

Original Article



Antidiabetic Effects of Gastric Banding Surgery in Morbidly Obese Patients with Type 2 Diabetes Mellitus

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Received: Jul 6, 2017
Revised: Jul 18, 2017
Accepted: Jul 21, 2017

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Funding

This research was supported by Changwon National University in 2017–2018.

ABSTRACT

This study was performed to investigate the effect of gastric banding surgery on the improvement of glycated hemoglobin (HbA_{1c}) of morbidly obese (MO) patients with type 2 diabetes mellitus (T2DM) with the consideration that obesity was associated with insulin resistance and T2DM. We retrospectively reviewed the medical records of 38 MO with T2DM patients and 50 MO patients. Pre-surgery and post-surgery data were analyzed a year later. The medical data from these patients, including sex, age, height, weight, body composition, HbA_{1c}, triglyceride, total cholesterol, aspartate transaminase (AST), and alanine transaminase (ALT) were measured. There were significant reductions of body weight and body mass index (BMI), body fat, body fat percentage, waist-hip ratio, visceral fat, and obesity in each group before and after gastric banding surgery. Results of AST, ALT, and HbA_{1c} had significant reductions in each group. For HbA_{1c}, treatment rate was 71% in the MO group with T2DM with significant reduction of 22.8%. It is thought that a gastric banding surgery is one of the breakthrough methods not only for weight loss but also for the prevention of complication of the obese patients with T2DM. Thus, gastric banding surgery could be effective in controlling HbA_{1c} in obese patients with type 2 diabetes mellitus.

Keywords: Morbidly obesity; Type 2 diabetes mellitus; Gastric banding surgery; Hemoglobin A1c

INTRODUCTION

Obesity is referred to as a serious health problem worldwide, shortening life, and threatening the quality of life [1]. The prevalence of adult obesity in Korea increased from 26.0% in 1998 to 31.7% in 2007 and remained at 33.2% in 2015 [2,3]. In addition, the prevalence of morbidly obese (MO) with body mass index (BMI) of 30 kg/m² or more was 3.1% in male and 3.6% in female over 20 years of age in 2010 compared with 1998, which is more than double [4,5]. According to the Korea National Health and Nutrition Examination Survey, the risk of complications such as hypertension, diabetes mellitus, and dyslipidemia was more than 2 times higher in obese people than people in normal weight [6].

In particular, type 2 diabetes mellitus (T2DM) has a higher relative risk of obesity than hypertension or other obesity complications [7]. It has been reported that visfatin secreted from visceral adipocyte, is closely related to the induction of complications of T2DM by

Conflict of Interest

The authors declare that they have no competing interests.

directly contributing to insulin resistance [8]. Kenkel and Manning [9] reported that 60% of diabetic patients were associated with obesity, while Colditz [10] reported that about 57% of diabetic patients were associated with obesity. In Korea, the relative risk of T2DM was higher in the obese group than in the non-obese group [11]. The prevalence of T2DM in adults over 30 years of age has remained at around 9% since 2005, with 9.5% in 2015. The mortality rate from diabetes mellitus was 24.0% in 2005 and 20.7% in 2015 [2,3].

Methods for treating obesity include surgical and non-surgical methods such as diet, exercise, behavioral therapy, and medication [13]. The bariatric surgery methods include adjustable gastric banding, laparoscopic adjustable gastric banding (LAGB), sleeve gastrectomy, Roux-en-Y gastric bypass (RYGB). Bariatric surgery has been used as a treatment for obesity in the US and has increased 9-fold from 13,386 in 1998 to 121,055 in 2007 [11]. In Korea, the rate of bariatric surgery increased sharply from 139 in 2003 to 1,687 in 2013 [14]. Many studies have reported that bariatric surgery is effective not only for obesity, but also for diabetes treatment [15]. Improvement of T2DM has been reported after sleeve gastrectomy for the treatment of MO patients [16]. In addition, in cases of MO diabetic patients, the bariatric surgery group showed improvement in physical health and quality of life compared with the non-surgery group [12]. However, the studies on LAGB surgery have been limited to studies on obesity treatment, and studies on the effect of LAGB surgery in morbid obese diabetic on diabetes improvement have been lacking in Korea [17,18]. Therefore, in this study, we investigate the effect of LAGB surgery on the improvement of MO patients with T2DM.

