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What does the volume of stomach resected during Laparoscopic Sleeve Gastrectomy depend on and what impact does it have on postoperative results?

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ABSTRACT

Introduction: Obesity is a chronic, multifactorial disease and its extent is equal to pandemics. Sleeve gastrectomy is one of the methods of obesity treatment. Constantly, research is conducted on factors influencing postoperative bariatric-metabolic results. In this study, a correlation between the volume of stomach resected during LSG with preoperative anthropometric measurements and its influence on postoperative results was analysed.

Material and methods: The study included 196 patients who qualified and were subjected to laparoscopic sleeve gastrectomy in the study Centre. Surgery was conducted by the same surgical team according to standard procedure. The volume of the stomach resected was analysed, filling it with CO_2 under the pressure of 15 mm Hg. The influence of the volume of stomach resected on bariatric efficiency as well as parameters of lipid and carbohydrate profile results in a 1-year follow-up was analysed.

Results: The statistically significant connection between the volume of the stomach resected with preoperative body mass, height and body surface was proved. A correlation between BMI and stomach volume was not found. The volume of stomach resected did not influence body mass loss in a 1-year follow-up. The influence of the volume of the stomach resected on the percentage of glycated haemoglobin and HDL was proved. A significant decrease in body mass and BMI in a 1-year follow-up, as well as an improvement in lipid and carbohydrate balance, was observed.

Conclusions: LSG is an efficient method of obesity treatment and for the improvement of biochemical parameters. The volume of stomach resected correlates with preoperative measurements of body mass, height and body surface, but not BMI. There is a lack of correlation between the volume of stomach resected with postoperative body mass loss results.

Key words: obesity, laparoscopic sleeve gastrectomy, the volume of the stomach

Introduction

Global development in all areas of life led to the development of obesity which became a serious issue of public health. Currently, the constantly increasing percentage of obese patients causes progress in clinical studies conducted in order to understand the multifactorial, complex background of obesity including social, psychological and genetic aspects. Obesity is a chronic disease which should be prevented and efficiently treated in interdisciplinary teams due to its influence on many aspects of life and human health [1, 2]. Data from World Obesity Federation included in The World Obesity Atlas 2022 predict million obese patients in 2030 [3].

Obesity coexists with many other disease units, among others, metabolic syndrome, cardiovascular diseases, type 2 diabetes, insulin resistance, dyslipidaemia, depression, joint degeneration, and particular

types of cancers. It also influences a higher rate of mortality in comparison to the population without overweight and obesity [4]. The scale of global obesity pandemics prompts the search for durable, safe and efficient methods of obesity treatment. All preservative methods of obesity and its co-morbidities treatment are less efficient and do not bring long-term effects that is why metabolic-bariatric surgery is considered to be the most efficient and safe method of morbid obesity treatment, and the number of procedures is growing annually [5].

Many surgical methods were developed, among which, laparoscopic sleeve gastrectomy (LSG) is the most frequently used — in 2016 it constituted 53.6% of all bariatric-metabolic procedures [6]. Laparoscopic sleeve gastrectomy gained popularity due to satisfactory postoperative results and its safety [7]. It involves the resection of three-quarters of stomach volume from the greater curvature of the stomach. Reduction of food intake is a result of many factors: decrease of stomach volume, neuromodulation and changes in hormone secretion responsible for the appetite as well as changes in intestines microflora [8].

The aim of the study was determination whether the volume of the resected part of the stomach correlates with preoperative measurements of the patient and its influence on postoperative results in a 1-year follow-up.

