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Weight loss and metabolic improvements in obese patients undergoing gastric banding and gastric banded plication: A comparison

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ABSTRACT

Objectives: Obesity is a pandemic health problem. Bariatric surgery is the only efficient method for long-term effective weight loss in subjects with severe obesity. Laparoscopic adjustable gastric banding (LAGB) has been widely applied for weight loss. However, a novel technique called laparoscopic adjustable gastric banded plication (LAGBP) has been proposed as an alternative to LAGB. Surgeons generally consider LAGBP to have a relative advantage on weight loss than that derived from LAGB. This initial study applied various biostatistical models and considered a relative longer observation period to compare the effects of LAGB and LAGBP.

Methods: A total of 340 obese patients (290 who underwent LAGB and 50 who underwent LAGBP) with a body mass index of ≥35 kg/m^2 and ages 20 to 55 y were recruited from the Division of General Surgery, Taipei Medical University Hospital in Taipei, Taiwan and observed for 24 to 36 mo postoperatively.

Results: Both surgical procedures resulted in significant weight loss, amelioration of poor glucose metabolism, and decreased serum triacylglycerol levels. However, the trend analysis showed no significant differences between the postoperative effects of LAGB and LAGBP (P for trend = 0.21 for body mass index reduction, 0.13 for total body fat percentage reduction, 0.25–0.29 for glucose metabolism amelioration, and 0.10–0.29 for blood pressure improvement). Improvements in serum total cholesterol and high-density lipoprotein cholesterol levels were observed after LAGB only and LAGBP only, respectively, at 24 mo postoperatively. The Framingham Coronary Heart Disease Risk score also showed significant decrease for patients who underwent LAGB and LAGBP.

Conclusions: Both LAGB and LAGBP demonstrated comparable efficacy in reducing body weight and improving metabolic parameters in a 24 to 36 mo follow-up period. LABG showed the ability to reduce systolic blood pressure and LAGBP exhibited triacylglycerol-lowering effects. A longer observational period is needed in future studies.

Introduction

Obesity is a pandemic health problem. Bariatric surgery is the only proven method for long-term effective weight loss for patients with severe obesity [1–4]. Laparoscopic adjustable gastric banding (LAGB) is a restrictive type of bariatric surgery that is safe, has a low failure rate, requires a shorter hospital stay [5], and causes

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fewer long-term sequelae. However, LAGB has a lower efficiency for weight loss and metabolism amelioration compared with other bariatric surgical procedures [6,7].

The surgery involves the restriction of the upper stomach and creation of a small pouch by using an adjustable band to ideally control patients' food-intake amount and reduce their speed of eating. The use of only a band can neither control patients' eating behavior nor restrict the passage of high-calorie liquid diets, the consumption of which cannot be limited in the gastric pouch.

For severely obese patients, a novel technique called laparoscopic adjustable gastric banded plication (LAGBP) has been proposed as an alternative to traditional gastric banding. LAGBP additionally involves a plication procedure over the greater curvature of the stomach distal to the band, which further limits the gastric volume distal to the band as well as to the proximal pouch. LAGBP is considered more effective for weight loss [8,9] and increasing lipid metabolism compared with other procedures on the basis of short- and midterm responses [10,11].

Although gastric plication has been demonstrated to lead to acceptable weight loss compared with other restrictive bariatric surgeries, the procedure increases readmission rates for postoperative nausea and vomiting [12,13]. With respect to weight loss, surgeons tend to favor LAGBP over LAGB because LAGBP involves an additional plication, which mimics sleeve gastrectomy and yields a smaller stomach volume than LAGB. To date, most studies have focused on exploring the efficiency of weight loss between LAGBP and sleeve gastrectomy [13–15] and their similar operative procedures and postoperative sequelae. However, most studies were designed from a postoperative rather than from a presurgical time point; thus, without offering a sufficiently long observation period to cover the entire procedure.

Until now, relatively few studies have compared the postoperative effects of LAGBP and LAGB with a sufficiently long experimental time. In the present study, we applied various biostatistical models and considered long observation periods (up to 36 mo), using repeated generalized linear model (GLM; trend analysis) to compare the postoperative effectiveness of LAGB and LAGBP. Moreover, a multivariate analysis of variance (MANOVA) was applied to analyze the time effect on bariatric surgery outcomes.

In this study, we aimed to comprehensively explore whether the postoperative effects of LAGBP are superior to those of LAGB in terms of reduction in body mass index (BMI), total body fat percentages, and improvements in metabolic responses related to blood pressure, serum lipid, glucose levels, and changes in Framingham Coronary Heart Disease Risk (FCHDR) score.

Materials and methods

Patients

All patients were recruited from the Division of General Surgery, Taipei Medical University Hospital in Taipei, Taiwan. Between May 2006 and December 2013, a total of 356 obese patients (age 20–55 y) with a BMI of ≥35 kg/m^2 underwent bariatric surgery for weight reduction. The patients were recommended to undergo either LAGB (Lap-Band from Bioenterics Corp., Carpinteria, CA) or LAGBP. All patients who were scheduled for bariatric surgery were evaluated for their physiological status, and only patients who were willing to undergo LAGB and LAGBP were included. Patients selected either LAGB or LAGBP based on their personal preference after a detailed and objective consultation with the surgeon.

A total of 340 patients were included and followed for a 3-y period. Of these patients, 290 patients underwent LAGB and 50 patients LAGBP. The postoperative rates at the first, second, and third year were 99.3%, 72.7%, and 35.2%, respectively, on LAGB and 96%, 56%, and 22%, respectively, on LAGBP. This study was performed with the approval of the ethics committees of the Taipei Medical University Hospital and Chang Jung Christian University (IRB protocol approval No. CRC-06-09-10; 201203002 and CJCU-98-013).

Patients had a 24- to 36-mo follow-up period in accordance with the provisions of the Health Insurance Bureau in Taiwan. The band adjustment was performed if inadequate weight loss was noted during the follow-up period. The present study was an observational study, not an interventional study, whereby biochemical and blood pressure data are collected only within 24 mo after surgery due to budget constraints of Taiwan National Health Insurance.

Study design

We noted the changes in postoperative effects of LAGB and LAGBP within a 2 to 3-y period and compared the differences in the effects between the two surgical procedures (data collection at every 6 mo within 2–3 y postoperatively). The effects of the two surgeries on weight loss, blood pressure, and glucose and lipid metabolism were also assessed. In addition, the individual potential physiological pathways underlying these effects were explored.

