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ORIGINAL CONTRIBUTIONS

# Effect of Laparoscopic Sleeve Gastrectomy on Type 2 Diabetes Mellitus in Patients with Body Mass Index less than 30 kg/m$^2$

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## Abstract

**Background** Laparoscopic sleeve gastrectomy (LSG) has been proved to be the most effective treatment strategy for the treatment of type 2 diabetes mellitus (T2DM) with a body mass index ≥ 30 kg/m$^2$ achieving high remission rates. However, there are few clinical studies on the treatment of T2DM patients with a body mass index less than 30 kg/m$^2$ by LSG. This study aims to study the effect of LSG on type 2 diabetes mellitus(T2DM) in patients with a body mass index (BMI) less than 30 kg/m$^2$.

**Methods** The clinical data of 25 patients with type 2 diabetes mellitus (T2DM) and body mass index 23.23–29.97 kg/m$^2$ who were treated by LSG at the Department of Bariatric and Metabolic Surgery in China-Japan Union Hospital of Jilin University from May 2016 to May 2017 were retrospectively analyzed. The changes of fasting plasma glucose, glycosylated hemoglobin, insulin resistance index, body weight, body mass index, waist circumference, blood pressure, heart rate, blood lipids, and uric acid were analyzed at 3 months, 6 months, and 12 months after operation, respectively. All the clinical data were analyzed by SPSS 22.0. They were tested with a single-sample K-S test to determine whether they were normal distribution data. The normal distribution data were analyzed by a matched *t* test, and the Mann-Whitney test was used to examine skewed data.

**Results** All patients (9 males, 16 females) with a median age of 57(24~65) years were treated successfully by laparoscopic sleeve gastrectomy. The median duration of type 2 diabetes mellitus was 10(0~20)years. The preoperative fasting plasma glucose, glycosylated hemoglobin, body weight, body mass index, and waist circumference were 10.32 ± 2.66 mmol/L,8.20 ± 1.47%,76.54 ± 10.02 kg,27.92 ± 1.72 kg/m$^2$, and 99.88 ± 5.38 cm, respectively. The meaning fasting plasma glucose was 7.26 ± 1.36 mmol/L, 6.90 ± 1.07 mmol/L, and 6.62 ± 0.97 mmol/L, respectively, at 3, 6, and 12 months after operation. The mean HbAlc in the same observation intervals was 6.88 ± 1.23%,6.54 ± 1.02%, and 6.51 ± 0.89%, respectively. The body weight was 62.18 ± 8.38 kg,59.07 ± 8.58 kg, and 58.62 ± 8.53 kg, respectively. The corresponding body mass index was 22.56 ± 1.56 kg/m$^2$, 21.35 ± 1.58 kg/m$^2$, and 21.24 ± 1.86 kg/m$^2$, respectively. The waist circumference was 82.84 ± 5.10 cm,78.60 ± 5.21 cm, and 76.92 ± 5.21 cm, respectively. The complete remission rates of type 2 diabetes mellitus were 40%, 60%, and 68%, respectively, at 3, 6, and 12 months after operation. The complete remission rates for insulin resistance index were 52.4%, 80%, and 80%, postoperatively, at 3, 6, and 12 months, respectively. The complete remission rates of hypertension were 22.2%, 50%, and 75%,respectively, at 3,6, and 12 months after operation. The complete remission rates of hypertriglyceridemia were 66.7%, 66.7%, and 100%,and the complete remission rates of hypercholesterolemia were 41.7%, 60%, and 100%;the abnormal elevations of plasma cholesterol in two patients with normal cholesterol before operation were significantly higher, postoperatively, at 3 monthsand 6 months, respectively. The complete remission rates of hyperuricemia were 37.5%, 33.3%, and 100% in the same observation period, respectively. The abnormal elevations of uric acid in two patients with normal uricemia before operation were significantly higher at postoperative 3 months.

**Conclusion** LSG has a significant effect on patients with type 2 diabetes mellitus whose BMI less than 30 kg/m$^2$ in a short time, but its long-term effectiveness needs to be further followed up.

