Original Article

Laparoscopic sleeve gastrectomy for the treatment of diabetes mellitus type 2 patients—single center early experience

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Background: In recent years, laparoscopic sleeve gastrectomy (LSG) has become one of the most commonly used primary bariatric procedures for morbid obesity. While laparoscopic Roux-en-Y gastric bypass (LRYGB) has well documented positive clinical influence on type 2 diabetes, the role of LSG in diabetes treatment is debatable. The main aim of this study is to present our early experience in LSG as a method of bariatric treatment in patients with type 2 diabetes or abnormalities in glucose homeostasis.

Methods: Prospectively collected data of patients operated for morbid obesity at the 2nd Department of Surgery. The study was designed to assess the influence of LSG on type 2 diabetes and glucose homeostasis. The primary endpoint was the diabetes type 2 remission. Secondary endpoint was the change of glucose metabolism parameters after LSG. Patients were assessed preoperatively and allocated to two groups: group 1—with any preoperative abnormalities in glucose homeostasis (prediabetes, diabetes) and group 2—with non-elevated fasting glucose level. During follow-up (6 months after surgery) all glucose homeostasis parameters were analyzed again. One hundred and thirty-six patients after LSG were enrolled in the study (90 females, 46 males; mean age 40.5±9.9 years). Preoperative abnormalities in glucose homeostasis were confirmed in 64 (47%) patients. Twenty (15%) patients in this group had diabetes.

Results: We observed significant reduction of body mass index (BMI) after surgery. Mean percent of EBMIL for all groups after 6 months from surgery was 59.90% (46.75–69.28%). There were no full remissions after surgery in patients with preoperative diabetes. We found significant improvement in biochemical markers of glucose homeostasis. We observed significant reduction of HbA1c% after surgery in both groups. The level of postoperative HbA1c% was related to BMI loss after surgery.

Conclusions: LSG leads to significant improvement in biochemical glucose homeostasis and can be considered as a method of treatment in morbidly obese patients with glucose metabolism abnormalities. LSG as a method of treatment for patients with clinical type 2 diabetes still needs some further observation.

Keywords: Sleeve gastrectomy; diabetes; bariatric surgery; obesity

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Introduction

The main answer to the worldwide obesity epidemic is the increase in the number of performed bariatric procedures. Type 2 diabetes and glucose metabolism abnormalities are one the most important effects of morbid obesity which lead to severe and chronic reduction in quality of health. High effectiveness of bariatric therapy for weight reduction and treatment of comorbidities has been proven in numerous studies (1). But it is yet still unclear which bariatric procedure should be chosen for diabetic patients in order to achieve the best results in diabetes remission (2).

In recent years, laparoscopic sleeve gastrectomy (LSG) has become one of the most commonly used primary bariatric procedure for morbid obesity (3,4). Numerous authors strive to prove that effect of LSG on type 2 diabetes treatment is as good as laparoscopic Roux-en-Y gastric bypass (LRYGB), which was known as a "gold standard" for diabetic patients. Potential mechanisms of diabetes remission and improvement in glucose homeostasis after LSG are the main topic of recent studies, yet its results are still unclear (5). While LRYGB has well documented positive clinical influence on type 2 diabetes, the role of LSG in diabetes treatment is debatable. Many studies show great biochemical results. Although this should induce diabetes remission, the clinical long-term results are not so optimistic.

Aim of study

The main aim of this study is to present our early experience in LSG as a method of bariatric treatment in patients with type 2 diabetes or abnormalities in glucose homeostasis. The secondary aim of our study is identification of potential preoperative predictors of diabetes remission and glucose homeostasis improvement.

Methods

Prospectively collected data of patients operated for morbid obesity at the 2nd Department of Surgery, Jagiellonian University Medical College were analyzed. Guidelines of the Metabolic and Bariatric Surgery Section of the Polish Surgical Society were used as criteria for surgical treatment, i.e., body mass index (BMI) ≥35 kg/m^2 with obesity comorbidities, or BMI ≥40 kg/m^2, with or without comorbidities. All patients included in the study underwent LSG. The study was designed to assess the influence of LSG on type 2 diabetes and glucose homeostasis. The primary endpoint was the diabetes type 2 remission, which was described as glycosylated hemoglobin—HbA1c <6% (42 mmol/mol) without the use of diabetes medications. Secondary endpoint was the change of glucose metabolism parameters after LSG. Patients were assessed preoperatively and allocated to two groups: group 1—with any preoperative abnormalities in glucose homeostasis (prediabetes, diabetes) and group 2—with non-elevated fasting glucose level. To identify potential preoperative factors which can predict results of metabolic outcome, typical glucose homeostasis parameters were analyzed: fasting glucose level, insulin, proinsulin, C-peptide, HOMA-IR, HOMA-B and HbA1c%. During follow-up (6 months after surgery) all glucose homeostasis parameters were analyzed again.

