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Does weight loss after laparoscopic sleeve gastrectomy contribute to reduction in blood pressure?

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Short title: The effect of LSG on hypertension

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Key words: bariatric surgery; hypertension; obesity; sleeve gastrectomy
What’s new?

Obesity has been rapidly becoming an emerging health issue worldwide and is a major risk factor for developing cardiovascular diseases. The need to effectively fight against obesity has led to the rapid development of metabolic/obesity surgery. Laparoscopic sleeve gastrectomy (LSG) being one of the most effective surgical methods results in long-term weight loss and resolution of obesity-related diseases such as hypertension. This study was performed to evaluate the impact of LSG on resolution or amelioration of hypertension. This paper reveals that weight loss induced by LSG does not contribute to the treatment of hypertension. This finding may serve as a benchmark for future studies to evaluate the exact mechanism of hypertension resolution after LSG.
Abstract

Introduction: Obesity-related hypertension is a life-threatening medical condition that significantly increases the risk of cardiovascular diseases and premature mortality. Effective treatment of obesity may be achieved by laparoscopic sleeve gastrectomy (LSG). This surgical method contributes not only to sustained weight loss, but also to resolution of hypertension.

Objectives: The aim of the study was to evaluate the efficacy of weight loss after LSG on resolution or amelioration of hypertension.

Patients and methods: A retrospective analysis of medical and clinical data of 305 patients who had undergone LSG was performed. The bariatric effect of LSG was assessed by calculating percentage of total weight loss (%TWL), percentage of excess weight loss (%EWL) and BMI loss (%EBMIL). Blood pressure status after surgery was categorized as partial or total remission of hypertension.

Results: 143 patients (46.9%) were diagnosed with hypertension preoperatively with median hypertension duration of 7.52 (1.88 – 13.16) years. Hypertensive patients were older (49 vs. 38.5 years) and had higher prevalence of coexisting diseases (type 2 diabetes, dyslipidemia and obstructive sleep apnea) than patients with normal blood pressure. During one-year observation 90 patients (63%) reduced antihypertensive medications and 33 patients (23%) discontinued the therapy. Twelve months after the surgery %TWL in control group was 32.5 (28.1-37.7)%, while in hypertensive group 29.1 (25.9-33.6)% (p<0.001), %EWL was 62.9 (53-74.6)% and 54.8 (47.4-68.2)% respectively (p=0.001) and %EBMIL 73.9 (59.5-91.2)% and 63 (55-80.5) % (p=0.002) respectively.

Conclusions: LSG is an effective method of obesity-related hypertension treatment. However, weight loss induced by LSG does not affect the blood pressure status after the surgery.
Introduction

The incidence of obesity worldwide has been constantly rising reaching the size of global pandemic with almost 2 billion of adults considered to be overweight or obese [1]. In Poland, abdominal obesity is observed in every third men and every second women [2]. A significant percentage of obese people in general population and insufficient effect of conservative treatment has led to the development of bariatric surgery. Among all bariatric procedures, laparoscopic sleeve gastrectomy (LSG) is considered to be one of the most effective method that promotes long-term weight loss and improvement or resolution of obesity-related diseases such as hypertension, type 2 diabetes mellitus and hypercholesterolemia [3-5]. LSG is recently the most common bariatric procedure worldwide and is highly recommended by the experts as a first choice standalone procedure for patients who are considered high risk; kidney and liver transplant candidates, morbidly obese patients with metabolic syndrome, patients with a BMI of 30–35 with co-morbidities; patients with inflammatory bowel disease and elderly morbidly obese patients [6]. The pathophysiologic mechanism leading to the development of hypertension in obese patients is complex and includes sympathetic nervous system (SNS) overactivation, stimulation of the renin – angiotensin – aldosterone system (RAAS), insulin resistance and alterations in adipose – derived cytokines such as adiponectin and leptin [7,8]. Available studies demonstrates that weight loss results in decline in activity of RAAS and SNS that may have a significant effect on reducing blood pressure [9,10]. Reduction in body mass also results in elimination of the adipose tissue-related source of hypertension. Additionally, surgically induced weight loss combined with better control of blood pressure decrease the rate of cardiac events and premature death. The objective of this study was to determine the efficacy of LSG for resolution of hypertension in morbidly obese patients.
Patients and methods