**Keywords** Type 2 diabetes mellitus · Body mass index · Sleeve gastrectomy · Laparoscopy

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## Introduction

With the development of social economy and the change of people's life style, the number of people with diabetes increased significantly. According to the International Diabetes Federation,there were about 425 million people with diabetes all over the world in 2017, accounting for 9.1% of the total population. At the current rate of growth, there will be nearly 629 million adult diabetic patients by 2045 [1]. Diabetes not only increases the significant risk of cardiovascular disease, but also is the main cause of disability, quality of life declining, and premature death,making it become one of the serious public health problems we have to face at present. Fortunately, the birth of bariatric and metabolic surgery brings a new hope to the treatment of diabetes. After more than half of a century progress, bariatric and metabolic surgery has become an effective way to cure or relieve type 2 diabetes and other metabolic syndromes, included in the diabetes treatment guidelines.

It is well known that the incidence of diabetes in East Asian countries characterized by central obesity is significantly higher than that in European and American countries for relative low BMI population. Laparoscopic sleeve gastrectomy has been proved to be effective and safe in alleviating T2DM and its complications in patients with BMI≥ 35 kg/m$^2$ [2–4]. Recent studies have shown that laparoscopic sleeve gastrectomy (LSG) also significantly remits T2DM in patients with BMI 30–35 kg/m$^2$ [5, 6]. However, up to now, there are few clinical studies on the treatment of T2DM patients with BMI less than 30 kg/m$^2$ by LSG; thus, its therapeutic effect is also a hot spot. In our study, the clinical data of 25 patients with type 2 diabetes mellitus (T2DM) with BMI less than 30 kg/m$^2$ who were treated by LSG at the Department of Bariatric and Metabolic Surgery in China-Japan Union Hospital of Jilin University from May 2016 to May 2017 were retrospectively analyzed to investigate its efficacy and safety.

## Clinical Data

Twenty-five patients met inclusion criteria in the above period in our study. Sixteen (64%) were female and 9 (36%) were male. Median age was 57 years (24~65). Median duration of T2DM was 10 years(0–20). Median HBAlc was 7.90%(6.00–11.60%). Body mass index (BMI) was 28.09 kg/m$^2$(23.23–29.97). Median insulin resistance index (IRI) was 8.59(2.10–123.74). Average preoperative fasting plasma glucose, body weight, and waistline were10.55 ± 2.67 mmol/L, 77.80 ± 9.48 kg, and 99.95 ± 5.03 cm, respectively. The proportion of comorbidities were described as follows: IR was 92%(23/25), hypertriglyceridemia 72%(18/25), hypercholesterolemia 48%(12/25), hypertension 80%(20/25), and hyperuricemia 36%(9/25).

## Inclusion Criteria

T2DM was diagnosed by the following criteria and patients are required to meet all of the following conditions: FPG≥ 7.0 mmol/L, or 2-h plasma glucose≥ 11.1 mmol/L during an oral glucose tolerance test (OGTT), or a random plasma glucose ≥ 11.1 mmol/L; diabetes-associated antibodies were negative. Body mass index was less than 30 kg/m$^2$.Abdominal circumference was more than 90 cm for male patients and was more than 85 cm for female patients. The fasting C-peptide was more than half of the lower limit of the normal value. Patients understood the surgical methods and were willing to bear the potential complications and risks of surgery. Patients understood the importance of changes in lifestyle and eating habits after operation for postoperative recovery.

## Exclusion Criteria

The exclusion criteria were as follows, patients who met any of the following criteria would be excluded: patients with type I diabetes; BMI was equal or greater than 30 kg/m$^2$;persons with alcohol or drug dependenceor mental disorders;patients underwent other operation methods;patients lost visit after operation.