Statistical analysis was performed using STATISTICA 10.0 PL. Data are presented as median values with inter-quartile range. Chi-square exact Fisher test, Pearson and Yates tests were used to compare of qualitative data. The *t*-test and Mann-Whitney, Wilcoxon, Cochrane-Cox tests analyzed quantitative differences between groups. Data were found statistically significant with P value of 0.05.

Ethical statement: the study was approved by the ethics review committee of the Jagiellonian University (approval number KBET/156/B/2011) and written informed consent was obtained from all patients.

Material

Two hundred and thirty-six patients underwent laparoscopic bariatric procedures at 2nd Department of General Surgery, Jagiellonian University Medical College between 2014 and 2016. One hundred and thirty-six patients after LSG were enrolled in the study (90 females, 46 males; mean age 40.5±9.9 years). Preoperative abnormalities in glucose homeostasis were confirmed in 64 (47%) patients [42 females, 22 males; mean age 47 (35.5–54) years]. Twenty (15%) patients in this group had diabetes and 44 (32%) had prediabetes defined as abnormal level of glucose homeostasis parameters. Seventy-two (53%) patients had normal fasting glucose level [48 females, 24 males; mean age 34 (27.5–43.5) years]. Median preoperative BMI in group with preoperative abnormalities in glucose homeostasis and without was respectively 46 (42.95–51.9) and 44.85 (40.9–48.2) kg/m^2. Typical comorbidities were more common in the group of patients with preoperative abnormalities in glucose homeostasis. *Table 1* presents groups characteristics. Patients' flow through the study is illustrated in *Figure 1*.

Table 1 Patients characteristics

Parameter	Preoperative abnormalities in glucose homeostasis	Non-elevated fasting glucose level	P
Gender [%]			0.898
Female	42 [66]	48 [67]	
Male	22 [34]	24 [33]	
Median age (IQR), years	47.0 (35.5–54.0)	34.0 (27.5–43.5)	<0.001
Median preoperative BMI (IQR), kg/m^2	46.00 (42.95–51.90)	44.85 (40.90–48.20)	0.020
Median obesity duration [IQR], years	15 [7–29]	15 [10–22]	0.552
Operative time, mean ± SD, min	102.5 (80.0–130.0)	120.0 (90.0–147.0)	0.133
Smoking [%]	42 [66]	28 [40]	0.003
Median smoking duration (IQR), package years	2.0 (0–15.0)	0 (0–2.8)	0.001
Median no-smoking period (IQR), years	0 (0–3)	0 (0–4)	0.910
Arterial hypertension [%]	44 [69]	40 [56]	0.114
Median arterial hypertension duration (IQR), years	2.5 (0–10.0)	0.1 (0–5.0)	0.025
Coronary artery disease [%]	10 [16]	0 [0]	–
Myocardial infarction [%]	4 [6]	2 [3]	0.571
Obstructive sleep apnea [%]	10 [17]	2 [3]	0.019
Hypercholesterolemia [%]	22 [34]	20 [28]	0.406
Mean hypercholesterolemia duration (IQR), years	0 (0–1)	0 (0–0)	0.057
NAFLD [%]	52 [81]	62 [86]	0.442
Physical activity [%]			0.189
Mild physical activity	12 [21]	8 [15]	
Moderate physical activity	24 [43]	34 [63]	
Severe physical activity	18 [32]	10 [19]	

Results

We observed significant reduction of BMI after surgery in the group with abnormalities in glucose homeostasis [46 (42.95–51.9) to 33 (29.4–38.9) kg/m^2]. Comparable results we found in the group with non-elevated fasting glucose level [44.85 (40.9–48.2) to 33.3 (31.4–37.2) kg/m^2]. Mean percent of EBMIL for all groups after 6 months from surgery was 59.90% (46.75–69.28%).