This is a retrospective cohort study of consecutive adult patients between 18 and 65 year old who underwent laparoscopic sleeve gastrectomy as a single stage procedure between January 2014 and December 2018 at University Hospital in Bialystok. All patients were qualified to surgical treatment of morbid obesity according to the European Guidelines on Metabolic and Bariatric Surgery [11]. Inclusion criteria regarded inability to achieve sustained weight loss with conservative management and BMI ≥ 40.0 kg/m² or 35 – 40 kg/m² with the presence of obesity-related comorbidities such as type 2 diabetes mellitus, hypertension, obstructive sleep apnea, non-alcoholic fatty liver disease (NAFLD) and steatohepatitis (NASH), hyperlipidemia, depression and others. The surgical procedure was performed by the same surgeon with two alternating assistants. Patients were excluded from the study when they had developed perioperative complications and in the case of lack of necessary data.

Data collection

Demographic and clinical data were gathered prospectively along with repeated measurements of selected laboratory parameters. The preoperative measurements included fasting glucose and insulin concentrations, glycated hemoglobin level (HbA₁c), alanine aminotransferase (ALT), aspartate aminotransferase (AST), total cholesterol and its fractions, triglycerides (TG) and C-reactive protein (CRP). Bariatric effect was assessed using following equations:

\[
\text{a) Percent of total weight loss (%TWL): } \%\text{TWL} = \frac{\text{initialweight} - \text{currentweight}}{\text{initialweight}} \times 100
\]

\[
\text{b) Percent excess BMI loss (%EBMIL): } \%\text{EBMIL} = \frac{\text{initialBMI} - \text{postoperativeBMI}}{\text{initialBMI} - 25} \times 100
\]
c) Percent excess weight loss (%EWL): 
\[
\text{%EWL} = \frac{\text{initialweight} - \text{postoperativeweight}}{\text{initialweight} - \text{idealweight}} \times 100
\]

while an ideal weight is defined by the weight corresponding to the BMI of 25 kg/m².

Homeostatic model assessment of insulin resistance index (HOMA-IR) was performed using the following formula: 
\[
\text{HOMA-IR} = \frac{\text{fastingglucoselevel}}{\text{insulinconcentration} \times 405}
\]
result >2.6 confirmed insulin resistance.

The hypertensive status of the patients and bariatric effect were assessed during follow–up visits that were scheduled 1, 3, 6 and 12 months postoperatively.

Patients were considered hypertensive when the blood pressure was >140/90 mmHg or if they were receiving antihypertensive medications. The diagnosis of arterial hypertension was made according to Guidelines of the Polish Society of Hypertension [12]. Any adjustment in antihypertensive therapy during the follow-up was made by the primary care providers. Data about any medication changes was assessed during the follow-up visits at surgical out-patient clinic based on medical interview. Partial remission of hypertension was defined as reduction in the dose of the antihypertensive drugs, while total remission was defined as blood pressure <140/90 mmHg in combination with the absence of the antihypertensive therapy.

All patients were informed about the risk of surgical procedure and written informed consent was obtained from every participants prior to the surgery. The study was approved by the Bioethics Committee of the Medical University (the reference number of the consent: R-I-002/248/2018).

Statistical analysis

Data was analyzed using GraphPad Prism 8.0 software (GraphPad Software Inc., La Jolla, CA, USA). The normality of variables distribution was assessed in Shapiro-Wilk test. The
The differences between control and hypertensive group in a particular follow-ups were analysed with Mann-Whitney test. Continuous values were presented as median and interquartile range (IQR). Qualitative data respecting the occurrence of hypertension and the effect of bariatric surgery on a modification of its treatment were analyzed using Pearson chi-square test. P-values ≤ 0.05 were considered statistically significant.

