Gender-related metabolic outcomes of laparoscopic sleeve gastrectomy in 6-month follow-up

Dawid Groth1,2, Paulina Woźniewska1, Magdalena Olszewska1, Piotr Zabielski3, Jerzy R. Ładny4, Jacek Dadan1, Anna Zalewska5, Agnieszka Błachnio-Zabielska6, Inna Diemieszczyk1, Adam Krętowski7, Hady Razak Hady6

11st Department of General and Endocrine Surgery, Medical University of Bialystok, Bialystok, Poland
2Department of Regenerative Medicine and Immune Regulation, Medical University of Bialystok, Bialystok, Poland
3Department of Medical Biology, Medical University of Bialystok, Bialystok, Poland
4Department of Emergency Medicine and Disasters, Medical University of Bialystok, Bialystok, Poland
5Department of Conservative Dentistry, Medical University of Bialystok, Bialystok, Poland
6Department of Hygiene, Epidemiology and Metabolic Disorders, Medical University of Bialystok, Bialystok, Poland
7Department of Endocrinology, Diabetology and Internal Medicine, Medical University of Bialystok, Bialystok, Poland

Abstract

Introduction: Laparoscopic sleeve gastrectomy (LSG) is recently a leading method in surgical treatment of morbid obesity. The metabolic outcome of intervention may be a result of many factors such as age, gender, preoperative weight loss and dietary restrictions.

Aim: To evaluate gender-related differences in the results of LSG in 6-month follow-up.

Material and methods: The study included 101 patients who underwent LSG at the University Clinical Hospital of Bialystok. Patients were divided and analyzed in 2 groups: males (n = 48) and females (n = 53). The primary analysis included the influence of gender on postoperative weight loss calculated using the percentage of excess weight loss (%EWL) and excess BMI loss (%EBMIL). For secondary outcomes the levels of glucose, insulin, glycated hemoglobin, aspartate transaminase, alanine transaminase, total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglycerides and C-reactive protein were analyzed.

Results: A significant influence of patients’ gender was proved for both %EWL (p = 0.026) and %EBMIL (p = 0.001). Females had significantly higher %EWL in 6-month follow-up than males (p = 0.0034). The analysis also showed significantly higher %EBMIL for women at 3 and 6 months observation (p = 0.022 and p < 0.001 respectively).

Conclusions: Laparoscopic sleeve gastrectomy is an effective method of obesity treatment especially in terms of postoperative weight loss. Females seem to benefit more from the procedure when analyzing the parameters of body mass reduction. However, further research is needed to provide strong evidence of an association between gender and the results of LSG.

Key words: obesity, laparoscopic sleeve gastrectomy, bariatric surgery.

Introduction

Metabolic/bariatric surgery has been developing intensely as a method of treating obesity and its systemic consequences. Among available surgical approaches, laparoscopic sleeve gastrectomy (LSG) is worth attention due to satisfactory body mass reduction and amelioration of co-morbidities. It is...
the most common bariatric procedure performed in Poland [1]. The final effect of treatment is a result of stomach volume reduction and, in consequence, restriction of food intake. Furthermore, recent research suggests that resection of the major part of a stomach (the fundus and body) leads to significant changes in gastrointestinal tract peristalsis, as well as neurohormonal and carbohydrate-fat balance [2–4]. Long-term metabolic effects depend on many factors and most of them are still unknown. The differences in outcomes of bariatric surgery may be the results of the patients’ gender, age, physical activity, preoperative weight loss and compliance with dietary recommendations. However, no clear conclusions regarding factors influencing the effect of LSG have been established.

Aim

The research has been conducted to evaluate gender-related differences in the results of laparoscopic sleeve gastrectomy in 6-month follow-up.

Material and methods

The study group included 101 patients who underwent surgery between January 2012 and December 2014. All patients provided written informed consent prior to the study and additional written informed consent was obtained before the surgical procedure. The study was approved by the Ethics Committee of the Medical University of Bialystok, Poland (No. R-I-002/438/2014) in accordance with the guidelines of the Helsinki Declaration and its later amendments.

Inclusion criteria for the surgical procedure were failure of weight loss after conservative treatment, body mass index (BMI) \( \geq \) 40.0 kg/m\(^2\) or \( \geq \) 35.0 kg/m\(^2\) with the presence of obesity-related co-morbidities, no alcohol or drug abuse as well as no active psychosis. All qualified patients underwent laparoscopic sleeve gastrectomy performed by the same operating team – the operator and 2 assistants. The procedure included dissection of the major curvature that started 2 or 6 cm from the pylorus and continued toward the left crus of diaphragm. 32 Fr or 40 Fr calibrating tubes were used to control the diameter of the remaining stomach. As the final step the leak test was performed using a 5% glucose solution and air.