Unfortunately there were no full remissions after surgery in patients with preoperative diabetes. Every patients with preoperative insulin treatment remained on insulin, however the dose of insulin decreased. Of 60 (44%) patients who were preoperatively taking oral diabetic medications, only 36 (26%) need them during follow up. The number of patients with poor glycemic control decreased from 14 (70%) to 8 (40%) (*Table 2*).

We found significant improvement in biochemical markers of glucose homeostasis. Number of patients with prediabetes significantly decreased from 44 (32.35%) to 16 (11.76%), P<0.001. Insulin resistance (HOMA-IR) in both groups (with and without abnormalities in glucose homeostasis) decreased significantly after surgery from 6.62% (5.58–8.41%) and 5.30% (3.99–8.47%). Median insulin level dropped from baseline 30.37 (24.33–34.75) to 15.91 (11.02–24.46) mU/mL in first group and from 24.59 (19.54–41.04) to 17.33 (13.95–22.04) mU/mL in the second. Proinsulin level decreased from 3.40 (2.30–4.77), 3.18 (2.37–5.14) to 1.66 (1.45–2.77), 2.18 (1.28–2.53) pmol/L respectively. There were no significant changes in postoperative levels of C-peptide. Medium level of HbA1c% before surgery in the group with preoperative abnormalities in glucose homeostasis was 5.95% (5.7–6.6%) and 5.35% (5.1–5.5%) in the group with non-elevated fasting glucose level. We observed significant reduction of HbA1c% after surgery in both groups to 5.6% (5.5–5.7%) and 5.15% (4.9–5.2%) (*Table 3*). The level of postoperative HbA1c% was related to BMI loss after surgery (*Figure 2*).

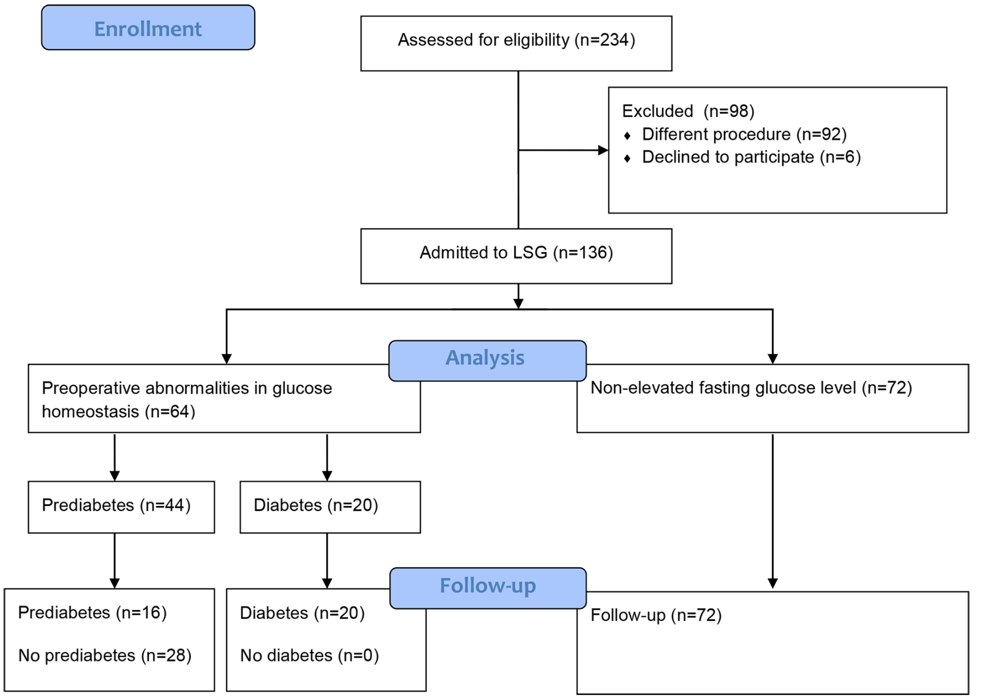

Figure 1 Flow chart. LSG, laparoscopic sleeve gastrectomy.