Data collection

Cardiovascular disease- and diabetes mellitus (DM)-related indicators including anthropometry and serum biochemistry data were collected. All anthropometry and serum biochemistry data were retrieved using the standard operating procedures of the Taipei Medical University Hospital. Body composition data (percentages of fat mass, fat-free mass, muscle mass, and water content in the muscle and total body) were collected using a bioelectrical impedance analyzer (BIA), Inbody 230 (Biospace, Seoul, Korea). Weight-loss efficacy was documented as the change in BMI and total body fat percentage preoperatively, and at 6, 12, 18, 24, 30, and 36 mo postoperatively. Sex and changed responses at 24 mo postoperatively of age, smoking status, serum total cholesterol and high-density lipoprotein (HDL) cholesterol levels, systolic blood pressure, and blood pressure treated with medication were also collected to calculate changes in FCHDR score preoperatively to 24 mo postoperatively.

Statistical analysis

SAS (version 9.4) was applied for the data analysis. The Student *t* test was used to compare preoperative age, BMI, waist circumference, total body fat percentage, and resting metabolic rate between patients who underwent LAGB and those who underwent LAGBP. The χ^2 test was used to analyze sex distribution. Postoperative serum biochemical data (except BMI) were analyzed using an ANCOVA model to adjust for preoperative age, sex distribution, and BMI for LAGB and LAGBP. The paired Student *t* test was used in comparisons between presurgical data with data at each time point within 36 mo postoperatively.

A trend analysis (to obtain *P* values for the trend) was performed using the repeated GLM to explore whether LAGB and LAGBP had a significantly different effect on postoperative indicators within 24 or 36 mo postoperatively. The SAS syntax of PROC GLM with "/NOUNI" was used to construct the relationships among the 6 to 8 repeated sets of observed data for each indicator of one surgical type within 24 to 36 mo postoperatively because all sets of repeated observed data related to the other data (test total effect of each surgical type within the entire experimental period). This aided in comprehensively understanding the postoperative efficacy in a consecutive time course postoperatively.

The time effect was applied using a MANOVA to examine whether surgery type maintained a consistent efficacy over time within 24 to 36 mo postoperatively. If postoperative data presented a larger fluctuation over time, the time effect may not exist (i.e., no changed trend exists). The Pearson correlation coefficient was used to explore correlations among different postoperative indicators to explain possible physiological pathways. A *P* value of <0.05 was considered to denote significance.

Results

No significant difference was noted between the LAGB and LAGBP groups in sex distribution as well as cardiovascular disease- and DM-related indicators (Table 1). The mean preoperative BMI values of the LAGB and LAGBP groups were 38.5 ± 5.8 and 38.1 ± 6.6 kg/m^2, respectively, which indicates that there is no significant difference between the two groups ($P = 0.593$). Patients who underwent either LAGB or LAGBP had similar physiological conditions preoperatively in this study.

As shown in Figure 1, BMI and total body fat percentage decreased to the lowest levels in postoperative mo 18 to 30 (lowest BMI after LAGB and LAGBP = 30.8 at month 24 and 30.2 at month 18, respectively; lowest total body fat percentage after LAGB and LAGBP = 35.2% at month 18 and 33.1% at month 30, respectively). Compared with the preoperative data, BMI reduction and total body fat percentage reduction were not biostatistically significant

Table 1
Characteristics of severely obese patients before bariatric surgery

	Bariatric surgery type		
	LAGB	LAGBP	*P*
Women/men, n	158/132	29/21	0.644
Age, y	34.6 ± 8.5	34.2 ± 7.6	0.761
Anthropometric data			
Body mass index, units	38.5 ± 5.8	38.1 ± 6.6	0.593
Waist circumference, cm	114.5 ± 15.0	114.0 ± 15.3	0.870
Total body fat percentage, %	43.2 ± 6.3	42.8 ± 6.0	0.658
Resting metabolic rate, Kcal/d	1673.4 ± 274.6	1690.9 ± 292.8	0.720
Blood pressure			
Systolic blood pressure, mm-Hg	136.9 ± 16.2	138.3 ± 22.5	0.621
Diastolic blood pressure, mm-Hg	89.4 ± 17.3	89.0 ± 18.4	0.887
Biochemical data (serum)			
Fasting blood glucose, mg/dL	114.9 ± 43.9	109.2 ± 46.8	0.540
Glycated hemoglobin, %	6.3 ± 0.9	6.4 ± 0.5	0.980
High-sensitivity C-reactive protein	0.5 ± 0.4	0.7 ± 1.0	0.248
Total triacylglycerol, mg/dL	180.2 ± 119.6	213.0 ± 232.5	0.246
Total cholesterol, mg/dL	193.8 ± 34.4	199.2 ± 45.8	0.453
High-density lipoprotein, mg/dL	48.7 ± 14.0	48.6 ± 10.4	0.971
Low-density lipoprotein, mg/dL	130.4 ± 29.6	126.2 ± 25.8	0.231
Blood urea nitrogen, mg/dL	13.9 ± 4.6	13.9 ± 4.7	0.923
Creatinine, mg/dL	0.9 ± 0.4	0.9 ± 0.2	0.126
Uric acid, mg/dL	9.6 ± 1.9	9.7 ± 1.9	0.680

LAGB, laparoscopic adjustable gastric banding; LAGBP, laparoscopic adjustable gastric banded plication.
Anthropometric and serum biochemical data were analyzed in the analysis of covariance model to adjust for age, sex, and body mass index.

for the two surgical types within 36 postoperative mo. The *P* values for the time effect on BMI reduction and fat percentage changes by LAGB and LAGBP were not shown (Fig. 1).

A trend analysis using the repeated GLM also showed that surgical types were not a dominant effector for BMI loss (*P* for trend = 0.21; Fig. 1A) and total body fat percentage reduction (*P* for trend = 0.13; Fig. 1B) within 36 mo after surgery. Figures 1A and B illustrate the largest difference in BMI loss and total body fat percentage reduction between the two surgery types at 18 and 30 mo after surgery, respectively, but the difference was only of borderline significance (d = 1.4; *P* = 0.1 for BMI and d = 3.5% for fat percentage reduction; *P* = 0.08). Compared with the preoperative data, significant differences were observed from month 6 to 36 after LAGB and LAGBP, respectively. The time effect on total body fat percentage reduction was significant after LAGB and LAGBP (*P* = 0.008 and 0.006, respectively; data not shown).