MATERIALS AND METHODS

Subjects

This was a retrospective study, using patients' medical records at C surgical hospital in Seoul. We analyzed data from MO patients who received LAGB surgery with or without T2DM. The study included data collected during April 2014 to March 2016. The subjects' medical records included information on sex, age, height, weight, body composition, blood pressure, and blood metabolic profiles. Changwon National University's Institutional Review Board (IRB) approved this retrospective medical record review (IRB No. 104027-201604-HR-006). We analyzed their medical record before LAGB and a year after LAGB. Subjects whose BMI were less than 30 kg/m², under 18 years of age and absent medical record before and after LAGB were excluded from the study. The participants were divided into 2 groups according to their glycated hemoglobin (HbA_{1c}) levels. The number of total subjects included was 88; of whom 38 with high HbA_{1c} levels (> 6.5%) were in the MO with T2DM (MOD) group and 50 subjects with HbA_{1c} less than 6.5% were in the MO group.

Anthropometric analysis

For all the subjects, anthropometric measurements were measured. Height and weight were recorded to the nearest 0.1 cm and 0.1 kg using an automatic height-weight scale. BMI was calculated by dividing weight (kg) by height squared (m²). Percent body fat, lean body mass, body water, obesity degree, and visceral fat area were measured by bioimpedance analysis (Inbody 3.0; Biospace, Seoul, Korea). Waist and hip circumference were measured with a flexible measuring tape. Waist circumference was measured between the costal inferior border and the iliac crest. Hip circumference was measured at the widest point of the hip.

Biochemical analysis

All blood samples were sent to the Green Cross Laboratory (Yongin, Korea) for analysis. The analysis of HbA_{1c}, hemoglobin (Hb), hematocrit (Ht), albumin, triglyceride (TG), total cholesterol (TC), aspartate transaminase (AST), and alanine transaminase (ALT) were commissioned.

Statistical analysis

Statistical analyses were performed using SPSS software version 21.0 (IBM SPSS Statistics for Windows; IBM Corp., Armonk, NY, USA). Measurement data were presented as mean \pm standard deviation (SD). The difference between the MOD and MO groups was analyzed using t-test. The values for pre-operation and a year after operation were compared using paired t-test. In addition, categorical data were compared using the χ^2 test. All statistical results were verified with the significance level set at $p < 0.05$.

RESULTS

General characteristics

General characteristics of the MOD and MO groups are summarized in **Table 1**. In the MOD group, 5 males and 33 females participated; and in the MO group, 6 males and 44 females participated. There were no differences between the 2 groups in weight, height, BMI, and blood pressure. However, severe obese patients with a BMI over 40 in the MOD group were more than those in the MO group. In the MOD group, 10 and 12 subjects had hyperlipidemia and hypertension, respectively; and in the MO group, 6 and 4 subjects had hyperlipidemia and hypertension, respectively. Thus, patients with hyperlipidemia and hypertension were more frequently found in the MOD group.