**Results**

The study group included 305 patients – 131 males and 174 females (43%/57%), in median age of 43 (37 – 54) years. Median preoperative BMI was 45.0 (41.4-49.4) kg/m². 143 patients (46.9%) were diagnosed with hypertension preoperatively. All patients who were diagnosed with hypertension prior to the surgery received anti-hypertensive therapy. The most frequently taken drugs were: angiotensin converting enzyme inhibitors (ACE inhibitors), angiotensin II receptor blockers, diuretics, calcium channel blockers and alpha-blockers. Median hypertension duration was 7.52 (1.88 – 13.16) years. The most common comorbidities beside hypertension were: type 2 diabetes mellitus (63 patients), obstructive sleep apnea (56 patients) and dyslipidemia (96 patients). The repeated measurements of selected laboratory parameters in all patients at the beginning of observation as well as during follow-up visits are presented in Table 1, while Table 2 presents laboratory data in 12-month observation between hypertensive group and control group. Hypertensive patients were older (49 vs. 38.5 years) and had higher prevalence of type 2 diabetes, dyslipidemia and obstructive sleep apnea than patients with normal blood pressure. Figure 1 presents distribution of hypertension between women and men at the beginning of observation and during 12-month follow-up (Figure 1). There were no significant differences between women and men in the treatment of hypertension after laparoscopic sleeve gastrectomy.
During the observation median BMI in study group decreased from 45.0 (41.4-49.4) kg/m² preoperatively to 31.0 (27.1-35.2) kg/m² one year after the surgery (p<0.001). The percentage of total weight loss 12 months after LSG reached 31.2 (27.2-35.7)% (p<0.001), the percentage of excess weight loss was 59.6 (49.5-71.1) (p<0.001) and the percentage of the excess BMI loss reached 70.1 (57.1-86.7) (p<0.001). Table 3 present weight loss parameters in 12-month follow-up between hypertensive and non-hypertensive group. Although all patients have presented considerable weight loss after the surgical procedure, no association between total weight loss after the surgery and total or partial remission of hypertension was seen (Figure 2).

The reduction or discontinuation of antihypertensive therapy were already observed 1 month after the surgery. During one-year follow-up 90 patients (63%) reduced antihypertensive medications and 33 patients (23%) discontinued the therapy (Table 4). Figure 3 shows changes in hypertensive status during one-year follow-up (Figure 3).

**Discussion**

The present data indicate that laparoscopic sleeve gastrectomy significantly reduces body weight as early as one month after the surgical procedure in morbidly obese patients, which was seen as statistically significant decrease in BMI and increase in percentage of total weight loss, excess weight and BMI loss at every point of the observation. During the follow -up, an increase in patients with partial or complete resolution of hypertension was also observed.

Hypertension is a serious medical condition and a primary, modifiable risk factor for cardiovascular diseases such as stroke, ischemic heart disease and heart failure [13,14]. Analyses have shown that more than 1 billion people have been living with hypertension worldwide [15]. Medication therapies are commonly used to control blood pressure, however the results are insufficient especially in morbidly obese hypertensive patients. There is a lot of evidence that bariatric procedures improve the course of type 2 diabetes mellitus, however the
impact of laparoscopic sleeve gastrectomy on blood pressure have been investigated in few cohort studies [16]. The remission rates of hypertension after bariatric surgery vary between 60 – 70% in one-year observation and may reach even 90% for long-term follow-up [17,18].

In our study, improvement of blood pressure control after LSG was observed in 86% of patients in one-year follow-up. Additionally, several studies proved that hypertension remission rates were lower compared with other obesity-related diseases [19,20]. Flores et al. showed a reduction in systolic and diastolic blood pressure (respectively 20 and 11 mmHg) in 12-month observation in hypertensive patients who had undergone bariatric surgery [21]. Kaya et al. observed statistically significant decrease in systolic and diastolic pressure only 6 months after laparoscopic sleeve gastrectomy. They also noticed significant reduction in heart rate, triglyceride and LDL cholesterol levels [22].