The primary endpoint of the study was the influence of patient’s gender on postoperative weight loss. Secondary outcomes were differences in laboratory test results observed in the postoperative period with regard to patient’s gender. Patients were divided and analyzed in two groups: males vs. females.

Data were collected before the surgery, as well as 1, 3 and 6 months postoperatively. The measurements included body mass, BMI, fasting glucose and insulin concentrations, glycated hemoglobin level (HbA\(_{1c}\)), alanine aminotransferase (ALT), aspartate aminotransferase (AST), total cholesterol and its fractions, triglycerides, and C-reactive protein (CRP).

The calculation of the percentage of excess weight loss (%EWL), the percentage of excess BMI loss (%EBMIL) and the homeostatic model assessment of insulin resistance index (HOMA-IR) was performed using the following formulas:

1) \( %\text{EWL} = (\text{body mass before the surgery} – \text{body mass during follow-up})/\text{(body mass before the surgery} – \text{ideal body mass}) \times 100. \)

2) \( %\text{EBMIL} = (\text{BMI before the surgery} – \text{BMI during follow-up})/(\text{BMI before the surgery} – 25) \times 100. \)

3) \( \text{HOMA-IR} = \text{glucose level (mg/dl)} \times \text{insulin concentration (mU/l)}/405; \text{result} > 2.6 \text{confirmed insulin resistance}. \)

Statistical analysis

Data analysis was conducted using Statistica v13.5 (StatSoft Inc., Tulsa, Oklahoma, USA). Continuous variables with normal distribution are presented as mean, standard deviation (SD) and 95% confidence interval (95% CI). Skewed variables are presented as median with inter-quartile range (IQR). Student’s \( t \) test was used to compare continuous variables between groups or the Mann-Whitney test for skewed ones. Dichotomous variables were analyzed with Pearson’s \( \chi^2 \) test. For repetitive observations, the repetitive measurements ANOVA with post-hoc Tukey’s test was used. In the case of skewed variables, Friedman’s ANOVA with its post-hoc test was used. A \( p \)-value of \( < 0.05 \) was considered to be statistically significant.
Results

Material

The cohort included 101 patients with the average age of 43 years. Women accounted for 52% of the cohort (n = 53), men for 48% (n = 48). The characteristics of the groups are presented in Table I. Patients reported a number of co-morbidities preoperatively, of which the most common were: type 2 diabetes (6 women – 11%, 11 men – 23%), depression (14 women – 26%, 7 men – 15%), hypertension (13 women – 25%, 12 men – 25%) and dyslipidemia (5 women – 9%, 7 men – 15%).

Preoperative differences

As presented in Table I, age did not differ between males and females. Males had significantly higher body mass and BMI. Operative technique distribution was comparable between groups in Pearson’s χ² test. Males presented with significantly higher glucose and insulin level; therefore also HOMA-IR was higher in male patients. Median triglycerides, ALT and AST were also significantly higher in male patients (Table I).

Primary outcome

The influence of patient’s gender and operative technique was examined in repetitive measurements ANOVA of %EWL and %EBMIL, as presented in Table II. Main effects of repetitive measures ANOVA showed significant changes between measures both for %EWL (p < 0.001) and %EBMIL (p < 0.001), as well as a significant influence of patient’s gender on it (for %EWL p = 0.026, and for %EBMIL p = 0.001).