## Statistical Analysis

For the statistical analysis, the Statistical Package for the Social Sciences version 22.0 (SPSS, Chicago, IL, USA) program was used. All the clinical data were analyzed by SPSS 22.0. They were tested with a single-sample K-S test to determine whether they were normal distribution data. The normal distribution data were analyzed by a matched *t* test, and the Mann-Whitney test was used to examine skewed data. The statistics were expressed by *t* and *U*, respectively. *P* values < 0.05 were accepted as statistically significant.

## Observation Index and Follow-up

We followed up patients by outpatient, WeChat, and telephone. Total weight loss (%TWL), excess of weight loss(%EWL), BMI, and laboratory test results were calculated or collected before surgery and subsequently at 3, 6, and 12 months of follow-up. The %TWL was calculated using the following formula: (weight loss/initial weight) × 100. The %EWL was calculated using the formula (weight loss/baseline excess weight) × 100, where excess weight = initial weight − ideal weight (ideal BMI = 23 kg/m$^2$). The insulin resistance index was calculated using the following formula: (fasting plasma glucose × fasting insulin)/22.5.

Evaluation of curative effect of LSG on patients with T2DM:non-effective is defined as there was no significant improvement in blood glucose and glycosylated hemoglobin after LSG and the types and doses of hypoglycemic drugs were not significantly decreased

**Table 1** Improvement in parameters following surgery

| Time | FPG (mmol/L) | HBAlc(%) | Body weight (kg) | BMI (kg/m$^2$) | Waistline (cm) | FCP (nmol/L) | TWL(%) | EWL(%) |
|---|---|---|---|---|---|---|---|---|
| Pre-op | 10.32 ± 2.66 | 8.20 ± 1.47 | 76.54 ± 10.02 | 27.79 ± 1.82 | 99.88 ± 5.38 | 2.27 ± 0.94 | – | – |
| Post-op 3 months | 7.26 ± 1.36 | 6.88 ± 1.23 | 62.18 ± 8.38 | 22.56 ± 1.56 | 82.84 ± 5.10 | 1.62 ± 0.62 | 18.71 ± 4.05 | 184.99 ± 339.27 |
| Statistic | *t* = 5.918 | *U* = 142.50 | *t* = 18.641 | *U* = 10.000 | *t* = 18.393 | *U* = 187.50 | – | – |
| *P* | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.015 | – | – |
| Post-op 6 months | 6.90 ± 1.07 | 6.54 ± 1.02 | 59.07 ± 8.58 | 21.35 ± 1.58 | 78.60 ± 5.21 | 1.60 ± 0.43 | 22.87 ± 3.96 | 241.38 ± 482.15 |
| Statistic | *U* = 258.00 | *t* = 3.089 | *t* = 13.998 | *t* = 10.431 | *U* = 158.00 | *U* = 295.50 | *t* = 13.636 | *U* = 295.50 |
| *P* | 0.290 | 0.005 | 0.000 | 0.000 | 0.003 | 0.741 | 0.000 | 0.031 |
| Post-op 12 months | 6.62 ± 0.97 | 6.51 ± 0.89 | 58.62 ± 8.53 | 21.24 ± 1.86 | 76.92 ± 5.21 | 1.66 ± 0.38 | 23.39 ± 4.97 | 237.51 ± 447.08 |
| Statistic | *U* = 262.50 | *U* = 305.50 | *t* = 0.907 | *t* = 0.547 | *U* = 243.00 | *t* = 0.608 | *t* = 0.845 | *U* = 299.00 |
| *P* | 0.332 | 0.892 | 0.374 | 0.590 | 0.175 | 0.549 | 0.407 | 0.793 |

*FPG*, fasting plasma glucose; *FCP*, fasting C-peptide; *%TWL*, total weight loss; *%EWL*, excess of weight loss

compared with those before operation; notable improvement is defined as HBAlc < 7.5% or a significant decrease of doses of hypoglycemic drugsafter operation; partial remission is defined as HBAlc < 7.0% without using hypoglycemic drugs; the complete remission is defined as HBAlc < 6.5% without using hypoglycemic drugs.