To estimate glucose metabolic responses, fasting blood glucose (FBG) and glycated hemoglobin (A1c) levels were measured. For both types of surgery, FBG levels showed a significant reduction first at 6 mo postoperatively, and the reduction was maintained at the next three time points (12, 18, and 24 mo) after LAGB and LAGBP (Fig. 2A). A1C levels were initially significantly low at 12 mo after surgery in the LAGB group and 6 mo after surgery in the LAGBP group (Fig. 2B). The *P* values for the time effect on changes in the FBG levels after LAGB and LAGBP were both < 0.001 (data not shown and Fig. 2A, respectively). The *P* values for time effect on changes in the A1c levels after LAGB and LAGBP were 0.005 and 0.013, respectively (Fig. 2B). A comparison of the glucose metabolic responses (FBG and A1c) between the two surgery types yielded no significant differences at any time point within 24 mo postoperatively. With respect to A1c levels, larger differences were noted between the LAGB and LAGBP groups at 6, 12, 18, and 24 mo postoperatively, but the *P* values were not significant (d = 0.2%, with *P* = 0.056, 0.060, 0.060, and 0.058, respectively; Fig. 2B). A trend analysis using the repeated GLM also indicated that the surgery types were not significant effectors for postoperative glucose metabolism (*P* for trend = 0.29 for FBG, Fig. 2A; *P* for trend = 0.25 for A1c, Fig. 2B).

Compared with the preoperative data, systolic blood pressure showed a significant improvement at three time points after LAGB (12, 18, and 24 mo; Fig. 3A). However, after LAGBP, changes in systolic and diastolic blood pressure did not reach significance within 24 mo. For the two surgery types, the time effect on postoperative changes in systolic blood pressure did not reach significance (*P* = 0.82 for LAGB and 0.73 for LAGBP; data not shown and Fig. 3A, respectively). Similar results were observed for changes in diastolic blood pressure after LAGB and LAGBP (*P* = 0.08 and 0.12, respectively; data not shown). At most postoperative time points, differences in the effects of the two surgeries on blood pressure were not significant, except for those at 12 mo for systolic pressure (*P* < 0.001 and *P* = 0.012, respectively), as indicated by the asterisk. The trend tests showed insignificant effects on blood pressure between LAGB and LAGBP (*P*-value for trend was 0.10 and 0.26 for systolic- and diastolic pressure, respectively).

Figure 4 presents the postoperative lipid metabolisms. Compared with the preoperative data, the postoperative total serum total cholesterol levels almost failed to reach significance for both LAGB and LAGBP at the most time points, except for 12 and 24 mo after LAGBP (Fig. 4A). Similarly, the time effects on serum total cholesterol level improvement was significant for LAGBP but not for LAGB (LAGB *P* = 0.119; LAGBP *P* = 0.048; data not shown). Notably, postoperative serum total cholesterol levels showed a marginally significant improvement at 12 mo after LAGB compared with those after LAGBP (*P* = 0.061); however, the postoperative data for both surgeries showed a crossover at 18 mo after surgery. Serum total cholesterol levels after LAGBP were slightly higher than those after LAGB at 18 mo postoperatively but borderline lower (*P* = 0.088) than those after LAGB at 24 mo postoperatively (Fig. 4A). A trend analysis using the repeated GLM indicated that surgery type was not a significant effector for postoperative serum cholesterol levels (*P* for trend = 0.32; Fig. 4A).

As shown in Figure 4B, serum HDL levels were significantly elevated at 24 mo after LAGB and LAGBP, and the *P* values for time effect on changes in serum HDL levels for the two surgery types showed a biostatical significance (*P* = 0.036 and 0.048, respectively). HDL levels after LAGB and LAGBP showed a non-significant difference within 24 mo after surgery (Fig. 4B). A trend analysis using the repeated GLM indicated that surgery type was not a significant effector for postoperative serum HDL levels (*P* for trend = 0.46; Fig. 4B).

The differences in changes in serum low-density lipoprotein (LDL) levels between LAGB and LAGBP were not significant within 24 mo postoperatively (*P* for trend = 0.26), except the 18 mo postoperatively (Fig. 4C). In addition, the changes in LDL demonstrated two crossovers at intervals of 12 to 18 and 18 to 24 mo postoperatively. Notably, serum LDL levels were significantly lower in LAGB but significantly higher in LAGBP at 18 mo compared with the preoperative data. The difference reached 33 mg/dL between LAGB and LAGBP and showed a biostatical difference at the same time point (*P* < 0.032). Although the significantly lower levels disappeared at 24 mo postoperatively in LAGB (*P* = 0.088), the significant difference failed between LAGB and LAGBP at the same time point (Fig. 4C). The *P* values for the time effect on changes in serum LDL levels after LAGB and LAGBP were not significant (*P* = 0.831 and 0.752, respectively; data not shown).

Postoperative changes in serum triacylglycerol (TG) levels are presented in Figure 4D. With regard to the postoperative effects of LAGB on serum TG levels, these levels decreased significantly at 6 to 24 mo postoperatively compared with those preoperatively. However, LAGBP led to significant decreases in these levels only at