Table I. Characteristics of group differences at the time of LSG

| Parameter                        | Females       | Males        | P-value |
|----------------------------------|---------------|--------------|---------|
| N (%)                            | 53 (52%)      | 48 (48%)     | n/a     |
| Age, mean ± SD [years]           | 40.8 ± 11.24  | 43.48 ± 10.16| 0.216   |
| Body weight, mean ± SD [kg]      | 124.70 ± 17.94| 155.48 ± 24.86| < 0.001 |
| BMI, mean ± SD [kg/m²]           | 45.75 ± 7.16  | 50.05 ± 7.75 | 0.005   |
| Operative technique, n (%)       |               |              | 0.387   |
| 2 cm and 32 Fr                   | 14 (26%)      | 12 (25%)     |         |
| 2 cm and 40 Fr                   | 9 (17%)       | 15 (31%)     |         |
| 6 cm and 32 Fr                   | 15 (28%)      | 11 (23%)     |         |
| 6 cm and 40 Fr                   | 15 (28%)      | 10 (21%)     |         |
| Insulin, median (IQR) [µU/dl]    | 16.80 (12.70–26.40) | 23.10 (16.00–41.30) | 0.007   |
| Glucose, median (IQR) [IU/l]     | 102.00 (95.00–108.00) | 112.00 (99.00–130.50) | 0.002   |
| HOMA-IR, median (IQR)            | 4.10 (3.11–6.58) | 6.49 (3.99–12.81) | 0.001   |
| CRP, median (IQR) [mg/l]         | 6.40 (3.60–9.30) | 7.92 (4.10–13.20) | 0.535   |
| HbA₁c, median (IQR) [mg/dl]      | 5.60 (5.40–5.90) | 5.80 (5.40–6.13) | 0.285   |
| Cholesterol, mean ± SD [mg/dl]   | 203.89 ± 34.42 | 203.40 ± 37.55 | 0.540   |
| LDL, mean ± SD [mg/dl]           | 138.60 ± 34.25 | 138.5 ± 36.11 | 0.708   |
| HDL, median (IQR) [mg/dl]        | 45.00 (38.00–54.00) | 43.00 (36.50–50.50) | 0.081   |
| Triglycerides, median (IQR) [mg/dl] | 126.00 (101.00–191.00) | 165.50 (136.50–207.00) | 0.021   |
| ALT, median (IQR) [IU/l]         | 25.00 (20.00–33.00) | 35.00 (29.50–46.00) | 0.001   |
| AST, median (IQR) [IU/l]         | 22.00 (19.00–28.00) | 27.50 (20.50–41.00) | 0.013   |

ALT – alanine transaminase, AST – aspartate transaminase, BMI – body mass index, CRP – C-reactive protein, HbA₁c – glycated hemoglobin, HDL – high-density lipoprotein, HOMA-IR – Homeostatic Model Assessment of Insulin Resistance Index, LDL – low-density lipoprotein.
Gender-related metabolic outcomes of laparoscopic sleeve gastrectomy in 6-month follow-up

Furthermore, post-hoc Tukey’s test was conducted. %EWL in 1 month and 3 months did not differ significantly between males and females ($p = 0.904$ and $p = 0.335$ respectively). Females had significantly higher %EWL after 6 months ($p = 0.034$). Means of %EWL with 95%CI are presented in Figure 1. %EBMIL did not differ between males and females at 1 month ($p = 0.572$). Females had significantly higher %EBMIL at 3 months and 6 months than males ($p = 0.022$ and $p < 0.001$ respectively). Operative technique did not change %EWL with significantly regard to patients’ gender as a predicting factor ($p = 0.678$). The same was for %EBMIL ($p = 0.728$) (Figure 2).

Secondary outcomes

The analysis of carbohydrate profile showed a statistically significant decrease in glucose level in both men and women (median value after 6 months: female – 90 mg/dl, male – 93.00 mg/dl; $p = 0.001$). Among all analyzed additional parameters, the insulin and glucose levels showed statistically significant changes between men and women ($p = 0.031$ and $p = 0.012$ respectively). The assessment of lipid profile indicated statistically significant decreases in total cholesterol ($p < 0.001$), tri-glycerides ($p < 0.001$), and LDL ($p = 0.05$) and an increase in HDL level ($p < 0.01$). The total results of repetitive measurements of selected laboratory tests are presented in Table III.

Discussion

Due to the fact that obesity is not only a metabolic but also a social and economic issue, the world of medicine has been intensively looking for the best methods to cope with this problem [5]. Worldwide studies have repeatedly proven that bariatric surgery is the most effective treatment of morbid obesity and its co-morbidities in both short- and long-term observations. Implementation of bariatric procedures allows surgeons to achieve satisfactory weight loss and improvement in insulin, glucose and lipid metabolism [6].

| Gender | %EWL 1 month | %EWL 3 months | %EWL 6 months | P-value |
|--------|--------------|---------------|---------------|---------|
| Females | 21.14 ±7.78 | 38.64 ±10.84 | 56.32 ±15.93 | 0.026   |
| Males   | 18.61 ±7.19 | 33.76 ±12.06 | 49.09 ±16.25 |         |

| Gender | %EBMIL 1 month | %EBMIL 3 months | %EBMIL 6 months | P-value |
|--------|---------------|-----------------|-----------------|---------|
| Females | 25.80 ±11.24 | 47.17 ±15.62 | 68.73 ±22.98 | 0.001   |
| Males   | 20.64 ±8.26  | 37.33 ±13.47 | 54.30 ±18.22 |         |

%EBMIL – percentage of excess BMI loss, %EWL – percentage of excess weight loss.