Complete remission of hypertension is defined as blood pressure < 120/80 mmHg without antihypertensive drugs; complete remission of hypertriglyceridemia is defined as TG < 1.7 mmol/L without using lipid-lowering drugs; complete remission of hypercholesterolemia is defined as cholesterol < 5.7 mmol/L without using lipid-lowering drugs; complete remission of hyperuricemia is defined as uric acid < 357 μmol/L for female and uric acid < 428 μmol/L for male; complete remission of insulin resistance defined as IRI< 2.69.

We evaluated the impact of LSG on patient's quality of life according to the MOS 36-Item Short-Form Health Survey (SF-36). The SF-36 measures the following nine subscales: physical function (PF), role-physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role-emotion(RE), mental health (MH), reported health transition (HT).

## Results

All patients received LSG successfully without conversion to laparotomy. Complications were detected in 5 patients after operation; gastric tangential bleeding occurred in 3 cases, posterior cerebral artery insufficiency in 1 case, and pneumoniain 1 case. The clinical and laboratory characteristics of the 25 participants are summarized in Table 1. The patients were followed up, postoperatively, at 3 months, 6 months, and 12 months, respectively. Fasting plasma glucose, HBAlc, fasting C-peptide, BMI,body weight, and waist circumference were decreased significantly at 3 months after operation; their differences are statistically significant($P < 0.05$). Compared to those parameters at 3 months after operation, HBAlc, body weight, BMI, and waist circumference were decreased significantly at 6 months after operation, respectively, except for fasting plasma glucose and fasting C-peptide. However, there was no obvious change at 12 months after operation for them ($P > 0.05$). Compared with the results at 3 months after operation, %TWL and %EWL increased significantly, postoperatively, at 6 months and increased insignificantly at 12 months after operation.

**Table 2** Changes of SF-36 scores among preoperation and postoperation groups

| Group | PF | RP | BP | GH | VT | SF | RE | MH | HT |
|---|---|---|---|---|---|---|---|---|---|
| Pre-op | 88.20 ± 7.34 | 50.00 ± 17.68 | 38.40 ± 4.73 | 20.40 ± 11.72 | 42.0 ± 20.10 | 82.16 ± 22.16 | 50.68 ± 17.34 | 50.56 ± 17.58 | 38.00 ± 16.33 |
| Post-op 12 months | 91.20 ± 7.40 | 85.00 ± 14.43 | 39.20 ± 2.77 | 75.60 ± 11.58 | 73.80 ± 12.44 | 96.80 ± 21.76 | 81.48 ± 19.35 | 78.24 ± 14.38 | 77.00 ± 18.98 |
| Statistic | *U* = 241.00 | *U* = 51.50 | *U* = 299.00 | *U* = 0.00 | *t* = 6.504 | *U* = 197.00 | *U* = 97.00 | *U* = 60.00 | *U* = 50.00 |
| *P* | 0.154 | 0.000 | 0.615 | 0.000 | 0.000 | 0.023 | 0.000 | 0.000 | 0.000 |

*Pre-op*, preoperation; *Post-op*, postoperation; *PF*, physical function; *RP*, role-physical; *BP*, bodily pain; *GH*, general health; *VT*, vitality; *SF*, social functioning; *RE*, role-emotion; *MH*, mental health; *HT*, reported health transition

**Table 3** The postoperative curative effect varying with different durations of T2DM

| Duration | Post-op 3 months | | | | Post-op 6 months | | | Post-op 12 months | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CR(%) | PR(%) | NI(%) | NE(%) | CR(%) | PR(%) | NE(%) | CR(%) | PR(%) | NE(%) |
| < 5 years | 71.4 | 28.6 | 0 | 0 | 85.7 | 14.3 | 0 | 100 | 0 | 0 |
| 5–10 years | 28.6 | 14.3 | 42.9 | 14.3 | 71.4 | 28.6 | 0 | 85.7 | 14.3 | 0 |
| 11–15 years | 37.5 | 25 | 0 | 37.5 | 50 | 12.5 | 37.5 | 50 | 12.5 | 37.5 |
| > 15 years | 0 | 0 | 33.3 | 66.7 | 0 | 0 | 100 | 0 | 0 | 100 |

*CR*, complete remission; *PR*, partial remission; *NI*, notable improvement; *NE*, non-effective

It can be seen from Table 2 that the mean scores in all aspects of SF-36 were significantly increased postoperatively at 12 months except for physical function and body pain.