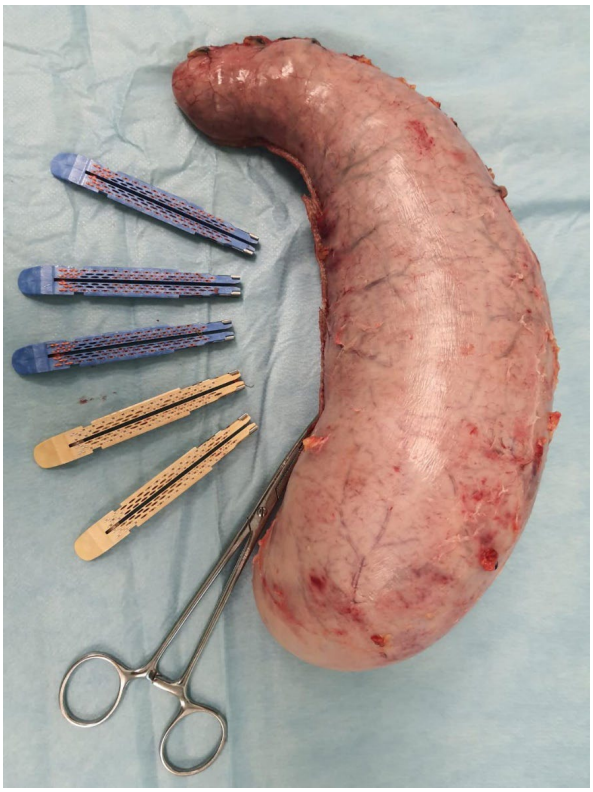

Figure 1. Resected stomach after inflation with CO_2

Material and methods

The study group consisted of 196 patients qualified and operated on due to obesity using laparoscopic sleeve gastrectomy in the study Department between 2016 and 2020 with the data gathered during a 1-year follow-up. The study included 107 men (54.6%) and 89 women (45.4%). The average age of patients in the study group was 44.9 years — the youngest patient was 21 and the eldest was 66 years old. The median BMI value on the day of operation was 47.7 kg/m^2.

Demographic and biometric data from the study group were gathered prospectively on the day of operation and during ambulatory postoperative visits, patients reported 1 month, 3 months, 6 months and 1 year after LSG. During control visits, blood samples were taken to analyse chosen laboratory and biochemical parameters. Body mass and bariatric treatment efficiency parameters calculated on its basis were assessed including BMI, %EWL, %EBL, and %TWL as well as parameters of lipid and carbohydrate balance within 1, 3, 6, and 12 months after the LSG.

Laparoscopic sleeve gastrectomy was performed by the same surgical team in a standardized way in order to minimize mistakes connected with the operative technique. Laparoscopic sleeve gastrectomy was performed with a 36F diameter tube by linear 60 mm stapler, starting 6 cm from the pylorus.

In this study, an innovative method was introduced for measuring the volume of the resected stomach during sleeve gastrectomy. The volume of the resected part of the stomach was measured in the same way in all cases. Directly after the surgery of removing the stomach from the peritoneal cavity, after the introduction of the Veres needle to the stomach lumen, the stomach was inflated with CO_2 under the pressure of 15 mm Hg using an Olympus insufflator. This is a previously undescribed method, which may be a limitation of the study. Figure 1 presents resected stomach after inflation with CO_2.

Data were analysed using STATA 13.0 software. Values of variables under statistical analysis were given as means with standard deviations. Statistical comparison of measurable variables was conducted with repeatable measurements in the Wilcoxon test with post hoc multiple comparisons of variables. Analysis of correlation was conducted using Pearson regression tests. Analysed variables were assumed statistically significant at the level of significance $p \leq 0.05$.

Results

The mean volume of stomach resected during laparoscopic sleeve gastrectomy was 860.2 ml, the standard deviation was 239.8 mL, the lowest volume — 400 mL

Table 1. Correlation between the volume of stomach resected with height, body mass, body surface and preoperative BMI

	Height	Body mass	BMI	Body surface
Volume of stomach resected	R_2 = 0.0546 p = 0.0010	R_2 = 0.0443 p = 0.0031	R_2 = 0.0060 p = 0.2810	R_2 = 0.0601 p = 0.0005

BMI — body mass index

Table 2. Correlations of resected gastric volume with %EBL. %EWL, %TWL after 1 year

	%EBL	%EWL	%TWL
Volume of stomach resected	R_2 = 0.0030 p = 0.4483	R_2 = 0.0026 p = 0.4755	R_2 = 0.0002 p = 0.8490

%EBL — the percentage of excess BMI loss, %EWL — the percentage of excess weight loss, %TWL — the percentage of total weight loss