![Figure 1](image1.png)  
**Figure 1.** Means %EWL with 95%CI in follow-up

![Figure 2](image2.png)  
**Figure 2.** Means %EBMIL with 95%CI in follow-up
Table III. Repetitive measurements of selected laboratory test results

| Parameter                        | Gender | 0       | 1 month | 3 months | 6 months | P of rep. measures | P of F vs. M |
|----------------------------------|--------|---------|---------|----------|----------|--------------------|--------------|
| Insulin, median (IQR) [µU/dL]    | Female | 16.80 (12.70–26.40) | 9.00 (7.00–14.40) | 7.60 (6.10–11.90) | 6.30 (5.10–9.40) | < 0.001 | 0.031 |
|                                  | Male   | 23.10 (16.00–41.30) | 10.85 (8.15–20.30) | 10.10 (7.40–14.50) | 7.25 (5.60–13.90) | < 0.001 | 0.012 |
| Glucose, median (IQR) [mg/dL]    | Female | 102.00 (95.00–108.00) | 93.00 (88.00–100.00) | 90.00 (85.00–98.00) | 90.00 (87.00–96.00) | < 0.001 | 0.012 |
|                                  | Male   | 112.00 (99.00–130.50) | 100.50 (91–112.50) | 99.00 (89.50–105.5) | 93.00 (88.00–100.0) | < 0.001 | 0.012 |
| HOMA-IR, median (IQR)            | Female | 4.10 (3.11–6.58) | 2.11 (1.56–3.30) | 1.66 (1.36–2.52) | 1.35 (1.11–2.02) | < 0.001 | 0.001 |
|                                  | Male   | 6.49 (3.99–12.81) | 3.02 (2.01–5.26) | 2.52 (1.61–3.71) | 1.63 (1.22–3.38) | < 0.001 | 0.001 |
| CRP, median (IQR) [mg/l]         | Female | 6.40 (3.60–9.30) | 5.50 (5.30–5.80) | 4.60 (3.50–9.20) | 4.70 (2.60–8.70) | 0.382 | 0.534 |
|                                  | Male   | 7.92 (4.10–13.20) | 7.15 (3.75–11.90) | 5.95 (4.40–9.90) | 5.05 (3.68–8.14) | 0.382 | 0.534 |
| HbA1c, median (IQR) %            | Female | 5.60 (5.40–5.90) | 5.50 (5.30–5.80) | 5.40 (5.20–5.70) | 5.20 (5.10–5.60) | < 0.001 | 0.499 |
|                                  | Male   | 5.80 (5.40–6.13) | 5.60 (5.25–5.90) | 5.50 (5.20–5.70) | 5.40 (5.10–5.60) | < 0.001 | 0.499 |
| Cholesterol, mean ± SD [mg/dL]   | Female | 203.89 ±34.42 | 184.00 ±35.7 | 186.83 ±29.36 | 190.15 ±31.55 | < 0.001 | 0.982 |
|                                  | Male   | 203.40 ±37.55 | 181.71 ±29.34 | 186.35 ±31.07 | 187.75 ±33.57 | < 0.001 | 0.982 |
| LDL, mean ± SD [mg/dL]           | Female | 138.60 ±34.25 | 128.64 ±38.16 | 131.21 ±31.60 | 132.62 ±31.16 | < 0.001 | 0.784 |
|                                  | Male   | 138.5 ±36.11 | 128.69 ±31.55 | 133.18 ±30.33 | 137.73 ±29.18 | < 0.001 | 0.683 |
| HDL, median (IQR) [mg/dL]        | Female | 45.00 (38.00–54.00) | 40.00 (34.00–48.00) | 48.00 (39.00–52.00) | 51.00 (44.00–58.00) | < 0.001 | 0.683 |
|                                  | Male   | 43.00 (36.50–50.50) | 34.00 (29.00–47.00) | 46.00 (38.00–54.00) | 51.5 (41.50–62.00) | < 0.001 | 0.417 |
| Triglycerides, median (IQR) [mg/dL] | Female | 126.00 (101.00–191.00) | 134.00 (108.00–172.00) | 123.00 (99.00–156.00) | 122.00 (93.00–145.00) | < 0.001 | 0.417 |
|                                  | Male   | 165.50 (136.50–207.00) | 159.5 (119.00–196.50) | 147.00 (116.00–185.00) | 144.00 (92.50–166.50) | < 0.001 | 0.417 |
| ALT, median (IQR) [IU/l]         | Female | 25.00 (20.00–33.00) | 29.00 (20.00–39.00) | 20.00 (16.00–31.00) | 18.00 (13.00–21.00) | < 0.001 | 0.194 |
|                                  | Male   | 35.00 (29.50–46.00) | 35.50 (26.00–56.50) | 24.50 (21.00–34.50) | 21.00 (17.00–26.00) | < 0.001 | 0.194 |
| AST, median (IQR) [IU/l]         | Female | 22.00 (19.00–28.00) | 26.00 (18.00–36.00) | 21.00 (17.00–26.00) | 16.00 (13.00–22.00) | < 0.001 | 0.840 |
|                                  | Male   | 27.50 (20.50–41.00) | 30.50 (21.50–43.00) | 25.00 (20.00–30.00) | 19.00 (15.00–27.00) | < 0.001 | 0.840 |