The complete remission rates of type 2 diabetes mellitus were 40%, 60%, and 68%,respectively,at 3,6, and 12 months after operation. The partial remission rates of T2DM were 20%, 16%, and 8%, respectively. The effective percentages were 76%, 76% and 76%,respectively. The postoperative curative effect varying with duration of T2DM is shown in Table 3. We can see from Table 3 that patients with T2DM with a duration of more than 15 years had no remission after operation. The complete remission rate of T2DM is 100% for patients with a duration of diabetes less than 5 years at 12 months after operation. The remission rate of T2DM increased with the prolongation of follow-up time and decreased with the prolongation of duration of diabetes.

The complete remission rates of hyperuricemia were 37.5%, 33.3%, and 100%, respectively,at 3, 6, and 12 monthsafter operation. However, the abnormal elevation of uric acid exceeded the upper limit at 3 months after operation in two patients with normal uric acid before operation. The complete remission rates of hypertriglyceridemia were 66.7%, 66.7%, and 100%. The complete remission rates of hypercholesterolemia were 42%, 60%, and 100%. Unfortunately, the abnormal elevation of plasma cholesterol exceeded the upper limit at 3 and 6 months after operation in two patients with normal plasma cholesterol before operation. The complete remission rates for hypertension were 22.2%, 50%, and 75%.

## Discussion

LSG was performed as a primary weight loss procedure or as an initial stage of a biliopancreatic diversion with duodenal switch (BPD-DS); it has been demonstrated to be safe and effective treating obesity and related diseases [7]. With the development of bariatric and metabolic surgery, LSG is not confined to the treatment of obesity anymore and is applied to the treatment for T2DM and other obesity-associated diseases. Compared with laparoscopic Roux-en-Y gastric bypass (LRYGBP), a classic operation method for T2DM, LSG is becoming more and more popular among bariatric and metabolic surgeons due to it not only has a significant effect on T2DM, but also has the advantages of less trauma, lower operation difficulty, and less postoperative complications [8–11]. A growing number of clinical research suggest that LSG has a significant remission on T2DM in patients with BMI ≥ 30 kg/m$^2$; its remission rate is between 50 and 81% [6, 12].

A study about the relationship between BMI and diabetes in Asian countries suggests that the percentage of diabetic individuals with a BMI of 35 kg/m$^2$ or higher was only 0.6% while that with a BMI of 27.5 kg/m$^2$ or higher was approximately 15.3%. Asians are particularly prone to central obesity-induced diabetes and show susceptibility to diabetes at a much lower BMI than Americans of European ancestry [13, 14]. At present, the clinical study about LSG on T2DM in patients with BMI less than 30 kg/m$^2$is rare. Therefore, it is every important to investigate the effect of LSG on T2DM in patient with BMI less than 30 kg/m$^2$, especially the East Asian population characterized by abdominal obesity.

In our study, LSG resulted in a significant improvement for patients with T2DM. The complete remission rates of type 2 diabetes mellitus were 40%, 60%, and 68%, respectively, at 3,6, and 12 monthsafter operation. The partial remission rates of type 2 diabetes mellitus were 20%, 16%, and 8%, respectively. The effective rates were 76%,76%, and 76%. Up to now, the mechanism of LSG in the treatment of T2DM is not clear. Its mechanism might be as follows:

(1) Increased secretion of glucagon-like peptide-1(GLP-1): After LSG, both the increase of intragastric pressure and the weakness of negative feedback regulation of intestinal tract on gastric emptying promoted gastric emptying, shortening the time of food reaching the end of the small intestine. Food quickly reaches the end of the small intestine and stimulates L cells to secrete GLP-1. GLP-1 can promote insulin secretion, inhibit glucagon secretion, inhibit apoptosis of islet B cells, and stimulate its regeneration [15].