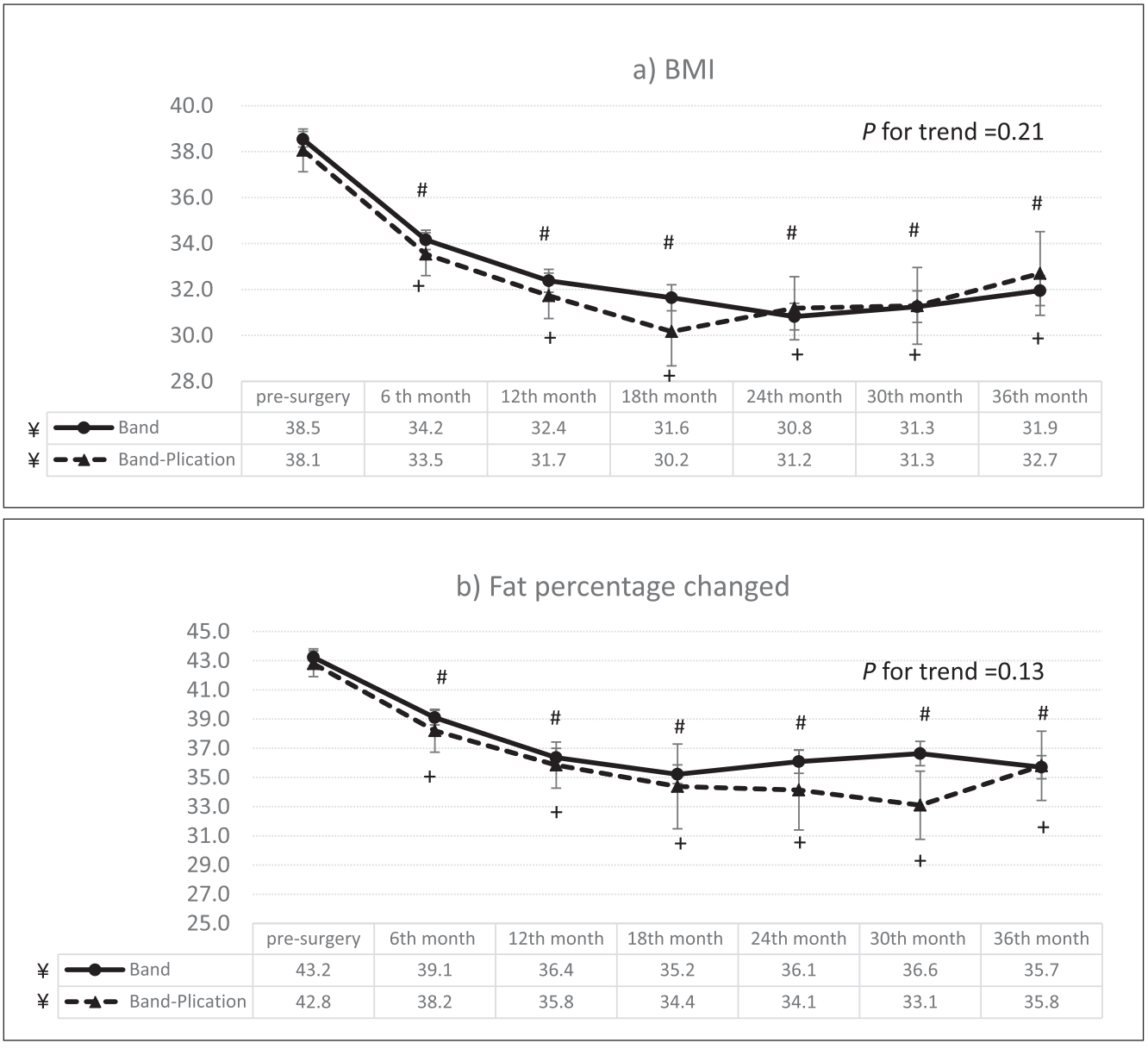

Fig. 1. Trend of changes in (A) body mass index and (B) total body fat percentage preoperatively to 36 mo postoperatively.
Data is expressed by mean ± SD.
[#] *P* < 0.05 between pre-and post-LAGB.
[+] P < 0.05 between pre-and post-LAGBP.
[¥] *P* for time effect < 0.05. *P* for trend denotes whether LAGB and LAGBP had a significantly different effect on postoperative indicators within the period of 24 months, as determined using the repeated general linear mode.

6, 12, and 24 mo postoperatively. *P* values for time effect on serum TG level reduction were significant after LAGB (*P* = 0.009) and LAGBP (*P* = 0.005; data not shown). According to the trend analysis using the repeated GLM, the two surgery types did not affect serum TG level reduction within 24 mo postoperatively (*P* for trend = 0.98; Fig. 4D).

The FCHDR score was applied on predication of coronary heart disease risk in obese patients after LAGB and LAGBP. The data showed that patients with a 10-y risk for myocardial infarction or coronary heart disease were 3.3% and 3.6% down to 2.2% and 2.4% after LAGB and LAGBP, respectively, at 24 mo postoperatively (*P* = 0.037 in LAGB; *P* = 0.041 in LAGBP; Fig. 5).

Table 2 indicates that the postoperative effects on blood glucose metabolism and blood pressure were associated with a BMI change after both LAGB and LAGBP. Although the postoperative effects of both surgeries on total body fat percentage were strongly associated with those on BMI, the relationship between the effects on total body fat percentage and blood glucose metabolism was not significant. The postoperative effects on blood pressure were significantly associated with those on total body fat percentage after LAGB but not after LAGBP.

Finally, at our center, the number of removal of implanted bands within 3 y was 14 in LAGB and 5 in LAGBP. The reasons for band removal in LAGB were acute outlet obstruction, repeated port infection, unwanted quality of life, and inadequate weight loss, and patient treatment was revised to sleeve gastrectomy and Roux-en-Y gastric bypass. One patient in the LAGBP group experienced gastrogastric herniation at the