Table 2 Remission of abnormalities in glucose homeostasis

Parameter	Preoperative (%)	6 months after surgery (%)	P
Prediabetes	44 (32.35)	16 (11.76)	<0.001
Diabetes mellitus	20 (14.71)	20 (14.71)	–
Poor glycemic control	14 (70.00)	8 (40.00)	0.024
Insulin resistance	4 (20.00)	4 (20.00)	–
Oral diabetic medications	60 (44.00)	36 (26.00)	0.002

A univariate logistic regression analysis showed that preoperative age (OR, 9.92; 95% CI, 0.87–0.97; P=0.003), fasting glucose level (OR, 0.5; 95% CI, 0.29–0.87; P=0.013), HbA1c% (OR, 0.19; 95% CI, 0.06–0.61; P=0.004), total cholesterol level (OR, 2.2; 95% CI, 1.24–3.91; P=0.007) and LDL (OR, 2.57; 95% CI, 1.28–5.16; P=0.006) were related with postoperative diabetes remission and improvement of glucose metabolism (*Table 4*).

Discussion

LRYGB and LSG are currently the most common bariatric surgeries in Poland (6). The role of bariatric surgery in treatment of morbid obesity is well established in our country. The effect of bariatric surgeries on weight reduction is important as well as its impact on comorbidities, especially type 2 diabetes. In the age of bariatric surgery, type 2 diabetes can be viewed as a curable disease. Bariatric surgery has been confirmed to be beneficial in remission of abnormalities in glucose homeostasis (7). Type 2 diabetes is an indication for bariatric surgery if patient's BMI exceeds 35 kg/m^2. Patients with BMI >30 and <35 kg/m^2 may be considered for metabolic surgery on an individual basis (8,9). Unfortunately, no surgical guidelines for bariatric treatment or any statements of international diabetes organization define what kind of surgery would best for diabetic patients with morbid obesity (9-11).

Due to very good long-term effects on weight

Table 3 Analysis of glucose metabolism related parameters

Parameter	Preoperative abnormalities in glucose homeostasis (n=64)			Non-elevated fasting glucose level (n=72)		
	Preoperative	6 months after surgery	P	Preoperative	6 months after surgery	P
Median HOMA-IR (IQR), (%)	6.62 (5.58–8.41)	3.71 (2.79–5.17)	<0.001	5.30 (3.99–8.47)	3.34 (2.75–5.56)	<0.001
Median HOMA-B (IQR), (%)	319.92 (187.52–478.06)	275.95 (160.66–345.86)	0.804	363.15 (263.97–603.61)	326.59 (286.33–433.28)	0.166
Median insulin (IQR), mU/mL	30.37 (24.33–34.75)	15.91 (11.02–24.46)	<0.001	24.59 (19.54–41.04)	17.33 (13.95–22.04)	<0.001
Median proinsulin (IQR), pmol/L	3.40 (2.30–4.77)	1.66 (1.45–2.77)	<0.001	3.18 (2.37–5.14)	2.18 (1.28–2.53)	<0.001
Median C-peptide (IQR), nmol/L	6.75 (5.22–8.63)	7.08 (4.00–8.13)	0.139	6.36 (4.79–8.13)	6.01 (4.34–9.18)	0.545
Median fasting glucose level (IQR), mmol/L	5.64 (4.92–6.60)	4.94 (4.50–5.21)	<0.001	4.89 (4.50–5.24)	4.66 (4.41–4.89)	0.002
Median HbA1c (IQR), (%)	5.95 (5.70–6.60)	5.6 (5.50–5.70)	<0.001	5.35 (5.10–5.50)	5.15 (4.90–5.20)	<0.001
Total cholesterol, mean ± SD, mmol/L	5.13±1.11	5.21±1.08	0.111	5.09±0.95	5.08±1.06	0.105
Median HDL (IQR), mmol/L	1.15 (1.00–1.33)	1.11 (1.01–1.50)	0.002	1.10 (1.00–1.30)	1.20 (1.10–1.42)	0.003
Median LDL (IQR), mmol/L	2.95 (2.35–3.50)	3.20 (2.50–4.20)	0.884	3.00 (2.40–3.40)	3.35 (2.40–3.80)	0.172
Median triglycerides (IQR), mmol/L	1.89 (1.41–2.41)	1.42 (1.06–1.67)	<0.001	1.77 (1.20–2.50)	1.05 (0.83–1.32)	<0.001
Median BMI (IQR), kg/m^2	46.00 (42.95–51.90)	33.00 (29.40–38.90)	<0.001	44.85 (40.90–48.20)	33.30 (31.40–37.20)	<0.001
Median WHR (IQR), (%)	0.93 (0.88–1.04)	0.89 (0.86–0.96)	0.001	0.91 (0.84–0.97)	0.86 (0.81–0.95)	<0.001
Median EBMIL (IQR), (%)	–	59.14 (46.84–73.29)	–	–	59.90 (46.75–69.28)	–
Median ejection fraction (IQR), (%)	66.00 (61.00–71.00)	64.00 (56.00–71.00)	0.094	66.00 (61.00–71.00)	69.50 (66.00–73.00)	0.082

BMI, body mass index.