(2) Reduced food intake:

   (a) Gastric volume reduced after LSG
   (b) Increased secretion of peptide YY: After SG, gastric emptying accelerates food to reach the end of the small intestineand stimulates L cells to secrete PYY who acts on the arcuate nucleus of the thalamus to inhibit the release of neuropeptide Y and produce a feeling of fullness and suppress appetite [16]
   (c) Decreased secretion of ghrelin: ghrelin is mainly secreted by the gastric mucosal acid secreting gland X/A cells in the stomach fundus or gastric body. The significant decrease of ghrelin after LSG results in the feeling of repletion quickly, reducing the intake of energy [17, 18].

(3) Weakness of insulin resistance: the increase of adipose tissue decomposition results in the decrease of adipose factor secretion, such as adiponectin, leptin, and resistin, reducing insulin resistance and increasing insulin sensitivity [6].

The duration of diabetes is one of the reference factors to evaluate the prognosis of T2DM. From our research, we can see that patients with shorter duration of diabetes have a higher postoperative remission rate and patients with longer duration of diabetes have a low postoperative remission rate; the effect increases with the prolongation of follow-up time (Fig.1). Patients with a duration of T2DM more than 15 years did not remit after LSG as well as the complete remission rate of T2DM is 100% for patients with a duration of diabetes less than 5 years at 12 months after operation (Table 3). In a comparison of the results with those of Guo Yulin et al.,the former have a higher remission rate in the same follow-up period [19]. It is worth noting that the inclusion criteria arepatients with T2DM and

**Table 4** Variables and score used for calculating ABCD

| Score | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Age (years old) | ≥ 40 | < 40 | | |
| BMI (kg/m$^2$) | < 27 | 27–34.9 | 35–41.9 | ≥ 42 |
| C-peptide(nmol/L) | < 2.0 | 2.0–2.9 | 3.0–4.9 | ≥ 5 |
| T2DM duration (years) | > 8 | 4–8 | 1–3.9 | < 1 |

BMI < 40 kg/m$^2$ in their study. Therefore, the age of the patient, the duration of diabetes, and the level of C-peptide should be taken into account comprehensively when we evaluate the prognosis of T2DM before operation.

The ABCD score was invented by Lee et al. in 2013 to predict the success of T2DM treatment after metabolic surgery and has been well validated in Asian patients and has become one of the scoring scales for evaluation of the postoperative efficacy in patients with T2DM [20]. ABCD score uses a 4-point scale, ranging from 0 (minimal value) to 3 (maximal value) for BMI, C-peptide, and duration of diabetes. For age, the score has a 2-point value from 0 to 1. Points for each variable are added, and a total score is calculated which ranges from 0 to 10 points (Table 4). Our study shows that the higher the score is, the better the effect was obtained (Fig.2). The complete remission rate of patients with ABCD score equal to or greater than 4 was 100% at 6 and 12 months after operation, respectively (Table 5). Our study result maintained in accordance with the research results of Li Weijie et al. [20].

Complications were detected in 5 patients after operation; gastric tangential bleeding occurred in 3 cases, posterior cerebral artery insufficiency in 1 case, and pneumonia in 1 case. However, all these complications were cured by conservative treatments. Gastric tangential bleeding is the most common complication after LSG. In our study, gastric