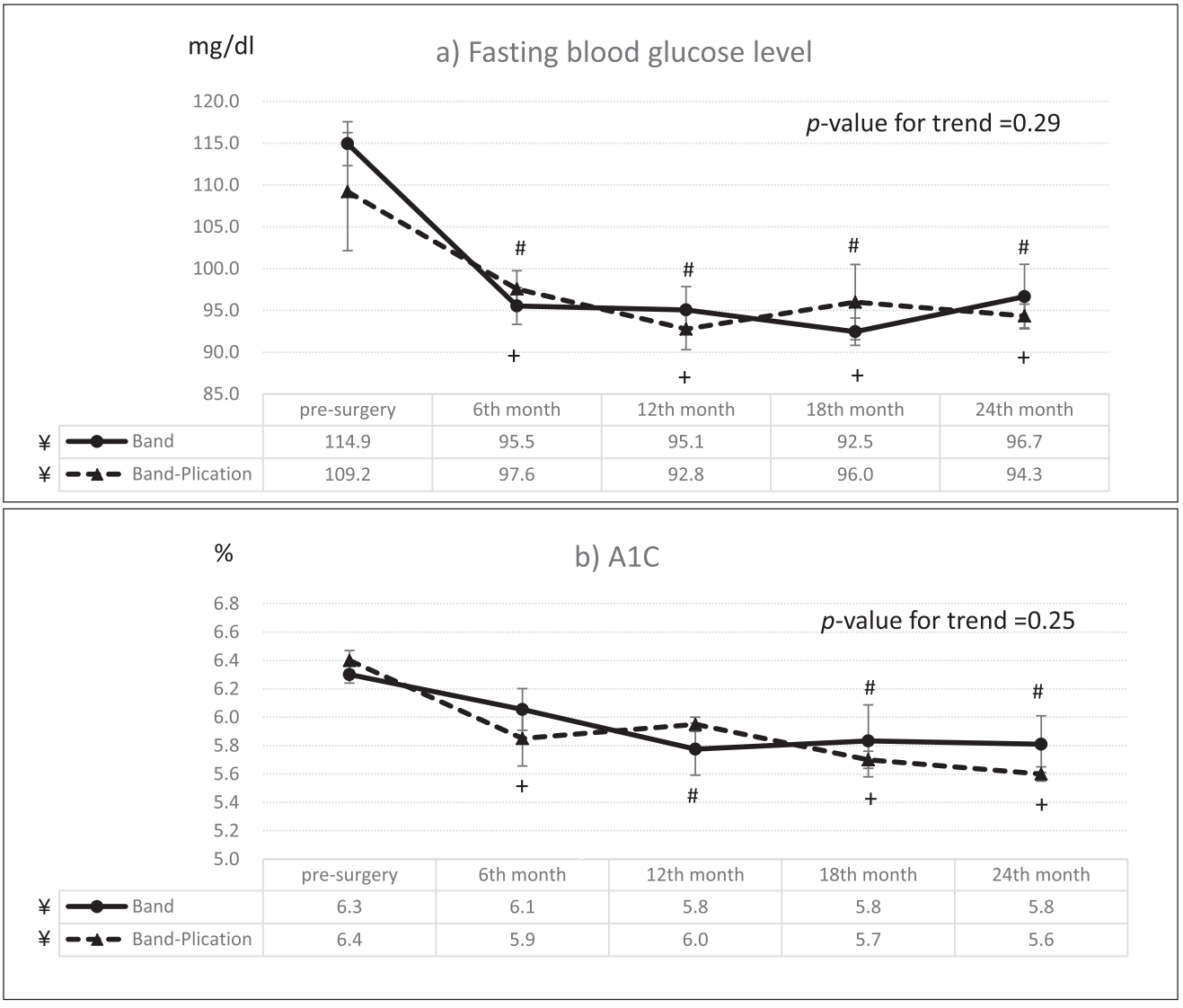

Fig. 2. Trend of changes in (A) fasting blood glucose and (B) glycated hemoglobin levels preoperatively to 24 mo postoperatively. Data is expressed by mean ± SD.
$^{\#}P < 0.05$ between pre- and post-LAGB.
$^{+}P < 0.05$ between pre- and post-LAGBP.
$^{¥}P$ for time effect < 0.05. P for trend denotes whether LAGB and LAGBP had a significantly different effect on postoperative indicators within the period of 24 months, as determined using the repeated general linear model.

plication site and received laparoscopic surgery for herniation reduction. Most other patients underwent band removal only and left the plication unrevised. There was no surgery-related mortality in either group. In the present study, these cases were excluded because of unmet inclusion criteria. Thus, we do not mention these in detail.

Discussion

LAGB is considered one of the easiest-to-perform bariatric surgeries, but its effectiveness in weight loss is lower than that of other bariatric surgeries [16–18]. LAGBP is also a gastric banding surgery with an additional plication step and can be used as an alternative bariatric surgery. LAGBP combines relative safety and possible feasibility for increased effectiveness in weight loss compared with the use of banding alone [16–18]. Because of the low effectiveness of gastric banding in weight loss, LAGBP is widely considered a more useful bariatric procedure [19]. In the present study, only one patient had an alternative LAGBP from LAGB because of their willingness for better weight reduction. No complication occurred in the LAGB group and only one patient had gastrogastric herniation at 6 mo after LAGBP, which required additional surgery for replication. The complication rate of LAGBP was not significantly higher than that of LAGB.

Theoretically, patients who undergo LAGBP have better weight loss results with an additional restriction of gastric volume below the band. However, the effectiveness of LAGBP in weight loss is under debate because relevant studies have a shorter observation duration and lack comprehensive analyses. In this study, we analyzed data over a longer duration of 24 to 36 mo by using various biostatistical models to comprehensively compare postoperative weight loss efficiency, metabolic responses, and FCHDR score changes of patients who underwent LAGBP and LAGB.

Most studies compared the differences between preoperative and postoperative stages or staged changes between two observed time points [15,19,20]; however, these may have ignored unstable