Table 3. Changes in bariatric parameters in a 1-year follow-up

	Before the surgery	1 month		3 months		6 months		12 months	
		mean +/–	p	mean +/–	p	mean +/–	p	mean +/–	p
Body mass [kg] (SD)	145.7 (120.6–170.7)	129.3 (106.7–152.0)	0.0000	117.4 (96.3–138.5)	0.0000	106.5 (85.7–127.4)	0.0000	101.4 (80.8–122.0)	0.0000
BMI [kg/m^2] (SD)	48.3 (41.5–55.1)	42.9 (36.6–49.3)	0.0000	39 (32.9–45.1)	0.0000	35.4 (29.3–41.4)	0.0000	33.7 (27.6–39.7)	0.0000
%EBL (SD)		24.3 (17.7–30.9)	0.0000	42.2 (31.4–52.9)	0.0000	58.4 (43.7–73.2)	0.0000	66.0 (48.5–83.5)	0.0000
%EWL (SD)		21.6 (16.1–27.1)	0.0000	37.5 (28.7–46.3)	0.0000	51.9 (39.7–64.2)	0.0000	58.2 (43.8–72.6)	0.0000
%TWL (SD)		11.2 (8.7–13.7)	0.0000	19.5 (15.8–23.1)	0.0000	27.0 (21.8–32.2)	0.0000	30.5 (24.2–36.8)	0.0000

BMI — body mass index, %EBL — the percentage of excess BMI loss, %EWL — the percentage of excess weight loss, %TWL — the percentage of total weight loss

and the highest — 1800 mL. In women, the mean volume was 794.4 mL, SD 236.6 ml, in men — 914.9 mL, SD 229.4 mL. The difference in volume depending on the gender was statistically significant.

The correlation of the volume of the stomach resected with the height of the patient, preoperative body mass, BMI and body surface was examined. Analysis revealed a statistically significant correlation of stomach resected with height, body mass and body surface, whereas there is a lack of correlation with preoperative BMI. Results were given in Table 1 and Figures 2–6.

Furthermore, the correlation between the volume of stomach resected with bariatric exponents of bariatric surgery efficiency such as %EBL, %EWL and %TWL after 12 months was analysed. No statistically significant correlations between the volume of stomach resected and postoperative body mass loss expressed in %EBL, %EWL and %TWL was proved. Results are presented in Table 2.

In the further stage of the study, results of body mass loss in subsequent control points were analysed. Gradual, statistically significant body mass loss was observed, the highest in the first months after the surgery. The loss of BMI was statistically significant and reached the average value of 24.6 kg/m^2. A decrease of excess BMI of 66% was observed 12 months after the surgery — the result is statistically significant. The mean value of the decrease of excess body mass after 1 year of observation was 58.2%, and the mean decrease of total weight loss — 30,5% — both results are statistically significant. Detailed results are presented in Table 3.

The correlation between the volume of the stomach resected during sleeve gastrectomy and the change in parameters of carbohydrate and lipid metabolism 12 months after the procedure was assessed. There was a statistically significant correlation between the volume of stomach resected and changes in the percentage of glycated haemoglobin (HbA1C) and high-density lipoprotein (HDL) levels before and after 12 months of observation. Changes in glucose and total cholesterol, low-density lipoprotein (LDL) and non-HDL as well as triglycerides do not correlate with the volume of the stomach resected. Results are presented in Table 4.

Table 4. Correlation between the volume of the resected stomach with changes in parameters of carbohydrate and lipid metabolism after 1 year

	ΔGlucose	ΔHbA1C	ΔTC	ΔLDL	ΔHDL	ΔNon-HDL	ΔTG
Volume of stomach resected	R_2 = 0.0023	R_2 = 0.0203	R_2 = 0.0074	R_2 = 0.0039	R_2 = 0.0875	R_2 = 0.0006	R_2 = 0.0160
	p = 0.0023	p = 0.0203	p = 0.2293	p = 0.3870	p = 0.0000	p = 0.7399	p = 0.0770

HbA1C — glycated haemoglobin, TC- total cholesterol, LDL — low density lipoprotein, HDL — high density lipoprotein, TG — triglycerides

Table 5. Changes in concentration of glucose, HbA1C, total cholesterol, LDL, HDL, non-HDL and TG in a 1-year follow-up