Table 1. General characteristics in MOD and MO patients

Variables	MOD (n = 38)	MO (n = 50)	Total (n = 88)
Sex			
Female	33 (86.84)	44 (88.00)	77 (87.50)
Male	5 (13.16)	6 (22.00)	11 (12.50)
Age, yr	36.5 \pm 10.2	32.6 \pm 7.5	34.3 \pm 8.9
18–29	10 (26.32)	21 (42.00)	31 (35.23)
30–39	13 (34.21)	21 (42.00)	44 (50.00)
40–49	11 (28.95)	7 (14.00)	18 (20.45)
50–59	4 (10.53)	1 (7.00)	5 (5.68)
Height, cm	164.1 \pm 8.0	163.1 \pm 5.9	163.6 \pm 6.9
Weight, kg	103.0 \pm 19.3	97.6 \pm 22.3	99.9 \pm 21.1
BMI, kg/m ²	38.1 \pm 6.1	36.7 \pm 8.3	37.3 \pm 7.4
30.0–34.9	11 (28.95)	22 (44.00)	33 (37.50)
35.0–39.9	9 (23.68)	18 (36.00)	27 (30.68)
\geq 40.0	18 (47.37)	10 (20.00)	28 (31.82)
SBP, mmHg	135.4 \pm 16.0	129.0 \pm 13.7	131.8 \pm 15.0
DBP, mmHg	83.5 \pm 20.4	78.9 \pm 13.7	80.9 \pm 16.1
Pulse, bpm	90.9 \pm 12.6	93.2 \pm 14.4	92.2 \pm 13.6
Hyperlipidemia			
Yes	10 (26.32)	6 (12.00)	16 (18.18)
No	28 (73.68)	44 (88.00)	72 (81.82)
Hypertension			
Yes	12 (31.58)	4 (8.00)	16 (18.18)
No	26 (68.42)	46 (92.00)	72 (81.82)

Values are presented as number (%) or mean \pm standard deviation. Analyzed using t-test for continuous variables and χ^2 test for categorical variables between the groups (MOD vs. MO).

MOD, morbidly obese patients with diabetes; MO, morbidly obese; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Changes in anthropometric indices after gastric banding surgery

Anthropometrics parameters are presented in **Table 2**. The result of anthropometrics indices before and after surgery showed significant reduction of body weight, BMI, body fat, fat-free mass (FFM), waist/hip ratio, visceral fat area, and obesity degree in the MOD and MO groups ($p < 0.001$). Especially, the decrease rate of the visceral fat area was the highest among the anthropometric measurement both in the MOD and MO groups ($-36.3\% \pm 24.6\%$ and $-46.9\% \pm 25.3\%$, respectively). The changes in anthropometric indices of MO group before and after surgery were higher than those of MOD group, but there was no significant difference between the 2 groups.

Changes in metabolic profiles after gastric banding surgery

Blood biochemical analyses before and after LAGB are presented in **Table 3**. The results showed that the levels of AST, ALT, and HbA_{1c} had significant reduction in each group. Although AST and ALT, as indicators of liver function, were higher than normal range prior to surgery, it was within normal range after the surgery in both groups and thus it was shown that the surgery was also effective in the treatment of fatty liver. For HbA_{1c}, treatment rate was 71% in the MO group with T2DM with significant reduction of 22.8%, and there were 6.1% of significant reduction in general MO patients. It was found in this study that the reduction of HbA_{1c} was greater as the pre-operative early body weight was heavier.

The ratio of changes in metabolic profiles after surgery is shown in **Figure 1**. The levels of TG and TC were not significantly change after LAGB of the MOD ($-39.3\% \pm 33.4\%$ and $-2.9\% \pm 27.0\%$, respectively) and MO ($-29.7\% \pm 38.4\%$ and $-2.3\% \pm 21.9\%$, respectively) groups.

Table 2. The changes of anthropometric parameters in MOD and MO patients after gastric banding surgery

Variables	MOD			MO		
	T0	T1	p*	T0	T1	p*
Weight, kg	102.9 \pm 19.2	82.5 \pm 18.6	< 0.001	97.4 \pm 21.8	73.7 \pm 18.6	< 0.001
BMI, kg/m ²	38.1 \pm 6.1	30.6 \pm 5.9	< 0.001	36.6 \pm 8.0	27.6 \pm 6.3	< 0.001
Body fat, %	45.4 \pm 6.2	36.2 \pm 7.6	< 0.001	44.4 \pm 7.1	33.7 \pm 9.0	< 0.001
Body fat, kg	47.3 \pm 12.9	31.1 \pm 13.0	< 0.001	44.2 \pm 15.6	26.1 \pm 13.7	< 0.001
FFM, kg	55.6 \pm 52.1	52.1 \pm 47.7	< 0.001	53.2 \pm 8.6	47.7 \pm 7.3	< 0.001
Waist/hip ratio	1.0 \pm 0.1	0.9 \pm 0.1	< 0.001	1.0 \pm 0.0	0.9 \pm 0.1	< 0.001
Vfat, cm ²	180.5 \pm 55.1	112.7 \pm 52.7	< 0.001	169.1 \pm 83.0	85.3 \pm 58.7	< 0.001
Obesity degree, %	179.6 \pm 28.7	144.1 \pm 27.5	< 0.001	172.7 \pm 37.5	130.2 \pm 29.0	< 0.001