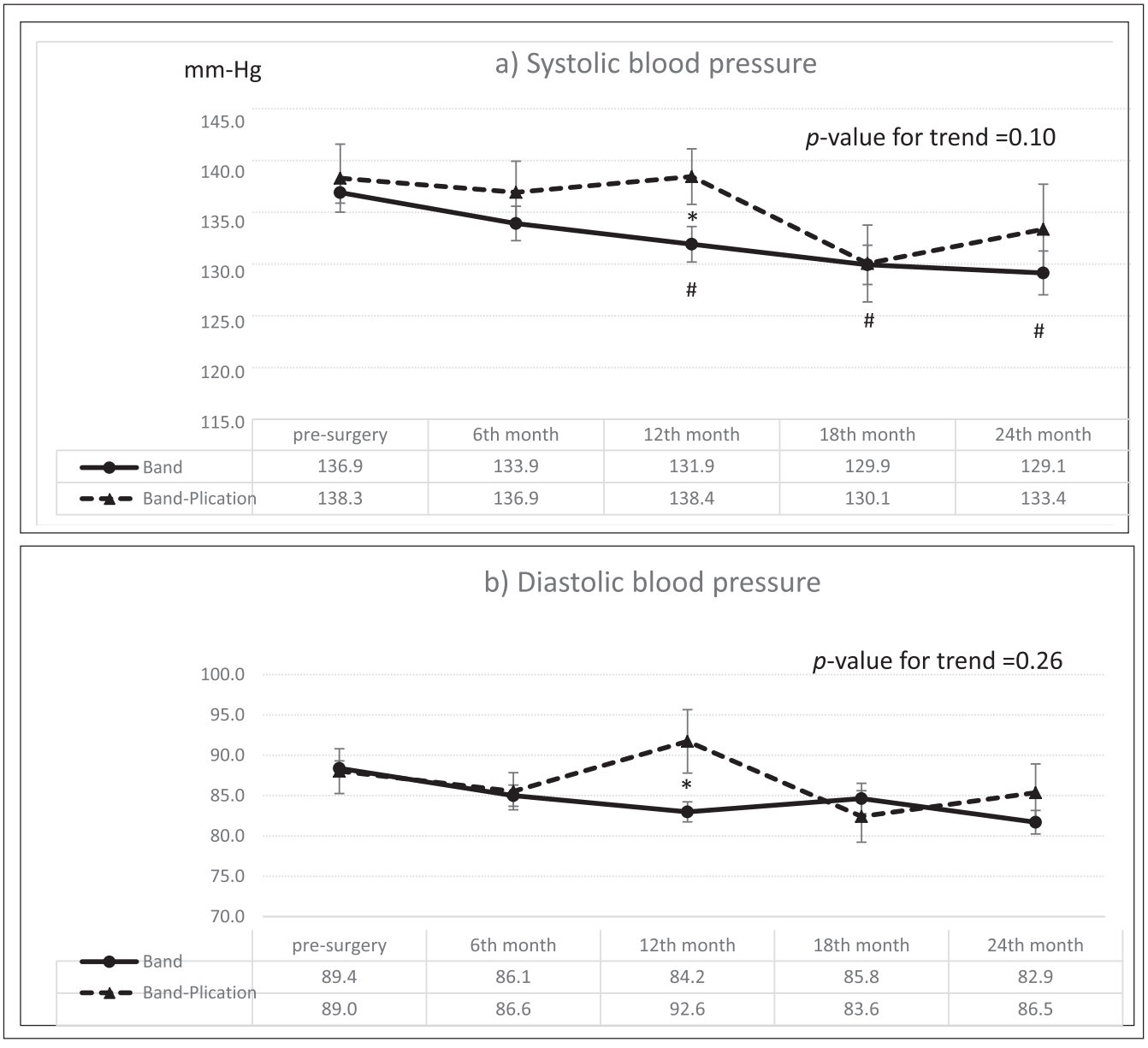

Fig. 3. Trend in blood pressure changes (A) systolic and (B) diastolic preoperatively to 24 mo postoperatively.
Data is expressed by mean ± SD.
[#] $P < 0.05$ between pre-and post-LAGB.
[*] $P < 0.05$ between LAGB and LAGBP at a specific time point.

episodes outside of the observation period. Our previous study indicated that bariatric surgery in obese people with a high-risk genotype had an extremely low weight-loss effectiveness 3 mo postoperatively and showed a fluctuated phenomenon within 2 y postsurgery [18]. The observation period was too short to reflect on a comprehensive phenomenon, much like electrocardiogram data recorded over 24 h deemed more effective in heart disease prediction than data recorded over the course of only 1 min [21]. Thus, a short observation period can result in biased estimates.

Most studies on bariatric surgery indicated that weight loss became stable after 60 mo of gastric banding [22–24]. Nevertheless, relatively few studies on gastric plication had observation periods of longer than 30 mo to explore weight loss efficiency and endocrine profiles [25–28]. A 2-y duration may be relatively insufficient to completely understand weight loss efficiency after gastric plication. In the present study, we not only considered a 3-y observation period with continuously measured data but also used BIA data with trend analysis and MANOVA for a detailed exploration of the continuous efficiencies of weight loss and fat reduction as well as time effect.

As shown in Figure 1, BMI and fat percentage began increasing 24 mo after surgery. The fluctuating phenomenon demonstrated that the observation period within 24 mo was highly insufficient and potentially resulted in the prediction of inconsistent bariatric surgery effectiveness levels. We carried out an observation period of >24 mo to explore surgical efficacies. However, because of funding constraints and budget considerations by Taiwan National Health Insurance, we could not consider an observation period longer than 36 mo on BMI and fat percentage changes. Thus, to alleviate problems caused by this