Age is an independent risk factor for developing hypertension which is associated with structural changes in the arteries mainly with significant vessels stiffness [23,24]. This explains higher frequency of hypertension in older obese patients. Higher preoperative BMI and presence of other obesity – related diseases in hypertensive patients may be explained with the hypertension duration and coexistence of metabolic syndrome. It highlights the need of performing laparoscopic sleeve gastrectomy as early as a patient meets the procedure criteria, what is in line with the experts surgeon opinion [6].

In this study, reduction or discontinuation of antihypertensive therapy were seen as early as one month after performing laparoscopic sleeve gastrectomy. This results are in line with previously published studies [25,26]. However, this rapid decrease in blood pressure is not significantly consistent with weight loss following bariatric surgery. This may indicate that blood pressure control after the surgery is not directly related to weight loss after laparoscopic sleeve gastrectomy.
The exact pathophysiological mechanism associated with the reduction of blood pressure after LSG in still unclear. The development of obesity-related hypertension is multifactorial and may be associated with gastrointestinal hormones, such as leptin and ghrelin. Removal of gastric fundus cells also results in increase in glucose – like peptide 1 (GLP-1) and peptide YY (PYY) levels [27]. This changes may play a significant role in the development of hypertension in obese patients due to diuretic and natriuretic effect of GLP-1 and PYY on the kidney [28,29]. Moreover, leptin secretion from adipose tissue stimulates sympathetic nervous system, that activates systemic and local renin-angiotensin-aldosterone system (RAAS). Therefore, decrease in leptin secretion could be responsible for the remission of obesity – associated hypertension [30,31]. Additionally, bariatric surgery promotes decrease in inflammatory response, which together with an amelioration in insulin resistance may decrease arterial stiffness and reduce sodium reabsorption. These changes lead to better control of blood pressure and may lead to the remission of hypertension after bariatric procedure [32]. Briones et al. also proved that adipocytes may produce aldosterone through calcineurin – dependent signaling pathways. Adipocyte – derived aldosterone is significantly higher in metabolic syndrome related to obesity which additionally contributes to vascular dysfunction [33]. Furthermore, dietary changes after LSG such as reduced salt and food intake and recovery of endothelial functions also play an important role in reducing blood pressure [34].

Nevertheless, our study has several limitation. First of all, it was conducted in a single bariatric center and there is no control group. Another limitation may be a short period of observation which was continued only for 12 months. The strong point of our study is considerable cohort size and fact that all procedures were performed by the same surgeon.
Conclusions

In summary, laparoscopic sleeve gastrectomy is an effective surgical method that induces significant weight loss and provides blood pressure control in obese patients. However, no relationship between total weight loss after the bariatric surgery and resolution or amelioration of hypertension was observed in this study. Further studies are needed to verify this observation and discover mechanisms of surgically-induced reduction in blood pressure.

Contribution statement:

PW, ID, HRH, JRL conceived the concept of the study. PW, ID, PG contributed to the design of the research. All authors were involved in data collection. PW, ID, KD analyzed the data. KD performed statistical analysis. All authors contributed to data acquisition and interpretation. All authors edited and approved the final version of the manuscript.
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Table 1. Repeated measurements of selected laboratory parameters in all patients during the follow-up