Values are mean \pm standard deviation.

MOD, morbidly obese patients with diabetes; MO, morbidly obese; T0, at baseline; T1, after gastric banding surgery; BMI, body mass index; FFM, fat-free mass; Vfat, visceral fat area.

*T0 vs. T1 by t-test.

Table 3. The changes of biochemical parameters in MOD and MO patients after gastric banding surgery

Variables	Normal range	MOD			MO		
		T0	T1	p*	T0	T1	p*
Hb	12.7–17.1 g/dL	14.2 \pm 1.2	13.5 \pm 1.4	< 0.001	13.9 \pm 1.1	13.8 \pm 1.1	0.214
Ht	38.0%–53.0%	43.4 \pm 2.6	40.7 \pm 3.8	< 0.001	42.4 \pm 2.8	40.9 \pm 2.7	< 0.001
Albumin	3.5–5.2 g/dL	4.5 \pm 0.2	4.4 \pm 0.3	0.048	4.5 \pm 0.3	4.5 \pm 0.3	0.840
TG	< 200 mg/dL	261.4 \pm 173.9	137.1 \pm 76.6	< 0.001	186.8 \pm 103.3	116.4 \pm 82.7	< 0.001
TC	< 230 mg/dL	211.6 \pm 31.6	207.1 \pm 36.3	0.610	203.1 \pm 30.9	196.8 \pm 44.6	0.299
AST	0–32 IU/L	39.7 \pm 30.1	24.9 \pm 17.2	0.001	35.6 \pm 22.0	20.4 \pm 7.5	< 0.001
ALT	0–33 IU/L	54.4 \pm 39.7	19.4 \pm 9.9	< 0.001	40.1 \pm 31.0	15.3 \pm 7.5	< 0.001
HbA _{1c}	< 6.5%	8.3 \pm 1.9	6.4 \pm 1.5	< 0.001	5.8 \pm 0.4	5.4 \pm 0.3	< 0.001

Values are mean \pm standard deviation.

MOD, morbidly obese patients with diabetes; MO, morbidly obese; T0, at baseline; T1, after gastric banding surgery; Hb, hemoglobin; Ht, hematocrit; TG, triglycerides; TC, total cholesterol; AST, aspartate transaminase; ALT, alanine transaminase; HbA_{1c}, glycated hemoglobin.

*T0 vs. T1 by t-test.

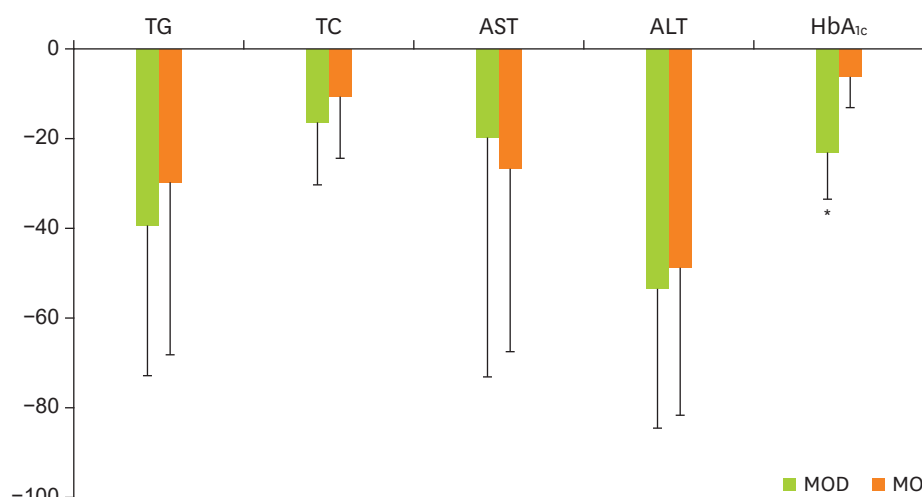


Figure 1. The ratio of changes of biochemical parameters in MOD and MO patients.