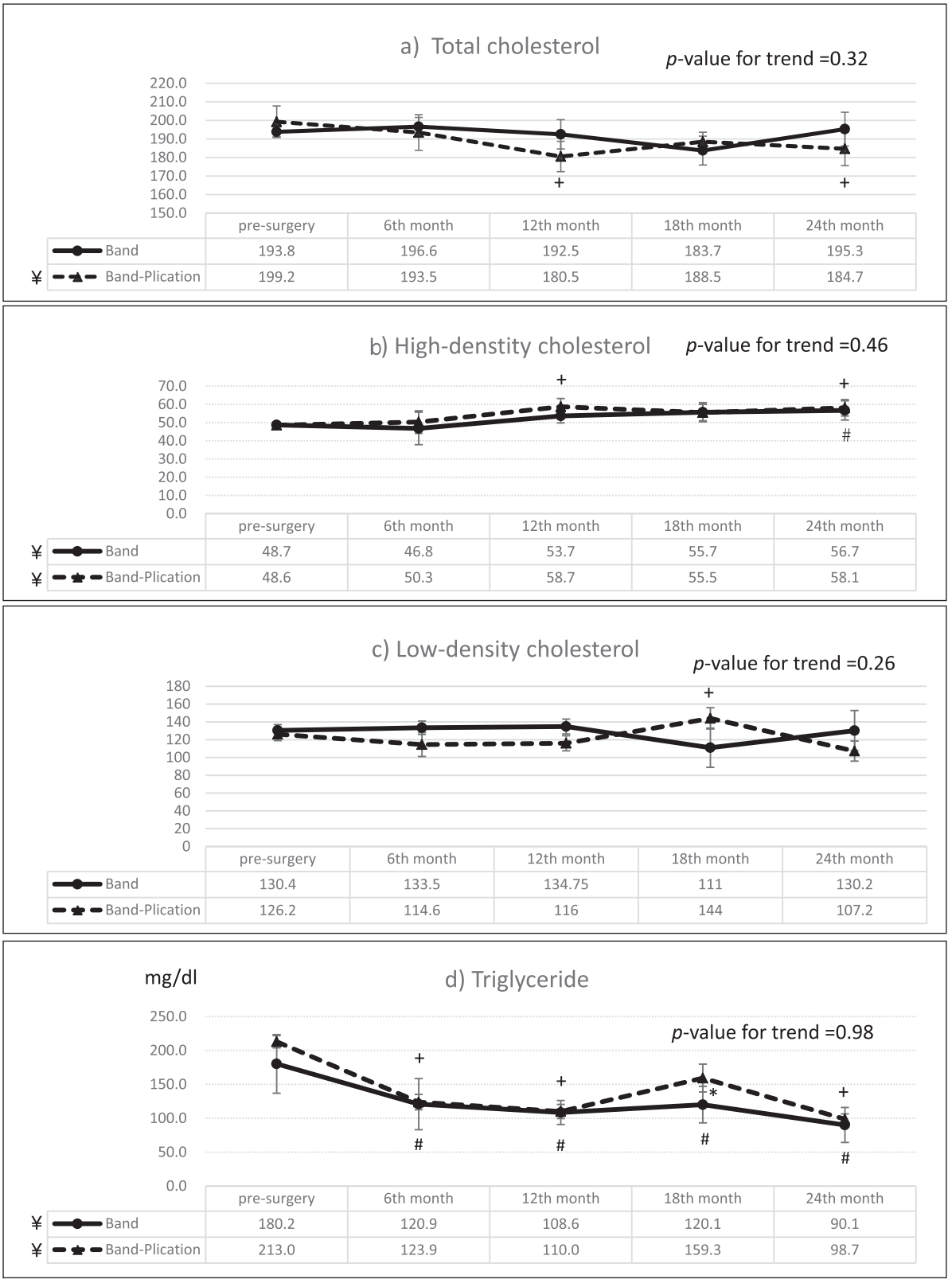

Fig. 4. Trend in lipid profile changes in lipid profiles (A) to (D) preoperatively to 24 mo postoperatively.
Data is expressed by mean± SD.
[#] $P < 0.05$ between pre-and post-LAGB.
[+] $P < 0.05$ between pre-and post-LAGBP.
[*] $P < 0.05$ between LAGB and LAGBP at a specific time point.
[¥] $P <$ for time effect < 0.05. P for trend denotes whether LAGB and LAGBP had a significantly different effect on postoperative indicators within the period of 24 months, as determined using the repeated general linear model.

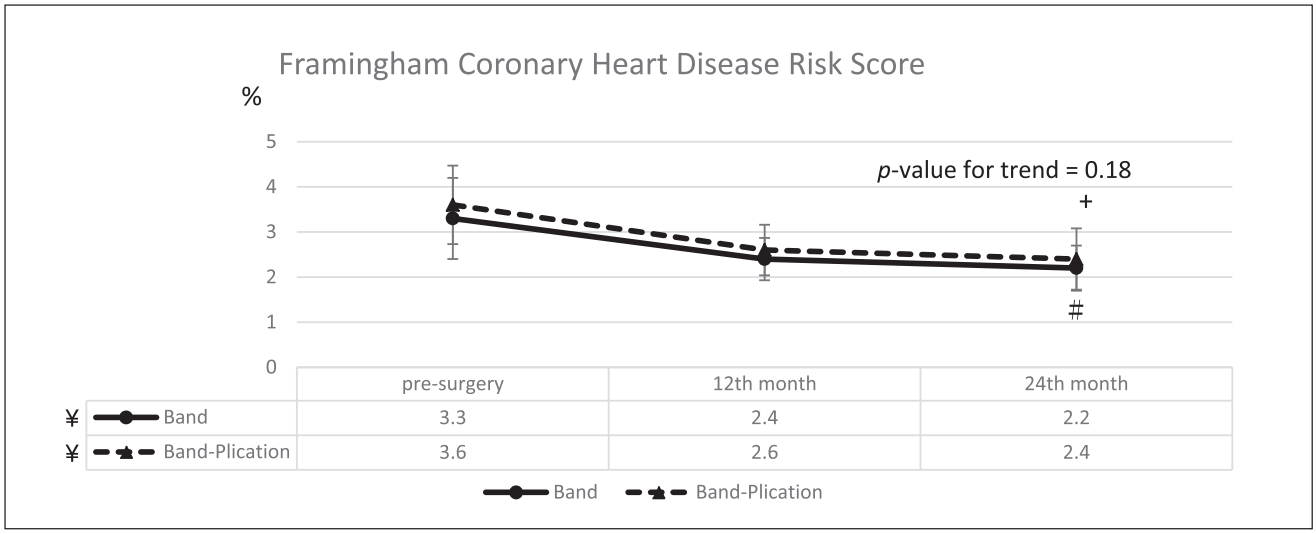

Fig. 5. Trend of changes in Framingham Coronary Heart Disease Risk score preoperatively to 24 mo postoperatively.
Data is expressed by mean ± SD.
[#] *P* < 0.05 between pre- and post-LAGB.
[+] P < 0.05 between pre- and post-LAGBP.
[¥] *P* for time effect < 0.05. *P* for trend denotes whether LAGB and LAGBP had a significantly different effect on postoperative indicators within the period of 24 months, as determined using the repeated general linear model.

moderate follow-up period, we used a trend analysis and applied the repeated GLM model, which demonstrated that surgery type did not play a crucial role in weight loss. The time-effect exploration using the MANOVA model on weight loss showed a significant change within 36 mo postoperatively. Of note, the median actual weight loss for LAGB participants was 18.5 kg and the weight loss percentage was 17.1% 3 y after surgery (data not shown). The current results were similar to those derived by Courcoulas et al. [29]. Thus, our results had relatively high objectivity.

In this study, we only included patients with gastric bands during the 3-y follow-up period. Patients who had their band removed were excluded from the analysis. The difference between two groups was only an additional plication, but the effect of gastric banding was equal in the two groups. The reasons for band removal in the long term were mainly slippage, gastric erosion, inadequate weight loss, port infection, and unwanted quality of life and were mostly related bands rather than the plication procedure. In this study, we wanted to evaluate whether an additional plication procedure had better impact on the top of the band. Therefore, we excluded patients who had their band removed within 3 y.

The follow-up rate in both groups was <40% and continued to decrease as years passed. Patients without regular follow-ups and band adjustments tended to have their band removed in the long term. Of note, patients in this study may have had access to local hospitals to adjust their bands. In addition to the limitations of a retrospective study, the statistics on adjustment frequency could not be accurately documented nor scientifically described. With the limitation of the regulation of the National Insurance reimbursement, panendoscopy for reflux esophagitis was not routinely performed and documented. Whether an additional plication procedure on top of a gastric band would be beneficial calls for a prospective study to conclude.