ALT – alanine transaminase, AST – aspartate transaminase, BMI – body mass index, CRP – C-reactive protein, F – females, HbA1c – glycated hemoglobin, HDL – high-density lipoprotein, HOMA-IR – Homeostatic Model Assessment of Insulin Resistance Index, LDL – low-density lipoprotein.
The research examined metabolic differences after LSG according to the patients’ gender.

Postoperative dynamics of body mass reduction and BMI changes over the examined period were calculated using the %EWL and %EBMIL indicators. Significant weight loss calculated by %EWL and decrease in BMI estimated by %EBMIL were recorded in both groups during the observation period. Females had significantly higher %EWL and %EBMIL at 6 months postoperatively than males. Perrone et al. described better outcomes in terms of %EBMIL in males than in females after LSG in 5-year follow-up, which is opposite to our results. However, we observed our patients for a shorter time and the male group had a higher BMI preoperatively [7]. Study conducted by Binda et al. showed that lower age and preoperative weight loss are conducive to achieving higher %EWL, but no differences between genders have been found to be essential for the results [8].

A study published by Yuval et al. compared the dynamics of changes in body mass of patients after sleeve gastrectomy with the division into two groups depending on the size of the calibrating tube (< 40 Fr vs. ≥ 40 Fr) and found no statistically significant difference in %EWL [9]. Unsatisfactory body mass loss frequently forces surgeons to convert the surgical technique to more restrictive one [10]. However, there is a lack of clear proof in the worldwide literature for the statement that application of a smaller calibrating tube is associated with higher body mass. Regardless of the technique of LSG, lifestyle changes and following doctor’s recommendations result in satisfactory weight loss. Lombardo et al. proved that the weight regain rate was lower in patients who more frequently participated in follow-up visits [11]. According to the study conducted by Stroh et al., men present with higher incidence of co-morbidities such as type 2 diabetes, hypertension and dyslipidemia, which subsequently reduces the rate of postoperative amelioration [12]. In our study, we observed higher incidence of type 2 diabetes and dyslipidemia in males.

Alignment of disorders of carbohydrate metabolism coexisting with obesity after sleeve gastrectomy is mainly related to the reduction of body weight [13]. However, it has been proved that the improvement of the glycemic profile, insulin concentration or the level of glycated hemoglobin is observed before significant changes in weight and body composition. In our study, the dynamics of changes in insulin levels and HOMA-IR were examined, useful in the assessment of insulin resistance of peripheral tissues and the function of pancreatic beta cells. In our study, the largest decrease in insulin level was noted after the first month of observation (16.80 µU/dl to 9.00 µU/dl in women and 23.10 µU/dl vs. 10.85 µU/dl in men). The assessment of HOMA-IR between males and females showed normalization (values < 2.6) 6 months postoperatively, reaching a median of 1.35 for females and 1.63 for males. Rizello et al. observed a significant decrease of insulin resistance in some patients after sleeve gastrectomy 3 days after the surgery [14]. Thus, 15 days after the surgery in all patients glucose and insulin concentrations in serum as well as HOMA-IR significantly decreased before the occurrence of changes in body mass. Similar results were obtained by Catoi et al., who described a similar decreasing tendency in insulin concentration and HOMA-IR 7 days postoperatively. In their study, statistical significance was reached 30 days after the surgery [15]. Sharma et al. described a case of a 49-year-old obese patient (BMI 59 kg/m²) who had shown a fast (14 days after the surgery) decrease of insulin concentration, from the initial value of 49.5 µU/ml to 16.5 µU/ml. What is more, HOMA-IR was 4.6 after 14 days (initial value 8.82) and after 7 months it normalized to 2.4 [16].