MOD, morbidly obese patients with diabetes; MO, morbidly obese; TG, triglycerides; TC, total cholesterol; AST, aspartate transaminase; ALT, alanine transaminase; HbA_{1c}, glycated hemoglobin.

*Significantly different between the values at MOD and MO groups by paired t-test ($p < 0.05$).

There were no significant differences in AST and ALT levels in the MOD ($-19.7\% \pm 53.2\%$ and $-53.4\% \pm 31.0\%$, respectively) and MO ($-26.6\% \pm 40.5\%$ and $-48.6\% \pm 32.8\%$, respectively) groups. LAGB surgery significantly lowered HbA_{1c} levels in the MOD group ($-22.8\% \pm 10.5\%$) compared with those in the MO group ($-6.1\% \pm 6.7\%$, $p < 0.05$).

DISCUSSION

This study investigated the effect of LAGB surgery on the improvement of HbA_{1c} of MO patients with T2DM with the consideration that obesity was associated with insulin resistance and T2DM. This is a retrospective study using the medical records of pre- and post-operative 38 MO patients with T2DM and 50 MO patients among patients who have undergone LAGB.

A total of 88 patients were selected as the study subjects, and analysis was performed by classifying people with $\geq 6.5\%$ of HbA_{1c} as the group of MOD and people with $< 6.5\%$ as the group of MO in reference of HbA_{1c} of 6.5%. In this study, the mean age, weight, and BMI were 34.3 ± 8.9 years, 99.9 ± 21.1 kg, and 37.3 ± 7.4 kg/m², respectively, which was similar to those of Kim et al. [13]. In the present study, there were no significant differences in pre-operative anthropometric data between the 2 groups. Schindler et al.'s study [17], in the obesity study, the mean weight of the subjects was 127.5 ± 4.1 kg and the mean BMI was 44.8 ± 1.0 kg/m². In Giusti et al.'s study [18], the mean weight of the subjects was 118.6 ± 14.5 kg and BMI was 43.6 kg/m². These results indicate that the standard of BMI for obesity, according to the World Health Organization (WHO) criteria, is lower in Korea than in Western countries [19]. Our study showed that body weight, body fat, FFM, waist/hip ratio, and visceral fat area decreased after LAGB compared to pre-operation (**Table 2**). Body weight decreased from 102.9 ± 19.2 kg to 82.5 ± 18.6 kg in the MOD group, and decreased from 97.4 ± 21.8 kg to 73.7 ± 18.6 kg in the MO group. Patients in both groups showed significant decreases in their body weight as compared to the pre-operation. BMI decreased significantly from 38.1 ± 6.1 kg/m² to 30.6 ± 5.9 kg/m² and from 27.6 ± 6.3 kg/m² to 36.6 ± 8.0 kg/m², in the MOD and MO group, respectively. Therefore, it was found that weight loss continued after surgery. This decrease