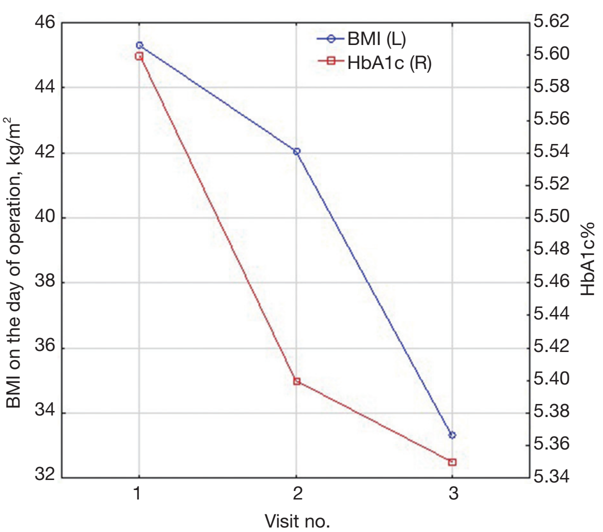

Figure 2 Relation between BMI and HbA1c%. BMI, body mass index.

reduction and remarkable resolution of comorbidities and improvements in glucose homeostasis, LRYGB formerly regarded as absorptive procedure became a standard procedure. However it is a difficult procedure, with numerous early and late complications and high risk of malnutrition in the future. For this reason many authors try to use different techniques to treat diabetic patients. LSG is technically easier, and the newest data suggest occurrence of some important metabolic changes after operation. Nowadays LSG is no more defined as an only restrictive procedure (2).

In the literature we can find confusing data about weight loss results after LRYGB and LSG. In some articles authors present higher percent of EWL after LRYGB. Our observation revealed that the weight reduction after both procedures is similar (12). In our study percent of EBMIL after LSG, measured 6 months after surgery, was 59.90% (46.75–69.28%) and it was comparable to others

Table 4 Uni- and multivariate logistic regression analyses of parameters affecting remission of abnormalities in glucose homeostasis

Parameter	Univariate logistic regression			Multivariate logistic regression		
	OR	95% CI	P	OR	95% CI	P
Gender (female *vs*. male)	2.93	0.94–9.16	0.059			
Age (years)	0.92	0.87–0.97	0.003	0.95	0.89–1.02	0.166
Obesity duration (years)	1.01	0.97–1.05	0.662			
Smoking (yes *vs*. no)	0.51	0.18–1.49	0.210			
Smoking duration (years)	1.00	0.96–1.04	0.938			
No-smoking period (years)	0.90	0.79–1.02	0.100			
Arterial hypertension (yes *vs*. no)	0.38	0.13–1.15	0.081			
Arterial hypertension duration (yes *vs*. no)	0.94	0.87–1.02	0.106			
Obstructive sleep apnea (yes *vs*. no)	0.10	0.01–10.30	0.340			
Hypercholesterolemia (yes *vs*. no)	0.34	0.11–1.06	0.059			
Hypercholesterolemia duration, mean ± SD (years)	0.93	0.82–1.05	0.246			
NAFLD (yes *vs*. no)	5.00	0.97–25.90	0.050			
Physical activity (severe *vs*. moderate *vs*. mild)	0.73	0.38–1.42	0.344			
HOMA-IR	0.87	0.74–1.02	0.069			
HOMA-B	1.00	0.99–1.00	0.153			
Insulin (1 mU/mL)	0.96	0.90–1.01	0.107			
Proinsulin (1 pmol/L)	0.85	0.65–1.11	0.208			
C-peptide (1 nmol/L)	0.98	0.79–1.22	0.859			
Fasting glucose level (1 mmol/L)	0.50	0.29–0.87	0.013			
HbA1c (1%)	0.19	0.06–0.61	0.004	0.29	0.07–1.11	0.065
Total cholesterol (1 mmol/L)	2.20	1.24–3.91	0.007			
HDL (1 mmol/L)	1.56	0.19–12.65	0.671			
LDL (1 mmol/L)	2.57	1.28–5.16	0.006	3.03	1.21–7.59	0.016
Triglycerides (1 mmol/L)	0.89	0.50–1.58	0.689			
BMI on the day of surgery	1.00	0.92–1.08	0.933			
WHR on the day of surgery	0.02	<0.01–5.51	0.155			
EBMIL	1.03	0.98–1.08	0.182			
Ejection fraction (1%)	0.98	0.92–1.04	0.424			