| Variable | 0 N=305  | 1 month N=305 | 3 months N=285 | 6 months N=273 | 12 months N=278 | P-value |
|----------|---------|---------------|----------------|----------------|----------------|---------|
| BMI, kg/m² | 45.0 (41.4-49.4) | 40.3 (37.2-44.9) | 36.1 (32.9-40.5) | 33.0 (29.8-36.9) | 31.0 (27.1-35.2) | < 0.001 |
| %TWL | N/A | 9.8 (8.2-11.9) | 19.3 (16.5-22.3) | 26.5 (22.7-30) | 31.2 (27.2-35.7) | < 0.001 |
| %EWL | N/A | 19.2 (15.3-23.6) | 37.0 (30.6-44.3) | 50.1 (41.6-59.8) | 59.6 (49.5-71.1) | < 0.001 |
| %EBMIL | N/A | 22.8 (17.8-28.1) | 43.5 (35.1-53.1) | 59.1 (46.5-72.6) | 70.1 (57.1-86.7) | < 0.001 |
| CRP, mg/l | 6.8 (3.6-9.8) | 3.4 (2.2-8.1) | 4.4 (2.0-8.7) | 3.2 (1.2-8.2) | 1.8 (0.8-4.9) | < 0.001 |
| FPG, mg/dl | 106 (97-120) | 101 (92-112) | 98 (90-106) | 98 (90-106) | 95 (89-101) | < 0.001 |
| Insulin, mIU/l | 21.5 (13.4-30.3) | 11.0 (7.8-13.9) | 10.4 (7.1-13.9) | 8.3 (5.3-14.3) | 8.2 (6.1-10.9) | < 0.001 |
| HOMA-IR | 5.4 (3.4-8.6) | 2.9 (1.9-3.8) | 2.5 (1.6-3.5) | 2.0 (1.2-3.6) | 1.8 (1.3-2.6) | < 0.001 |
| HbA1c, % | 5.7 (5.3-6.3) | 5.5 (5.2-6.0) | 5.3 (5.0-5.7) | 5.3 (5.0-5.7) | 5.3 (5.0-5.6) | < 0.001 |
| ALT, IU/l | 35.1 (24.0-55.2) | 35.0 (24.0-48.0) | 23.1 (18.0-33.0) | 19.0 (13.1-25.9) | 20.0 (15.0-26.0) | < 0.001 |
| AST, IU/l | 26.0 (19.7-43.5) | 27.0 (21.0-36.0) | 22.0 (16.8-29.0) | 19.0 (15.4-25.0) | 20.0 (16.0-25.0) | < 0.001 |
| Cholesterol, mg/dl | 205 (175-234) | 170 (148-191) | 176 (154.5-199) | 192 (165-219) | 179 (156-208) | < 0.001 |
| LDL, mg/dl | 141.7 (112-172) | 111.9 (94-133) | 117 (94-138) | 128 (102-151) | 119 (98.1-142.2) | < 0.001 |
|       | Median (IQR)       | Median (IQR)       | Median (IQR)       | Median (IQR)       | Median (IQR)       |
|-------|-------------------|-------------------|-------------------|-------------------|-------------------|
| HDL, mg/dl | 47.5 (39-60)      | 36 (31-42)        | 44 (36-50)        | 51 (41-61)        | 57 (47-66)        |
| TG, mg/dl   | 156.5 (113.5-199) | 127 (101-161)     | 114 (89-145)      | 98 (77-134)       | 93 (70.7-125.3)   |

For most variables measurements are presented as median and IQR due to non-Gaussian distribution. For parameters with normal distribution (%TWL, LDL) values are expressed as mean (SD).

BMI, body mass index; %TWL, percentage of total weight loss; %EBMIL, percentage of excess BMI loss; %EWL, percentage of excess weight loss; CRP, C-reactive protein; FPG, fasting plasma glucose; HOMA-IR, homeostatic model assessment of insulin resistance index; ALT, alanine transaminase; AST, aspartate transaminase; LDL, low-density lipoprotein; TG, triglyceride; HDL, high-density lipoprotein; HbA$_1$c, glycated hemoglobin.
Table 2. Repeated measurements of selected laboratory parameters after laparoscopic sleeve gastrectomy in control and hypertensive patients during the follow-up