in body weight and BMI was similar to that of RYGB reported by Kim et al. [13]. In addition, the rate of change for visceral fat area in the MOD and MO group significantly decreased compared to pre-operation ($-36.3\% \pm 24.6\%$ and $-46.9\% \pm 25.3\%$, respectively). Visceral fat obesity was defined by obese subjects with visceral-subcutaneous fat ratio (V/S ratio) of ≥ 0.4 , whereas obese subjects with V/S ratio of < 0.4 were defined as subcutaneous fat obesity [20]. Visceral fat is one of the predictors of cardiovascular disease (CVD). Also, visceral fat obesity is thought to be a basic pathology for metabolic syndrome (MS) [21]. We also found that the LAGB caused decrease in body fat mass of the MOD and MO groups. These findings are in line with previous studies demonstrating that LAGB decreased body fat mass [18]. This is similar to the decrease rate in body fat mass 27.3% in Giusti et al. [18]. However, Carey et al. [22], significant decreases in body weight (-50.9 kg) and body fat mass (-75.2%) were observed from pre-surgery to post-bariatric surgery. Carey et al.'s study [22] showed that the body fat reduction rate was higher than that in our study, but this result may be due to the difference according to the operation method. These results demonstrate that LAGB decreased body fat mass, body weight, and the risk of obesity related complications in MO patients with or without T2DM.

In this study, LAGB significantly reduced the HbA_{1c} level from $8.3\% \pm 1.9\%$ to $6.4\% \pm 1.5\%$ in the obese diabetic patients. Among the total T2DM, 71% of subjects (21 patients) showed decrease in HbA_{1c} less than 6.5%. Swedish obese subject (SOS)'s study [23], Buchwald et al. [24], and Pories et al. [25] reported that bariatric surgery is effective in diabetes treatment. Also, there was a difference in treatment rate between 45% and 100%, depending on the type of surgery. HbA_{1c} is an important bio-marker for long-term glycemic control and reflects fasting blood glucose and postprandial glucose. HbA_{1c} is a better predictor of diabetic complications than fasting glucose [26,27]. These results suggest that reduction of HbA_{1c} in response to LAGB could contribute to decreasing risk of diabetic complications [28]. The bariatric surgery is effective in treating T2DM because of weight loss. Weight loss is very important in the treatment of diabetes and it is known that 10% reduction in body weight reduces the incidence of diabetes by more than 50% and reduces diabetes-related mortality by 20% [29]. In the present study, the MOD group showed average of 19.6% weight reduction after LAGB, suggesting that diabetes treatment was effective. Also, these results suggest that the higher body weight before the weight loss was associated with the greater reduction rate of HbA_{1c} and the effect of diabetes treatment. In the study, LAGB was more effective in decreasing HbA_{1c} in the MOD group, suggesting that LAGB improved hyperglycemia and T2DM.

Hyperlipidemia was also present in the obese patients with or without T2DM, and the TG levels were also decreased to normal level after LAGB. The decrease of serum TG levels was thought to be due to the decrease of calorie intake after LAGB. Also, these results are similar to Kim et al.'s report [13]. It is known that the majority of obese patients have fatty livers [30]. As a result, this study also showed that serum ALT and AST levels exceeded the normal range in both groups, indicating the problems in liver function. The MOD and MO groups showed the normal range of serum ALT and AST levels after LAGB. Significant reductions in serum ALT and AST levels were similar to those of Mummadi et al.'s report [31]. Also, serum ALT levels showed greater changes than serum AST levels. After the gastric band surgery, changes in HbA_{1c} and liver function indicators showed improvement not only in T2DM but also in fatty liver.

Through this study, it was found that LAGB had therapeutic effect in MOD patients. It is thought that bariatric surgery is one of the breakthrough methods not only for weight loss but also for the prevention of complication, including diabetes mellitus in obese patients.

Although LAGB has less beneficial effects compared to other bariatric surgeries, it is relatively simple and safe, and thus there would be substantial demand in the treatment of MOD in the future. As the study about bariatric surgery mostly focuses on weight loss, there is lacking in study about surgical effect of MOD.

However, there are some limitations in this study. This was a retrospective study, using restricted medical records. Thus, there was no data on fasting blood glucose, glucose tolerance test, or insulin tolerance test. In the future, study about bariatric surgery in MOD and the study comparing the effects in MOD according to the type of surgery would be necessary. Also, studies investigating other effects of surgical complications of morbid obesity would be required.

In conclusion, LAGB alleviated T2DM in MOD group, in part by improving HbA_{1c} levels. Thus, LAGB may be useful for improving overall glycemic control in the management of DM in MOD patients.

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