	Before the surgery	1 month		3 months		6 months		12 months	
		mean +/–	p	mean +/–	p	mean +/–	p	mean +/–	p
Glucose [mg/dL] (SD)	122.2 (92.0–152.2)	109.0 (89.8–128.2)	0.0000	104.3 (87.2–121.4)	0.0000	101.6 (88.3–114.9)	0.0000	97.1 (82.9–111.3)	0.0000
HbA1C [%] (SD)	6.2 (5.3–7.1)	5.7 (5.1–6.3)	0.0000	5.4 (4.9–5.9	0.0000	5.3 (4.9–5.7)	0.0000	5.2 (4.8–5.6)	0.0000
TC [mg/dL] (SD)	192.5 (154.7–230.4)	170.5 (134.3–206.7)	0.0000	172.1 (143.4–200.9)	0.0000	175.0 (144.6–205.5)	0.0000	175.9 (141.9–209.9)	0.0000
LDL [mg/dL] (SD)	123.8 (92.6–155.0)	115.2 (82.9–147.5)	0.0000	114.0 (88.1–139.8)	0.0000	116.7 (87.5–145.9)	0.0032	109.3 (76.3–142.2)	0.0000
HDL[mg/dL] (SD)	44.0 (35.3–52.7)	36.8 (29.9–43.6)	0.0000	43.0 (35.5–50.4)	0.0486	49.9 (39.2–60.5)	0.0000	58.3 (42.8–73.8)	0.0000
Nie-HDL [mg/dl] (SD)	148,6 (110.8–186.3)	133.7 (97.2–170.2)	0.0000	129.2 (101.0–157.4)	0,0000	125.2 (94.1–156.3)	0.0000	117.5 (82.2–152.9)	0.0000
TG [mg/dL] (SD)	169.1 (74.2–264.0)	146.3 (95.5–197.1)	0.0013	123.8 (83.8–163.9)	0.0000	109.9 (66.0– 153.7)	0.0000	101.7 (54.2–149.2)	0.0000

HbA1C — glycated haemoglobin, TC- total cholesterol, LDL — low density lipoprotein, HDL — high density lipoprotein, TG — triglycerides

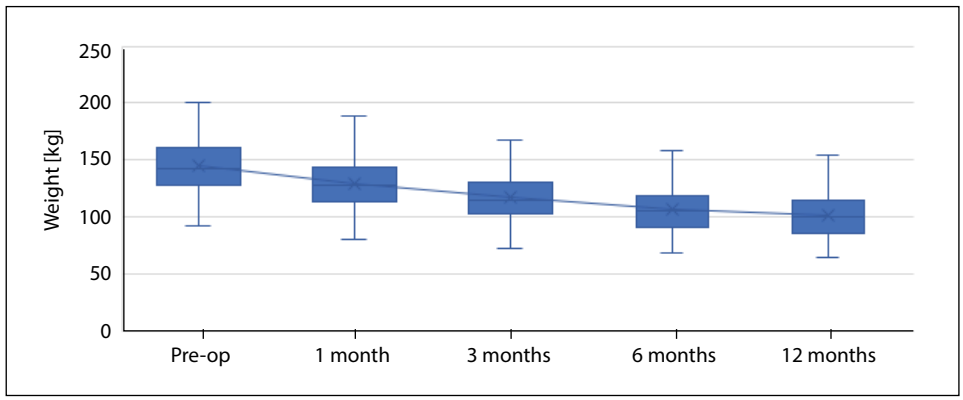

Figure 2. Body mass change in 12-month observation (all presented data are statistically significant)

Postoperative glucose, HbA1C, total cholesterol, LDL and HDL fractions, non-HDL and triglycerides were statistically analysed, 1, 3, 6 and 12 months after surgery. All the above results were statistically significant. The results are given in Table 5 and Figures 2–6.

Discussion

Bariatric-metabolic surgery is an efficient and durable method of obesity treatment. It is developing constantly in the past years, new surgical methods

