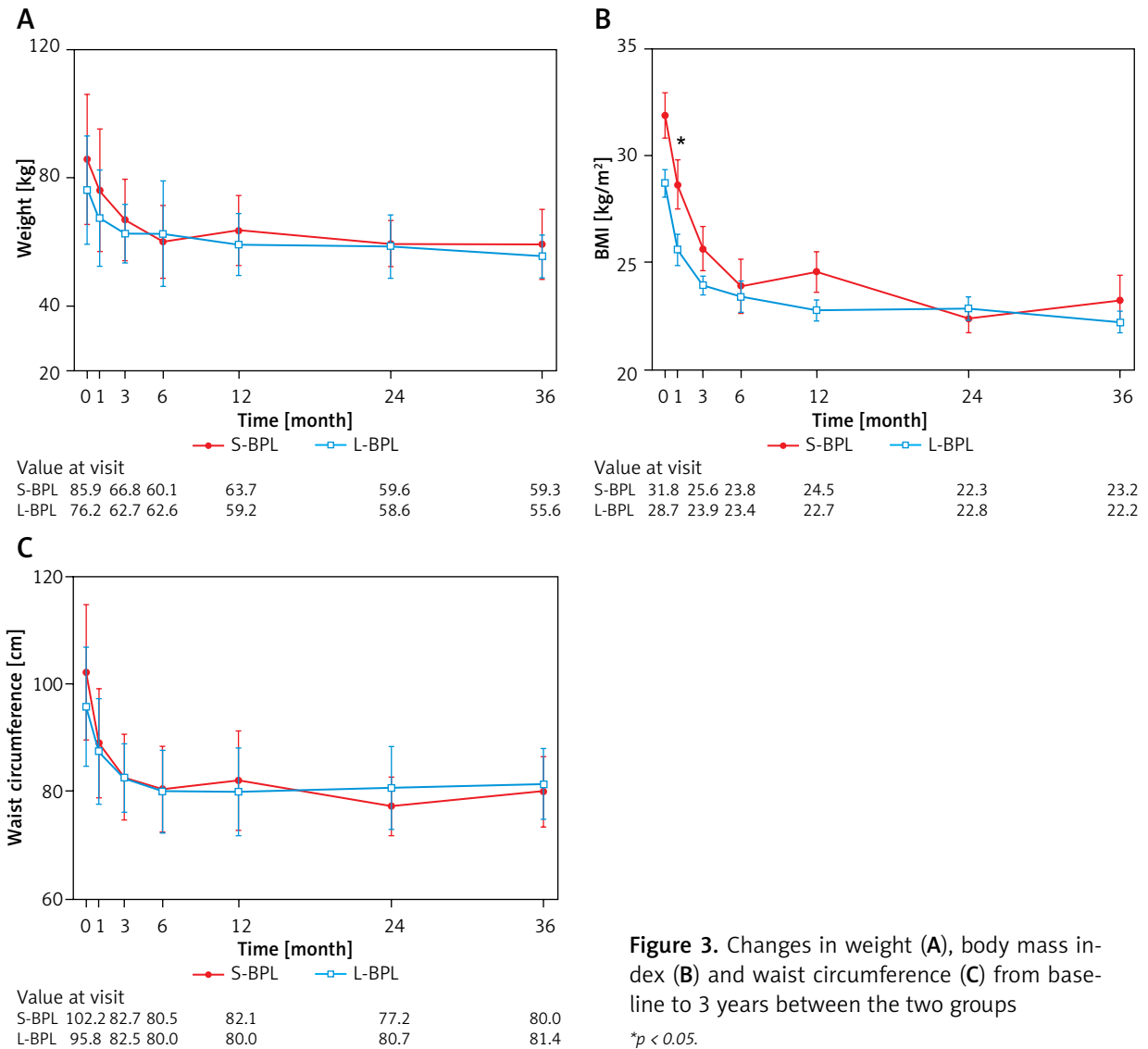

A

Value at visit
S-BPL 85.9 66.8 60.1   63.7   59.6   59.3
L-BPL 76.2 62.7 62.6   59.2   58.6   55.6

B

Value at visit
S-BPL 31.8 25.6 23.8   24.5   22.3   23.2
L-BPL 28.7 23.9 23.4   22.7   22.8   22.2

C

Value at visit
S-BPL 102.2 82.7 80.5   82.1   77.2   80.0
L-BPL 95.8 82.5 80.0   80.0   80.7   81.4