Improvement of carbohydrate profile after sleeve gastrectomy is strictly connected with body mass reduction and changes in volume of fat tissue. However, recent studies prove that amelioration occurs in the early postoperative period. The explanation of this mechanism is probably connected with neuro-hormonal balance of the gastrointestinal tract. Resection of the majority of the stomach is connected with removal of cells producing ghrelin, which occur mostly in the fundus. According to different publications, the concentration of this hormone decreases after the surgery by 40–50% in comparison to the initial value [17–19]. Research conducted by Dardzinska et al., who compared the pre- and post-prandial changes in both isoforms of ghrelin in obese patients showed that sleeve gastrectomy leads to a decrease in des-acyl ghrelin levels [20]. In consequence, it reduces appetite and glucose concentration in serum, increases secretion of insulin and lowers insulin resistance. A further mechanism explaining the process of carbohydrate metabolism improvement is regulation of incretin hormones. The influence of bariatric surgery on normalization of
Glycemia probably explains the hindgut hypothesis, which is connected with accelerated contact of food with the distal part of the small bowel and as a result increases secretion of glucagon-like peptide-1 (GLP-1) and peptide YY (PYY).

It is believed that sleeve gastrectomy is associated with accelerated stomach emptying from undigested food and its fast passage through the duodenum and initial part of the small intestine [21, 22]. Moreover, after the surgery, decreased secretion of hydrochloric acid is observed, which directly stimulates secretion of PYY as well as the peptide releasing gastrin and as a consequence release of GLP-1 [23]. Karamanakos et al. reported that after sleeve gastrectomy both fasting and postprandial concentration of PYY increases significantly and ghrelin concentration decreases [19]. Basso et al. observed increases of GLP-1 and PYY in the early postoperative period, which is similar to the results of Peterli et al. [24, 25]. Increase of PYY and GLP-1 concentration is responsible for reduction of appetite and, most importantly, decrease of glucose, restoration of insulin sensitivity, glucagon secretion inhibition and as a consequence inhibition of hepatic gluconeogenesis, which beneficially influences parameters of carbohydrate balance until a body mass reduction occurs. Wroblewski et al. observed that weight loss rather than type of procedure is mostly responsible for hormonal variation in obese patients and indicates the leptin level as the best indicator of body mass changes [26].

Research has shown that even in 60% of patients, obesity is connected with steatosis, including 55% of the pediatric population [27–30]. Despite routine abdominal ultrasonography, which according to different authors has low sensitivity and specificity in recognition of liver steatosis, measures of aminotransferases activity have been performed in all patients [31].

In our study group, changes regarding lipid metabolism included increase of HDL and decrease of total cholesterol, LDL and triglycerides 6 months postoperatively. The increase of HDL cholesterol level has also been proved in the studies of Zhang et al. [32] and Wong et al. [33]. However, there is no relationship between cholesterol increase and changes in body weight.

It is now assumed that fat tissue is responsible for homeostasis of the human organism and it is an important metabolic organ. Furthermore, in the occurrence of insulin resistance, fat tissue macrophages play a significant role and are the source of pro- and anti-inflammatory cytokines. A strong correlation was demonstrated in obese patients between C-reactive protein concentration in serum and BMI, and furthermore, body mass loss causes CRP decrease [33–35]. Moreover, a rapid increase of CRP in the early postoperative period is a marker of complications after LSG [36]. In our examined group, the concentration of CRP did not exceed laboratory norms in any observation period.

The limitation of our study was selection bias. Patients were not matched with respect to baseline body mass and BMI, which were significantly higher in males. The distribution of coexisting diseases was also not comparable. Males were diagnosed with type 2 diabetes in 11 (23%) cases, and females in 6 (11%) cases, whereas dyslipidemia occurred in 5 (9%) women and 7 (15%) men. These differences may affect weight loss outcome and changes in metabolic profile parameters after LSG.

Conclusions

Essential changes of %EWL and %EBMIL as well as the influence of patients’ gender on the postoperative weight loss parameters were observed in the study. According to our research, obese females benefit more after LSG than obese males in the terms of postoperative body mass reduction. The study reveals that patients’ gender may be a predictor for LSG outcomes. However, further research with a larger group and better patients’ selection is needed to provide strong evidence of an association between gender and results of laparoscopic sleeve gastrectomy.