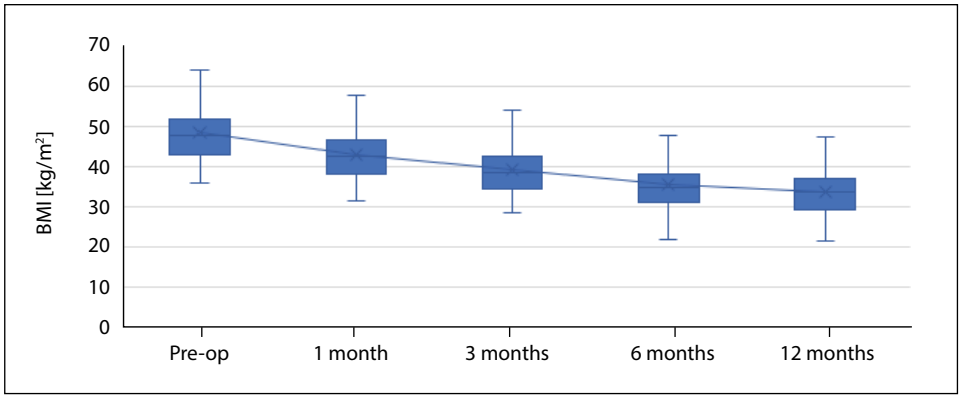

Figure 3. BMI change in 12-month observation (all presented data are statistically significant)

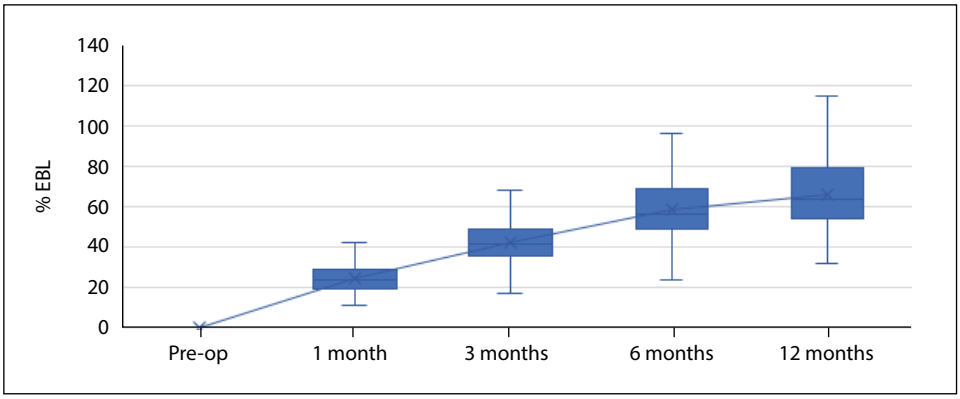

Figure 4. Excess BMI loss in 12-month observation (all presented data are statistically significant)

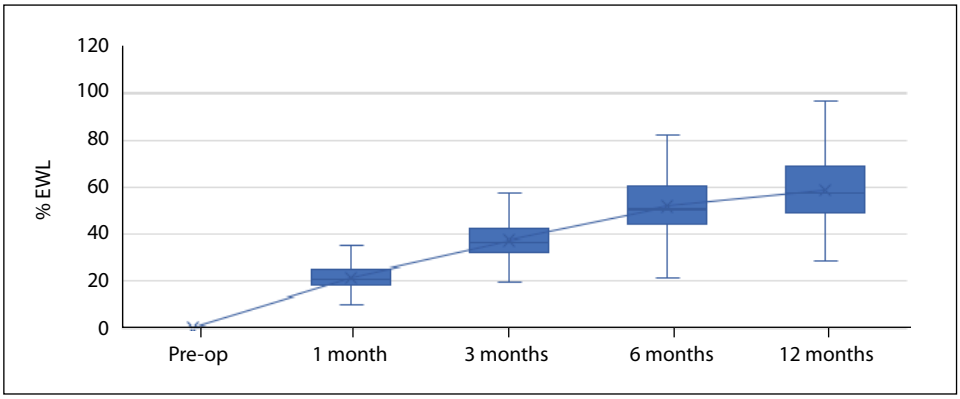

Figure 5. Excess weight loss in 12-month observation (all presented data are statistically significant)

are created. Laparoscopic sleeve gastrectomy gains its popularity over the years and it is recently the most commonly used bariatric-metabolic procedure [9, 10].

This study confirms the efficiency of LSG in body mass reduction and improvement of lipid and carbohydrate balance parameters. Laparoscopic sleeve gastrectomy is also a method with a low risk of complications and a low perioperative mortality rate [11]. Many variables influence the final results of bariatric surgery, among others, preoperative BMI, co-morbidities, mental disorders, cooperation between doctor-patient and following dietetic recommendations [12, 13]. However, sleeve gastrectomy is not a perfect method of obesity treatment. Cases of body mass regain and the necessity of reoperation are observed [14, 15].