Figure 3. Changes in weight (**A**), body mass index (**B**) and waist circumference (**C**) from baseline to 3 years between the two groups
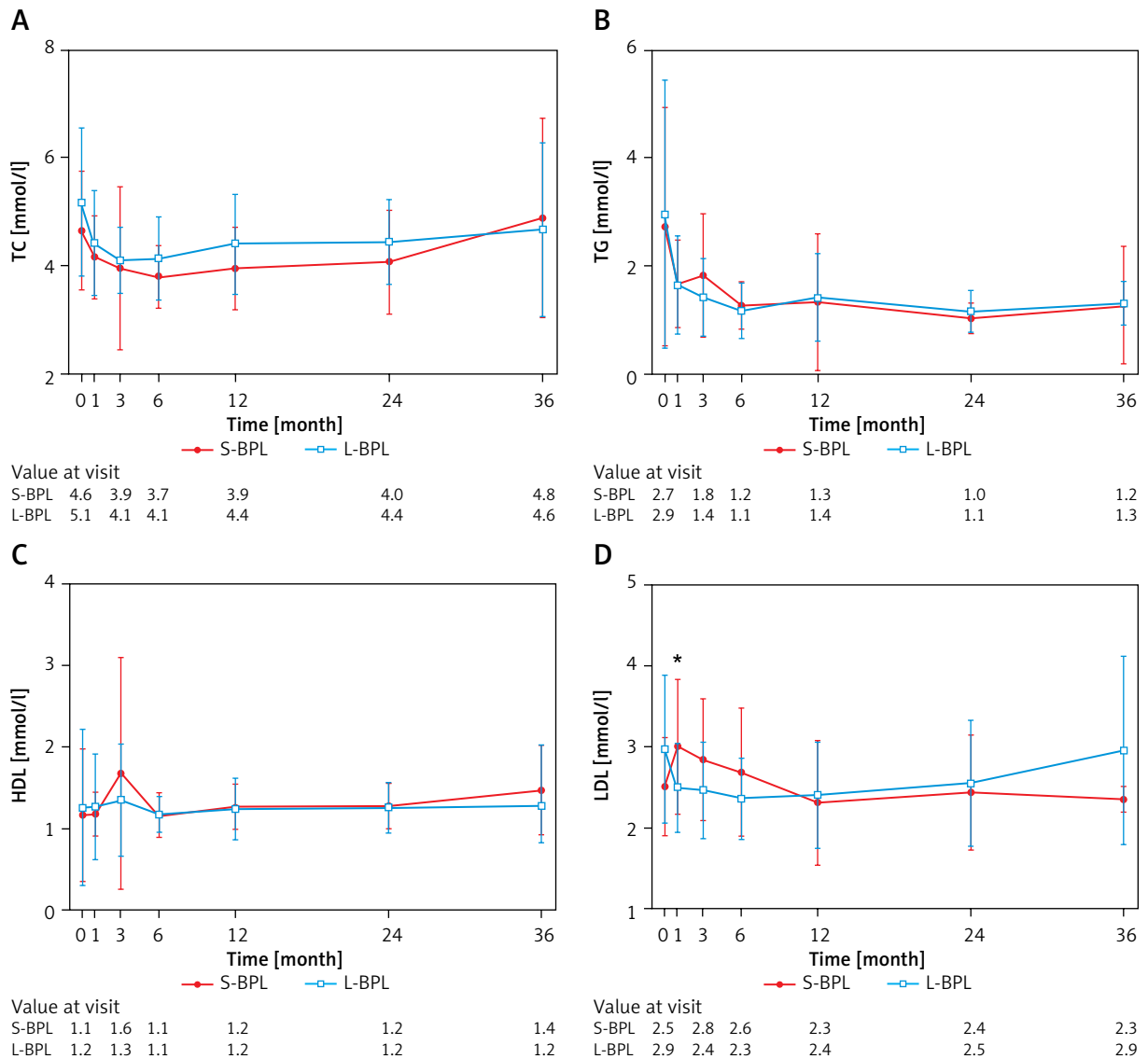
*p < 0.05.

Figure 4. Mean changes in measures of lipid profile from baseline to 3 years between the two groups. **A** – Total cholesterol (TC). **B** – Triglycerides (TG). **C** – High-density lipoprotein (HDL). **D** – Low-density lipoprotein (LDL)

revision, bypass limbs were shortened (BPL: 40 cm, AL: 70 cm), her diarrhea improved, but T2DM recurred immediately after the reoperation. Subsequently, a second revision procedure was performed again, during which the bypassed limbs were lengthened (BPL: 100 cm, AL: 70 cm). Eventually, T2DM remission was achieved again after the last operation. Therefore, the BPL length plays a key role in the treatment of type 2 diabetes after RYGB.