| Variable     | Group | 0 N=305 | 1 month N=305 | 3 months N=285 | 6 months N=273 | 12 months N=278 | P-value |
|--------------|-------|---------|---------------|---------------|---------------|---------------|---------|
| CRP, mg/l    | ctr   | 6.8 (3.6-10.5) | 3.7 (2.2-8.2) | 4.2 (2-10.4)  | 3.2 (1.2-8.4) | 2.3 (0.7-6.5) | <0.001  |
|              | HT    | 6.4 (3.7-9.5)  | 4.1 (1.8-8.1) | 4.4 (1.9-8.2) | 3.5 (1.7-8.2) | 1.6 (0.8-4.1) | <0.001  |
| P-value ctr vs HT |       | 0.39 | 0.87 | 0.72 | 0.70 | 0.28 |
| FPG, mg/dl   | ctr   | 105 (96-119.5) | 101 (91-108)  | 95 (88-105)   | 97.5 (90-106) | 93 (87-100)   | <0.001  |
|              | HT    | 107 (97.3-120) | 104.5 (95-116.5) | 100 (92-107) | 98.5 (90.3-107.5) | 98 (90-104) | <0.001  |
| P-value ctr vs HT |       | 0.40 | **0.013** | **0.026** | 0.52 | **0.006** |
| Insulin mIU/l | ctr   | 21.7 (14.5-30.9) | 11.0 (7.5-14.5) | 9.5 (6.6-13.8) | 8.5 (5.6-14.2) | 8.5 (6.4-11.3) | <0.001  |
|              | HT    | 19.9 (12.7-30.3) | 10.9 (7.9-13.6) | 10.9 (7.3-14.2) | 7.0 (4.9-15.1) | 7.9 (6.0-10.7) | <0.001  |
| P-value ctr vs HT |       | 0.93 | 0.93 | 0.55 | 0.93 | 0.93 |
| HOMA-IR      | ctr   | 5.5 (3.4-8.5)  | 2.7 (1.8-3.6)  | 2.3 (1.5-3.3) | 2.0 (1.2-3.6) | 1.8 (1.4-2.6) | <0.001  |
|                   | H     | T     | 5.1  | 3.1  | 2.7  | 1.4  | 1.7  | 0.001 |
|-------------------|-------|-------|------|------|------|------|------|-------|
|                   |       |       | (3.2-8.7) | (2.1-4.1) | (1.7-3.7) | (1.1-3.9) | (1.2-2.6) |       |
| P-value ctrl vs   | 0.92  | 0.99  | 0.99 | 0.99 | 0.99 | 0.99 |       |       |
| HT                |       |       |      |      |      |      |       |       |
| HbA1c, %          | 5.6   | 5.5   | 5.3  | 5.3  | 5.3  | 5.3  | < 0.001 |       |
|                   | (5.3-6.1) | (5.2-5.9) | (5.0-5.7) | (5.0-5.7) | (5.0-5.7) | (5.0-5.7) |       |       |
|                   | 5.7   | 5.5   | 5.4  | 5.3  | 5.3  | 5.3  | < 0.001 |       |
|                   | (5.3-6.4) | (5.2-6.0) | (5.1-5.7) | (5.0-5.7) | (5.0-5.7) | (5.0-5.6) |       |       |
| P-value ctrl vs   | 0.31  | 0.82  | 0.45 | 0.55 | 0.79 |       |       |       |
| HT                |       |       |      |      |      |       |       |       |
| ALT IU/l          | 36.0  | 35.6  | 22.5 | 19.3 | 20.0 | < 0.001 |       |       |
|                   | (24.9-55.2) | (24.0-47.7) | (17.0-32.6) | (13.3-25.9) | (15.8-26.4) |       |       |       |
|                   | 32.9  | 34.7  | 24.0 | 19.0 | 20.0 | < 0.001 |       |       |
|                   | (22.6-56.8) | (24.0-49.0) | (18.2-34.7) | (13.0-26.0) | (14.7-26.0) |       |       |       |
| P-value ctrl vs   | 0.68  | 0.88  | 0.14 | 0.83 | 0.65 |       |       |       |
| HT                |       |       |      |      |      |       |       |       |
| AST, IU/l         | 26.4  | 26.8  | 22.0 | 18.4 | 20.0 | < 0.001 |       |       |