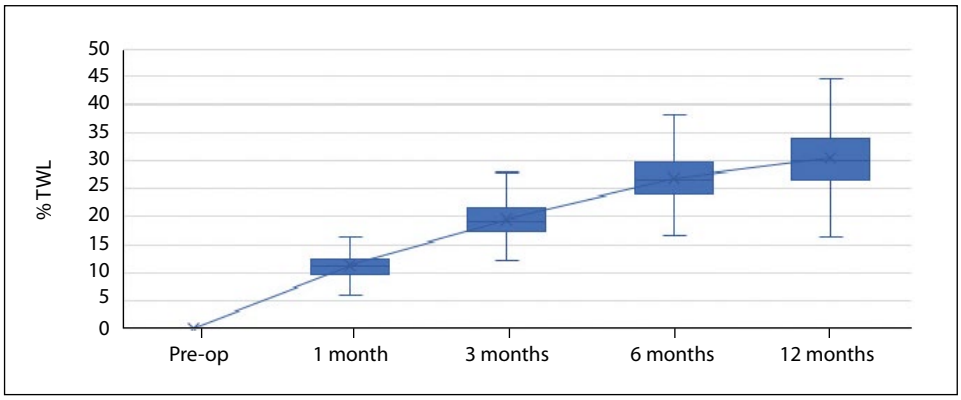

Figure 6. Excess total weight loss in 12-month observation (all presented data are statistically significant)

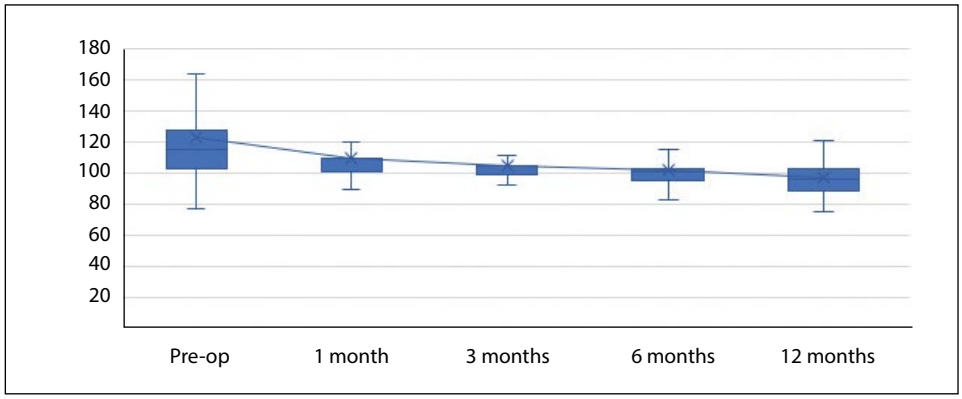

Figure 7. Changes in glucose concentration in 12-month observation (all presented data are statistically significant)

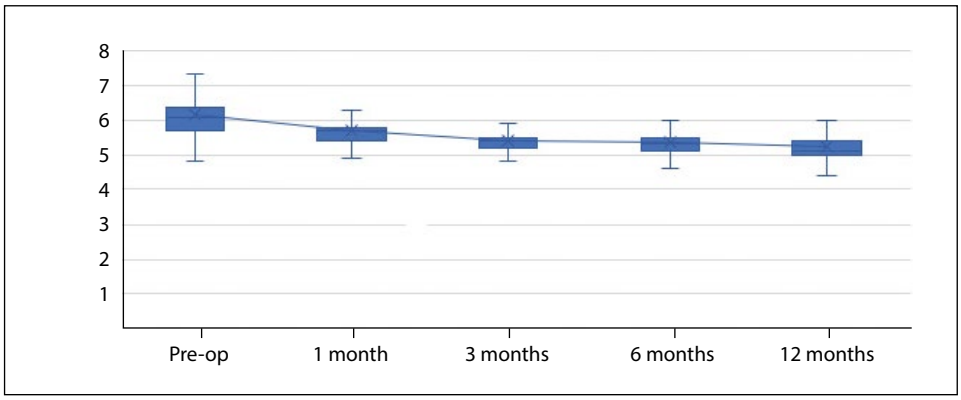

Figure 8. Changes in glycated haemoglobin percentage in 12-month observation (all presented data are statistically significant)