Acknowledgments

The study was funded by the Medical University of Białystok, Poland, Grant No. N/ST/ZB/15/003/1140. Special thanks to Michał Wysocki, MD for performing statistical analysis.

Conflict of interest

The authors declare no conflict of interest.

References

1. Janik MR, Stanowski E, Paśnik K. Present status of bariatric surgery in Poland. Videosurgery Miniinv 2016; 11: 22-5.
2. Gaur A, Naidu CS, Rao PP, et al. The effect of laparoscopic sleeve gastrectomy on glycemic control in morbidly obese patients. Int J Surg 2016; 28: 131-5.

3. Hady HR, Dadan J, Gołaszewski P, et al. Impact of laparoscopic sleeve gastrectomy on body mass index, ghrelin, insulin and lipid levels in 100 obese patients. Videosurgery Miniinv 2012; 7: 251-9.

4. Hady HR, Dadan J, Luba M. The influence of laparoscopic sleeve gastrectomy on metabolic syndrome parameters in obese patients in own material. Obes Surg 2012; 22: 13-22.

5. Hady HR, Zbucki R, Luba M, et al. Obesity as a social disease and the influence of environmental factors on BMI in own material. Adv Clin Exp Med 2010; 19: 368-78.

6. Jastrzebska-Mierzynska M, Ostrowska L, Hady HR, et al. The impact of bariatric surgery on nutritional status of patients. Videosurgery Miniinv 2015; 10: 115-24.

7. Perrone F, Bianciardi E, Benavoli D, et al. Gender influence on long-term weight loss and comorbidities after laparoscopic sleeve gastrectomy and Roux-en-Y gastric bypass: a prospective study with a 5-year follow-up. Obes Surg 2016; 26: 276-81.

8. Binda A, Jaworowski P, Kudlicka E, et al. The impact of selected factors on parameters of weight loss after sleeve gastrectomy. Videosurgery Miniinv 2016; 11: 288-94.

9. Yuval JB, Mintz Y, Cohen MJ, et al. The effect of bougie caliber on leaks and excess weight loss following laparoscopic sleeve gastrectomy. Is there an ideal bougie size? Obes Surg 2013; 23: 1685-91.

10. Weiner RA, Weiner S, Pomboff I, et al. Laparoscopic sleeve gastrectomy – influence of sleeve size and resected gastric volume. Obes Surg 2007; 17: 1297-305.

11. Lombardo M, Bellia A, Mattiuzzo F, et al. Frequent follow – up visits reduce weight regain in long – term management after bariatric surgery. Bariatric Surg Pract Patient Care 2015; 10: 119-25.

12. Stroh C, Groh C, Weiner R, et al. Are there gender-specific aspects of gastric banding? Data analysis from the Quality Assurance Study of the Surgical Treatment of Obesity in Germany. Obes Surg 2013; 23: 1783-9.

13. Al Khalifa K, Al Ansari A, Showaiter M. Weight loss and glycemic control after sleeve gastrectomy: results from a middle eastern center of excellence. Am Surg 2018; 84: 238-43.

14. Rizzello M, Abbattini F, Casella G, et al. Early postoperative insulin-resistance changes after sleeve gastrectomy. Obes Surg 2010; 20: 50-5.

15. Catoi AF, Parvu A, Mironiac A, et al. Effects of sleeve gastrectomy on insulin resistance. Clujul Med 2016; 89: 267-72.

16. Sharma R, Hassan C, Chabian JT. Severe insulin resistance improves immediately after sleeve gastrectomy. J Investig Med High Impact Case Rep 2016; 4: 2324709615625309.

17. Hady HR, Gołaszewski P, Zbucki RL, et al. The influence of laparoscopic adjustable gastric banding and laparoscopic sleeve gastrectomy on weight loss, plasma ghrelin, insulin, glucose and lipids. Folia Histochem Cytobiol 2012; 50: 292-303.

18. Peterl R, Steiner R, Woelmerhanssen B, et al. Metabolic and hormonal changes after laparoscopic Roux-en-Y gastric bypass and sleeve gastrectomy: a randomized, prospective trial. Obes Surg 2012; 22: 740-8.