Also, some previous studies have proved that the degree of malabsorption after gastric bypass is influenced mainly by the length of the CL rather than the lengths of the AL or BPL [29]. The better long-term weight loss and type 2 diabetes control described by some studies when longer AL and BPL are used are likely a reflection of the shortening common channel [12, 32], but the shorter the common limb, the more malnutrition and metabolic complications can be expected [18, 19]. Unfortunately, few studies have taken into consideration the length of the common channel, so we have a limited understanding of how long the common channel should be to achieve the best weight loss and glucose control outcomes without increasing the incidence of nutritional complica-
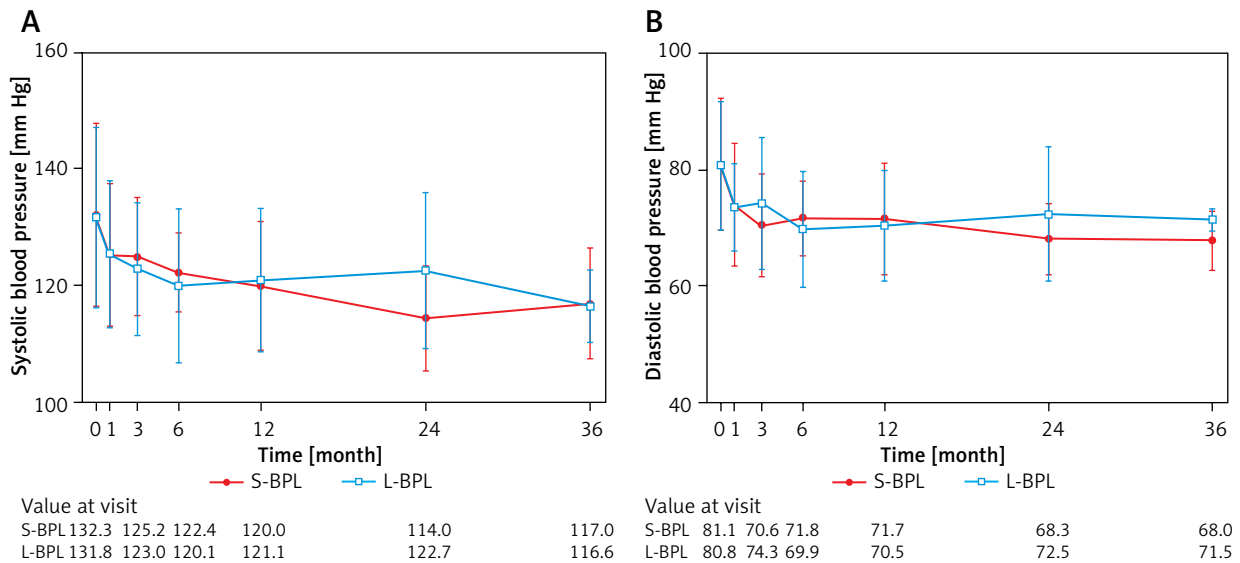
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Figure 5. Changes in blood pressure from baseline to 3 years between the two groups. **A** – Systolic blood pressure, **B** – diastolic blood pressure

tions. Many studies have shown that the total small bowel length can be extremely variable; a range of 300 to 900 cm is a widely accepted figure [27]. Therefore, we have to consider the total small bowel length in RYGB, given that the three limb lengths (AL, BPL and CL) are interdependent; the longer AL and/or BPL are, the shorter the CL becomes.

In this study, the length of total bypass (AL + BPL) was set at 200 cm in most patients, with unknown length of the common limb, and a few patients in the early stages of the operation with a short bypassed limb (range: 100–150 cm), so that we have kept long enough CL to reduce the risk related to the high degree of malabsorption from too short common limb. We wondered whether extending the BPL can improve clinical efficacy in T2DM remission. In a recent evidence-based review, Mahawar *et al.* came to the conclusion that RYGB achieves optimum results when the combined length of BPL or AL is between 100 and 200 cm. Furthermore, small differences in the proportion of BPL and AL do not result in significantly different outcomes. Our research also verified the conclusion. In our study, there was a trend of more reduction in the glucose metabolism and weight loss for the L-BPL group, but there was no significant difference at any point in the S-BPL and L-BPL groups. So future studies should examine greater differences in the lengths of BPL and AL.

The improvements of diabetes, hypertension and dyslipidemia play important roles in reducing microvascular disease, cardiovascular complications and all-cause mortality. In T2DM patients, lipid abnormalities are thought to be secondary to obesity, insulin resistance, and decreased insulin production [33]. Decreasing LDL cholesterol and blood pressure reduces the risk of cardiovascular events in populations of patients with diabetes [34]. In our study, lipid metabolism and blood pressure were improved in both groups of patients, although there was no statistically significant difference between the two groups. Thus, we concluded that RYGB can improve the patients' cardiovascular risk factors in both groups, which may in turn improve their life expectancy in the coming years.

There was no mortality and no need of reoperation in this study, and the overall morbidity of 9.5% was similar to large series in the literature, which reported an overall complication rate of 5–19% [35]. A previous study reported a higher internal hernia rate in patients with a longer limb length [9]. The mesenteric and Petersen defects were closed to prevent these hernias in our hospital. A patient with severe malnutrition was cured through conservative treatment 1 year after surgery in this study. Also there were reports of 2 cases of severe malnutrition after mini-gastric bypass surgery [19, 36]; unfortunately, 1 patient expired after all resuscitative measures were unsuccessful. Those case reports informed us that individualized treatment and long-term follow-up play a very important role in the whole treatment.

This study had several limitations. First, the relatively minor change (50 cm vs. 100 cm) in the proportion of BPL may have limited the contribution to glucose control and weight loss. Secondly, the case number was relatively small and 3-year follow-up was not long enough to determine late complications and maintenance of diabetes remission. Last and most important, we failed to take into consideration the CL, which could be a determinant factor for malabsorption.

Conclusions

RYGB is an effective procedure for the treatment of T2DM. With the total bypass (AL + BPL) lengths consistent, lengthening of the BPL from 30 to 100 cm did not affect post-RYGB glucose control and weight loss.

Acknowledgments

Conflict of interest

The authors declare no conflict of interest.

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