|                   | (20.0-46.7) | (20.8-35.7) | (16.0-28.0) | (15.2-25.0) | (16.0-25.0) |       |       |       |
|                   | 25.5  | 27.0  | 22.0 | 20.0 | 20.4 | < 0.001 |       |       |
|                   | (19.0-40.0) | (21.0-36.7) | (17.9-30.5) | (16.2-24.9) | (16.2-25.1) |       |       |       |
| P-value ctrl vs   | 0.63  | 0.63  | 0.14 | 0.35 | 0.48 |       |       |       |
| HT                |       |       |      |      |      |       |       |       |
| Cholesterol, mg/dl| 212   | 171   | 176.5| 195  | 177  | < 0.001 |       |       |
|                   | (179-234.8) | (152-190) | (157-202.3) | (165.8-222) | (162-208) |       |       |       |
|       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|
| H     | HT    | 202   | (171-234) | 166.5 | (146-192.3) | 176   | (151-198) | 189   | (163-215) | 182.5 | (154.5-209.8) | < 0.001 |
|       |       | 0.47  | 0.50  | 0.17  | 0.47  | 0.87  |       |
| P-value |       |ctr    |       |       |       |       |       |
| vs HT |       |       |       |       |       |       |       |
| LDL,  | ctr   | 145   | (113-173) | 114   | (96-131.3) | 120   | (94-143.2) | 132.5 | (105-151) | 119   | (93.3-138.7) | < 0.001 |
| mg/dl |       | 0.25  | 0.47  | 0.28  | 0.18  | 0.63  |       |
|       |       | 137.7 | (109-170.5) | 106.5 | (91-135.5) | 115   | (93-134) | 123   | (100-151) | 120   | (101-145) | < 0.001 |
|       |       | 0.49  | 0.11  | 0.44  | 0.80  | 0.33  |       |
|       |       | 47    | (39-58) | 37    | (32-42) | 43    | (37-48) | 51    | (42-59.2) | 56    | (47-64.9) | < 0.001 |
| HDL,  | ctr   | 49    | (38-62.5) | 35    | (30-41.2) | 44    | (36-51) | 50.3  | (41-62.5) | 58.2  | (47.1-67) | < 0.001 |
| mg/dl |       | 0.49  | 0.11  | 0.44  | 0.80  | 0.33  |       |
|       |       | 157.5 | (114.3-202.8) | 131   | (101.5-165) | 122.5 | (92.7-147.8) | 98.5  | (77-145) | 96    | (74-126) | < 0.001 |
|       |       | 0.70  | 0.27  | 0.04  | 0.63  | 0.24  |       |
|       |       | 154.5 | (112-198.3) | 123   | (100.3-154) | 107   | (88-140) | 98    | (76.5-133) | 90    | (69-125) | < 0.001 |
| TG,   | ctr   | 107   | (88-140) | 98    | (76.5-133) | 90    | (69-125) |       |       |       |       |       |
| mg/dl |       | 0.70  | 0.27  | 0.04  | 0.63  | 0.24  |       |
|       | HT    | 157.5 | (114.3-202.8) | 131   | (101.5-165) | 122.5 | (92.7-147.8) | 98.5  | (77-145) | 96    | (74-126) | < 0.001 |
|       |       | 0.49  | 0.11  | 0.44  | 0.80  | 0.33  |       |
|       |       | 154.5 | (112-198.3) | 123   | (100.3-154) | 107   | (88-140) | 98    | (76.5-133) | 90    | (69-125) | < 0.001 |
|       |       | 0.70  | 0.27  | 0.04  | 0.63  | 0.24  |       |
For most variables measurements are presented as median and IQR due to non-Gaussian distribution. For parameter with normal distribution (LDL) values are expressed as mean (SD).