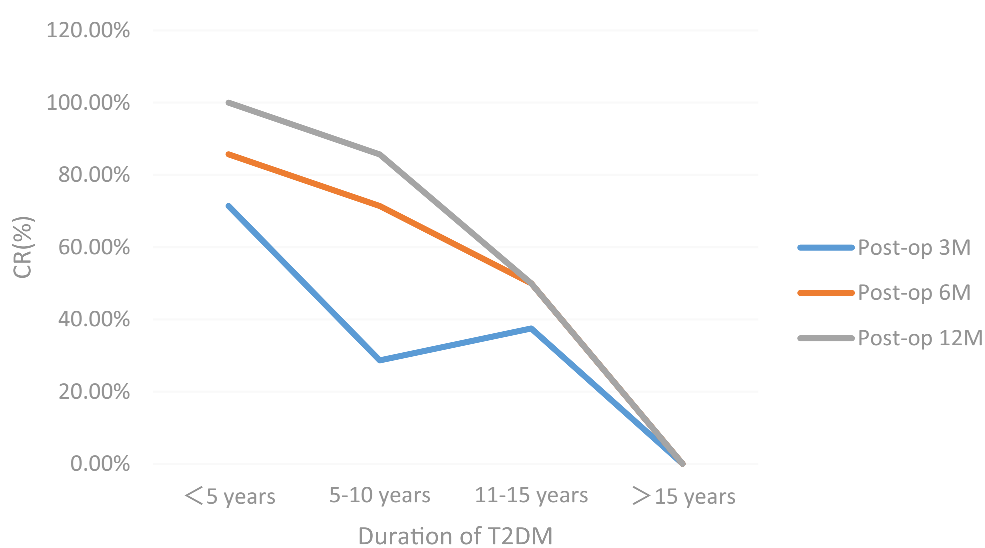


**Fig. 1** Chart of correlation between complete remission rate of type 2 diabetes mellitus and duration of diabetes and follow-up time after operation. The complete remission rate of type 2 diabetes mellitus increased with the prolongation of follow-up time when the duration of diabetes was within the same period. Moreover, at the same follow-up time after operation, the shorter the duration of diabetes was, the higher the complete remission rate of type 2 diabetes was obtained


**Fig. 2** Chart of correlation between complete remission rate of type 2 diabetes mellitus and ABCD scores and follow-up time after operation. The complete remission rate of type 2 diabetes mellitus increased with the prolongation of follow-up time when the ABCD scores were equal. Moreover, at the same follow-up time, the higher the ABCD scores were, the higher the complete remission rate of type 2 diabetes was obtained

tangential bleeding was detected in 3 cases and was treated conservatively. Average incidences of gastric tangential bleeding were 12%, which were significantly higher than those in previous studies. We analyzed the cause of gastric tangential bleeding is due to the unreinforced suture of gastric tangential. Janik et al. reported that the incidence of gastric tangential bleeding was 4%, and the risk factor of bleeding after LSG was the unreinforced suture of gastric tangential [21]. Abdallah et al. also think that the risk of bleeding for the patients without reinforced suture of gastric tangential is significantly higher than that for the patientswith reinforced suture of gastric tangential [22].

In a comparison of the results with those of Su Bin et al., their study shows that all aspects of SF-36 scores were increased significantly after operation [23]. This may be related to the patient's high BMI before operation. The preoperative body mass index was 39.5 ± 4.7 kg/m$^2$ in their study. However, our patient's preoperative BMI was only 27.92 ± 1.72 kg/m$^2$ in our study. Generally speaking, the preoperative physical functioning score of SF-36 is lower because the physical activity of the severely obese patients is obviously restricted. The physical activity restriction degree of the severely obese patients is significantly reduced when the body weight of the patients is obviously reduced after LSG. Consequently, the score of physical functioning increased significantly after LSG. In our study, preoperative BMI was lower, so physical activity was not significantly restricted. Consequently, the physical functioning score of SF-36 was higher. Therefore, there was no significant change in the score of physical functioning between preoperation and postoperation groups in our study.

In comparison between the remitters and the non-remitters at 12 months after operation, the non-remitters have a longer duration of diabetes than those in remitters ($P < 0.05$). Besides, the %TWL and ABCD scores were significantly higher than those in non-remitters ($P < 0.05$) (Table 6).

## Conclusion

Laparoscopic sleeve gastrectomy (LSG) has a significant effect on patients with type 2 diabetes mellitus whose BMI is less than 30 kg/m$^2$ in a short time. Various factors have been evaluated to predict T2DM remission following bariatric surgery. Our study shows that duration of T2DM and ABCD scores can be regarded as the important predictors of outcome. Besides, LSG can improve significantly the quality of life of patients.