19. Karamanakos SN, Vagenas K, Kalfarentzos F, et al. Weight loss, appetite suppression and changes in fasting and postprandial ghrelin and peptide-YY levels after Roux-en-Y gastric bypass and sleeve gastrectomy: a prospective, double blind study. Ann Surg 2008; 247: 401-7.

20. Dardzinska JA, Kaska I, Proczko-Stepaniak M, et al. Fasting and postprandial acyl and desacyl ghrelin and the acyl/desacyl ratio in obese patients before and after different types of bariatric surgery. Videosurgery Miniinv 2018; 13: 366-75.

21. Rubino F. Is type 2 diabetes an operable intestinal disease? A provocative yet reasonable hypothesis. Diabetes Care 2008; 31 Suppl 2: S290-6.

22. Scott WR, Batterham RL. Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy: understanding weight loss and improvements in type 2 diabetes after bariatric surgery. Am J Physiol Regul Integr Comp Physiol 2011; 301: R15-27.

23. Vigneshwaran B, Wahal A, Aggarwal S, et al. Impact of sleeve gastrectomy on type 2 diabetes mellitus, gastric emptying time, glucagon-like peptide 1 (GLP-1), ghrelin and leptin in non-morbidly obese subjects with BMI 30-35 kg/m2: a prospective study. Obes Surg 2016; 26: 2817-23.

24. Basso N, Capoccia D, Rizzello M, et al. First-phase insulin secretion, insulin sensitivity, ghrelin, GLP-1 and PYY changes after 72h after sleeve gastrectomy in obese diabetes patients: the gastric hypothesis. Surg Endosc 2011; 25: 3540-50.

25. Peterl R, Woelmerhanssen B, Peters T, et al. Improvement in glucose metabolism after bariatric surgery comparison of laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy: a randomized, prospective trial. Ann Surg 2009; 250: 234-41.

26. Wróblewski E, Swidnicka-Siergiejko A, Hady HR, et al. Variation in blood levels of hormones in obese patients following weight reduction induced by endoscopic and surgical bariatric therapies. Cytokine 2016; 77: 56-62.

27. Neelend I, Turer AT, Ayers CR, et al. Dysfunctional adiposity and the risk of prediabetes and type 2 diabetes in obese adults. JAMA 2012; 308: 1150-9.

28. Almazedi S, Al-Sabah S, Alshammari D. Routine trans-abdominal ultrasonography (US) prior to laparoscopic Roux-en-Y gastric bypass (LRYGBP) an laparoscopic sleeve gastrectomy: a learning curve? Obes Surg 2012; 22: 416-21.

29. Adibi A, Kelishadi R, Beihagi A, et al. Sonographic fatty liver in the first 100 operations. Was it beneficial and reliable during the learning curve? Obes Surg 2012; 22: 416-21.

30. Vajro P, Lenta S, Socha P, et al. Diagnosis of nonalcoholic fatty liver disease in children and adolescents: position paper of the ESPGHAN Hepatology Committee. J Pediatr Gastroenterol Nutr 2012; 54: 700-13.

31. Jaser N, Mustonen H, Pietila J, et al. Preoperative transabdominal ultrasonography (US) prior to laparoscopic Roux-en-Y gastric bypass (LRYGBP) an laparoscopic sleeve gastrectomy (LSG) in the first 100 operations. Was it beneficial and reliable during the learning curve? Obes Surg 2012; 22: 416-21.

32. Zhang F, Stain GW, Lei W, et al. Changes in lipid profiles in morbidly obese patients laparoscopic sleeve gastrectomy. Obes Surg 2011; 21: 305-9.

33. Wong ATY, Chan DC, Armstrong J, et al. Effect of laparoscopic sleeve gastrectomy on elevated C-reactive protein and athero-
genic dyslipidemia in morbidly obese patients. Clin Biochem 2011; 44: 342-4.
34. Pardina E, Ferrer R, Baena-Fustegeras JA, et al. Only C-reactive protein but not TNF-alpha or IL-6, reflects the improvement in inflammation after bariatric surgery. Obes Surg 2012; 22: 131-9.
35. Frohlich M, Imhof A, Berg G, et al. Association between C-reactive protein and features of the metabolic syndrome: a population-based study. Diabetes Care 2000; 23: 1835-9.
36. Frask A, Orlowski M, Dowgiallo-Wnukiewicz N, et al. Clinical evaluation of C-reactive protein and procalcitonin for the early detection of postoperative complications after laparoscopic sleeve gastrectomy. Videosurgery Miniinv 2017; 12: 160-5.

Received: 22.01.2019, accepted: 26.05.2019.