CRP, C-reactive protein; FPG, fasting plasma glucose; HOMA-IR, homeostatic model assessment of insulin resistance index; ALT, alanine transaminase; AST, aspartate transaminase; LDL, low-density lipoprotein; TG, triglyceride; HDL, high-density lipoprotein; HbA\textsubscript{1c}, glycated hemoglobin
Table 3. Repeated measures of weight loss effect after laparoscopic sleeve gastrectomy by groups

| Variables | Group | 0 N=305 | 1 month N=305 | 3 months N=285 | 6 months N=273 | 12 months N=278 | P-value |
|-----------|-------|---------|----------------|----------------|----------------|----------------|---------|
| BMI, kg/m² | ctr   | 44.9 (41.4-48.9) | 40 (37.1-44.4) | 35.7 (32.3-39.9) | 32.1 (29.1-36.1) | 30.1 (26.4-34.5) | <0.001 |
|           | HT    | 45.2 (41.5-49.9) | 40.8 (37.2-45.7) | 36.5 (33.5-41.4) | 34.5 (30.5-38.2) | 32.8 (28.5-35.8) | <0.001 |
| P-value ctr vs HT | 0.70 | 0.53 | 0.14 | 0.01 | 0.01 |
| %TWL      | ctr   | N/A | 10.6 (8.3-12) | 20 (16.9-23.1) | 27.9 (23.2-31.7) | 32.5 (28.1-37.7) | <0.001 |
|           | HT    | N/A | 9.5 (8-11.8) | 18.5 (16-20.8) | 25.3 (21.5-28.2) | 29.1 (25.9-33.6) | <0.001 |
| P-value ctr vs HT | 0.14 | | | < 0.001 | < 0.001 |
| %EWL      | ctr   | N/A | 19.8 (15.6-23.7) | 38.7 (31.2-46.1) | 54.2 (44.2-62.7) | 62.9 (53-74.6) | <0.001 |
|           | HT    | N/A | 18.4 (15.1-23.4) | 36 (28.8-42.7) | 48.7 (40.2-56.3) | 54.8 (47.4-68.2) | <0.001 |
| P-value ctr vs HT | 0.25 | | 0.02 | 0.001 | 0.001 |
| %EBMIL | ctr | N/A | 23.4 (18.1-28.6) | 46.1 (36.9-57.3) | 65.9 (50.2-75.5) | 73.9 (59.5-91.2) | <0.001 |
|-------|-----|-----|------------------|------------------|------------------|------------------|---------|
| HT    | N/A | 21.9 (17.6-27.7) | 41.7 (32.4-50.8) | 56.3 (44.4-68.0) | 63 (55.0-80.5) | <0.001 |
| P-value ctr vs HT | 0.17 | 0.02 | 0.002 | 0.002 |

Values are expressed as mean (SD) for %TWL and as median with IQR for BMI, %EWL and %EBMIL.

BMI, body mass index; %TWL, percentage of total weight loss; %EBMIL, percentage of excess BMI loss; %EWL, percentage of excess weight loss.

Table 4. Changes in hypertension status during the observation

| Blood pressure status | 0 | 1 month | 3 months | 6 months | 12 months | P-value |
|-----------------------|---|---------|----------|----------|-----------|---------|
| Hypertension          | 143 | 100 (69.9%) | 58 (40.6%) | 27 (18.9%) | 20 (14%) | p<0.001 |
| Partial remission     | N/A | 41 (28.7%) | 71 (49.7%) | 85 (59.4%) | 90 (63%) |
| Total remission       | N/A | 2 (1.4%) | 14 (9.8%) | 31 (21.7%) | 33 (23%) |

Number and % of patients regarding the blood pressure status during the follow-ups.
Figure 1. Distribution of hypertension among women and men before the surgery (A) and 12 months after the surgery (B)

Figure 2. Results of hypertension treatment according to percentage of total weight loss during 1 month (A), 3 months (B), 6 months (C) and 12 months (D) follow-up
Figure 3. Changes in hypertensive status (A) and therapy (B) during one-year follow-up.