**Table 5** Correlation of ABCD score with T2DM remission

| Scores | Post-op 3 months | | | | Post-op 6 months | | | Post-op 12 months | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CR(%) | PR(%) | NI(%) | NE(%) | CR(%) | PR(%) | NE(%) | CR(%) | PR(%) | NE(%) |
| 0 | 0 | 0 | 66.7 | 33.3 | 33.3 | 0 | 66.7 | 33.3 | 0 | 66.7 |
| 1 | 50 | 0 | 0 | 50 | 50 | 0 | 50 | 50 | 0 | 50 |
| 2 | 16.7 | 33.3 | 0 | 50 | 33.3 | 33.3 | 33.4 | 50 | 16.7 | 33.3 |
| 3 | 33.3 | 33.3 | 33.4 | 0 | 66.7 | 33.3 | 0 | 83.3 | 16.7 | 0 |
| 4 | 66.7 | 33.3 | 0 | 0 | 100 | 0 | 0 | 100 | 0 | 0 |
| 5 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 100 | 0 | 0 |

**Table 6** Comparison of preoperative characteristics between remission and non-remission groups at 12 months after operation

| Characteristics | Remission($n = 17$) | Non-remission($n = 8$) | $P$ |
|---|---|---|---|
| Age (years)* | 49.59 ± 11.03 | 56.75 ± 1.79 | 0.053 |
| Duration (years) | 6.32 ± 4.83 | 14.75 ± 2.96 | 0.000 |
| FPG (mol/L) | 10.27 ± 2.44 | 10.45 ± 3.27 | 0.880 |
| HBAlc(%) | 8.04 ± 1.49 | 8.64 ± 1.52 | 0.365 |
| FINS (mU/L)* | 28.86 ± 18.83 | 61.93 ± 82.71 | 0.683 |
| FCP (nmol/L) | 2.33 ± 0.79 | 2.14 ± 1.26 | 0.654 |
| IRI* | 13.23 ± 10.53 | 33.02 ± 46.39 | 0.954 |
| Body weight (kg) | 79.08 ± 9.56 | 71.13 ± 9.28 | 0.062 |
| BMI (kg/m$^2$) | 28.15 ± 1.79 | 27.04 ± 1.76 | 0.164 |
| Waistline (cm) | 99.47 ± 5.27 | 100.75 ± 5.87 | 0.590 |
| SBP (mmHg)* | 146.24 ± 16.31 | 155.38 ± 20.83 | 0.170 |
| DSBP (mmHg) | 84.41 ± 9.27 | 84.50 ± 11.07 | 0.984 |
| HR (bpm) | 78.06 ± 9.52 | 80.57 ± 13.65 | 0.873 |
| TG (mmol/L) | 2.75 ± 1.92 | 3.29 ± 1.91 | 0.517 |
| Chol (mmol/L) | 5.84 ± 1.04 | 5.41 ± 1.27 | 0.393 |
| Uric (μmol/L)* | 361.76 ± 83.67 | 333.63 ± 113.86 | 0.281 |
| %EWL* | 271.29 ± 540.36 | 165.72 ± 96.14 | 0.861 |
| %TWL* | 25.06 ± 4.81 | 19.84 ± 3.24 | 0.006 |
| ABCD scores | 2.94 ± 1.48 | 1.38 ± 1.06 | 0.013 |
| ALT | 29.69 ± 15.59 | 19.88 ± 7.73 | 0.110 |

*These group data were analyzed by the Mann-Whitney test

Due to the follow-up time and sample size is limited in our study, its long-term effect for LSG on T2DM in patients with BMI less than 30 kg/m$^2$ needs to be investigated further by prolonging the follow-up time and expanding the sample size.

## Compliance with Ethical Standards

**Statement of Human and Animal Rights** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

**Inform Consent** Since this is a retrospective study, formal consent is not required for this type of study.

**Conflict of Interest** The authors declare that they have no conflicts of interest.

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