BMI, body mass index.

authors (13,14).

In opposition to LRYGB, mechanisms of diabetes remission after LSG are not well-defined. The GLP-1 play the key-role in changes of glucose metabolism and it is responsible for improvement of glucose homeostasis after LRYGB. After LSG the level of GLP-1 rises as well, thus it has been suggested to contribute to potential improvements in diabetes remission (15). In our previous studies we noticed the same relations between gut hormones after LSG (16).

Numerous authors present satisfactory biochemical results which should be related with diabetes remission. Unfortunately long-term clinical observations are not so encouraging. Similarly, in our study after 6 months from the surgery we noticed significant remission of biochemical abnormalities of glucose homeostasis, however we did not cure diabetes. Twenty patients with type 2 diabetes before surgery still need medical treatment for glycemic control. Jammu and Sharma in their group described remission of type 2 diabetes in 13 of 23 patients (17). Sixty-seven percent of diabetes remission after LSG was presented in the study of Milone, who compared it with results after mini gastric bypass (18). All patients who preoperatively needed insulin still need it, but at a lower dose. All patients reduced oral diabetic medications. We noticed improvement in biochemical glucose homeostasis, which was described as significant changes of HOMA-IR, level of insulin, C-peptide and HbA1c% after 6 months. Despite that there were no cases of complete remission of diabetes. Similar results and very rare diabetes remission was presented by Aminian (19).

The most important issue in assessment of metabolic effects of bariatric surgery is the criteria for diabetes remission. This creates space for potential biases. It can explain the differences found in the literature.

Nevertheless even if patient did not meet the clinical criteria of complete remission of type 2 diabetes, the most important metabolic profit after surgery is improvement in glycemic control. It can be noticed in the level of HbA1c% after surgery, which reduced significantly. Our observation refers to both, group with abnormalities in glucose homeostasis and the group with non-elevated fasting glucose level. Vigneshwaran *et al*. present similar observations. In their study level of HbA1c% decreased from (8.7±1.6)% to (6.7±1.5)% (20). Interestingly the level of HbA1c% was correlated to percent of EBMIL in contrast to results presented in the Milone study (18).

The preoperative information about potential predictors of postoperative glycemic abnormalities remission can lead to improvement of long-term effects. In "ABCD score" we can find some potential factors (age, BMI, C-peptide, diabetes duration) which can be useful to predict diabetes remission after bariatric surgery (21). In our study we tried to confirm this relationship and identify some new factors, which can be related with better or worse metabolic answer after LSG. We noticed that only age, fasting glucose level, HbA1c%, total cholesterol level and LDL level were statistically important for remission of abnormalities in glucose homeostasis. Age and HbA1c% seem to be the most important factors. Similar to our observation, Milone *et al*. considered HbA1c% as a negative predictor of diabetes remission (18). In the study of Hamza, chance for diabetes remission was reduced by 20% with each additional 12 years of age (22). Older age and worse glycemic control, defined as a higher level of HbA1c%, are the negative predictors for diabetes remission. In patients with such condition LRYGB should be recommended.

Conclusions

LSG leads to significant improvement in biochemical glucose homeostasis and can be considered as a method of treatment in morbidly obese patients with glucose metabolism abnormalities. LSG as a method of treatment for patients with clinical type 2 diabetes still needs some further observation. In elderly patients with poorly compensated type 2 diabetes LRYGB should be recommended.

Long term observations from double-blinded randomized control trials will be helpful to make the final decision which procedure should be considered in candidates for bariatric treatment.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The study was approved by institutional ethics board of the Jagiellonian University (No. KBET/156/B/2011) and written informed consent was obtained from all patients.

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