With respect to glucose metabolism, the trend analysis indicated that both surgeries had similar effects on postoperative glucose metabolism. Bradnova et al. noted that laparoscopic plication resulted in type 2 DM remission in obese women by increasing ghrelin levels and the meal-induced gastric inhibitory polypeptide response [30]. Our previous study also showed that the laparoscopic band ameliorated poor glucose metabolism caused by weight loss [31]. The current results with regard to glucose metabolism were similar to those of our previous studies where we also presented that the glucose metabolism improvement efficacies of LAGB and LAGBP were similar (Fig. 2). Moreover, we demonstrated that glucose metabolism amelioration after LAGB and LAGBP might be engendered by BMI loss rather than fat-percentage reduction.

Most blood pressure responses that were derived postoperatively were not associated with surgical types within 24 mo postoperatively. The results of LAGBP showed a fluctuation and a 4.9 mm-Hg decrease was similar to results of previous studies (3.3 mm-Hg reduction for systolic pressure 2 y after surgery) [32]. However, the systolic blood pressure of patients who underwent

Table 2
Correlation coefficients for changes in BMI, fat percentage, FBG levels, A1C levels, DBP and DBP, and TG levels within 2 y postoperatively

	BMI	Fat %	FBG	A1C	SBP	DBP	TG
BMI	–	**0.469**	**0.640**	**0.812**	**0.319**	**0.282**	−0.128
(*P*-value)	–	**(0.003)**	**(0.025)**	**(0.008)**	**(0.032)**	(0.070)	(0.809)
Fat %	0.684	–	0.089	0.12	**0.558**	**0.414**	−0.312
(*P*-value)	**(0.014)**	–	(0.986)	(0.828)	**(0.003)**	**(0.035)**	(0.490)
FBG	0.667	−0.367	–	0.729	−0.160	−0.147	−0.261
(*P*-value)	**(0.034)**	(0.549)	–	(0.270)	(0.474)	(0.511)	(0.497)
A1c	0.512	0.134	0.958	–	0.149	−0.132	0.814
(*P*-value)	**(0.049)**	(0.321)	**(0.010)**	–	(0.777)	(0.802)	(0.394)
SBP	0.260	-0.332	-0.288	0.341	–	**0.667**	0.005
(*P*-value)	(0.359)	(0.096)	(0.419)	(0.671)	–	**(< 0.001)**	(0.992)
DBP	0.578	-0.315	−0.452	−0.011	0.341	–	0.246
(*P*-value)	**(0.030)**	(0.116)	(0.444)	(0.872)	(0.076)	–	(0.690)
TG	−0.124	−0.536	0.345	−0.146	0.246	−0.126	–
(*P*-value)	(0.789)	(0.214)	(0.501)	(0.595)	(0.594)	(0.786)	–

A1c, glycated hemoglobin; BMI, body mass index; DBP, diastolic blood pressure; FBG, fasting blood glucose; SBP, systolic blood pressure; TG: triacylglycerol.
Bold font indicates a significant difference. Data in dark areas indicate correlation coefficients for LAGB and data in light areas indicate correlation coefficients for LAGBP.

LAGB showed a persistent reduction from 12 mo to 24 mo postoperatively. A possible explanation is a biostatical bias caused by the relative smaller sample size (following rate was 56%, n = 28 at 24 mo postoperatively) for LAGBP. This is why the fluctuated responses in systolic blood pressure were observed in the LAGBP group but not the LAGB group. The current results and previous study indicate that blood pressure largely fluctuated within the first 24 mo postoperatively [32]; thus, staged differences for several months that were analyzed using the paired *t* test were unsuitable to explore changes in blood pressure.

Both surgeries had similar effects on lipid metabolism as indicated by trend analysis. The results with regard to the effects of LAGBP and LAGB on serum total cholesterol and TG metabolism were similar to those reported by Buzga et al. [10] and Busetto et al. [33], respectively. Notably, serum total cholesterol and TG level reduction were not associated with BMI and fat-percentage reduction (Fig. 4; Table 2); thus, the mechanism underlying lipid-metabolism amelioration may be different. The current results indicate that the surgical effects of LAGB and LAGBP showed fluctuations on glucose and lipid metabolisms and blood pressure at different time points within 12 to 24 mo. The trend analysis demonstrated comprehensive and nonbiased comparisons between LAGB and LAGBP on postoperative effects. FCHDR with regard to factors of age, sex, smoking status, serum total cholesterol and HDL-cholesterol levels, systolic blood pressure, and blood pressure treated with medications were collected for the present study. The FCHDR showed significant improvements after LAGB and LAGBP at 24 mo postoperatively because of smoking cessation, decrease in systolic blood pressure after LAGB, reduction in serum total cholesterol level after LAGBP, and elevated HDL cholesterol level after both types of surgery.

This study had some limitations. First, the sample size was relatively small and the observation period was not longer than 36 mo postoperatively; thus, some results showed only borderline significance. In addition, we could not include a gastrointestinal hormone analysis for glucose and lipid metabolism; therefore, we applied BIA data to explore the association between changes in body composition and lipid and glucose metabolism. To overcome the aforementioned limitations, we performed a trend analysis using the repeated GLM to explore postoperative effects stratified by surgery type and time.

Moreover, the current results of the comparison between LAGB and LAGBP have a relatively longer observed duration (24 to 36 mo) than other studies. Thus, the present study has certainly contributed to the field of bariatric surgery, although the non-randomized double-blind study design was also a limitation. The current work was a pioneer study, and the preliminary results allow for the consideration whether to carry out more comprehensive studies to explore the efficacies of LAGB and LAGBP.

Conclusions

This was, to our knowledge, the first study to comprehensively compare various postoperative effects of LAGB and LAGBP. Both LAGB and LAGBP demonstrated comparable efficacy to reduce body weight and improve metabolic parameters during 24 to 36 mo of follow up. LABG demonstrated the ability to reduce systolic blood pressure and LAGBP exhibited TG-lowering effects. Nevertheless, further detailed research on the postoperative effects of LAGB and LAGBP with a longer observational period and larger sample size is warranted.

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