In this study, the volume of stomach resected during LSG and its influence on postoperative results was analysed. The operation is performed by one team of surgeons, using the same method to minimize errors related to the surgical technique. About 80% of the stomach is resected during a sleeve gastrectomy. It can therefore be assumed that the volume of the resected stomach is proportional to the total volume of the stomach before surgery and the volume of the gastric sleeve left after surgery. The measurement of stomach resected volume is not standardized, there is no recommendation which method is the best. The authors proposed an innovative method of measuring the volume of the resected stomach with carbon dioxide insufflation. Other researchers measured the volume of stomach resected using other techniques. Bekkeit proposed the

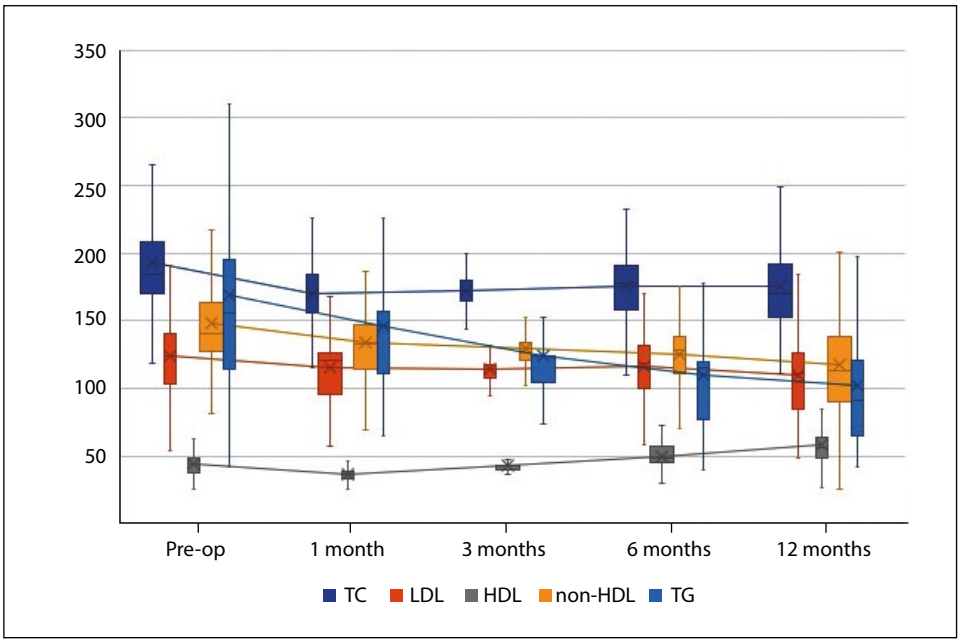

Figure 9. Changes in lipid balance parameters in 12-month observation (all presented data are statistically significant)

method of filling the stomach with water and measuring its volume [16]. D'Ugo elaborated mathematical formula for the measurement of stomach resected [17]. Other researchers used Computer Tomography in order to define the pre- and postoperative volume of the stomach [18, 19]. The presented innovative method of measuring the volume of the stomach creates limitations in comparison with the results of other scientists, at the same time, the presented method is safe, cost-free, available and does not expose the patient to X-rays.

Differences in measurement technique may influence further results. The wall of the stomach is extensible tissue, individual differences in the susceptibility of the stomach to the filling are not sufficiently known and may influence volume measurements [20]. Data regarding the correlation between the volume of stomach resected is inconsistent and anthropometric measurements before the operation. A statistically significant difference was revealed between height, body mass, body surface and the volume of stomach resected and the lack of such correlation with BMI. Other studies proved a correlation between BMI and gender [16]. Other researchers, similarly to the present study, proved that the volume of the stomach does not influence the results of body mass loss and BMI loss after LSG [17, 21]. Some researchers confirm the relationship between the postoperative volume of the stomach with postoperative body mass loss [22, 23].

What is more, the influence of the volume of the stomach resected on changes in carbohydrate and lipid profile after sleeve gastrectomy was analysed. Until now, there is no publications regarding those correlations. Multicentre studies are needed on this issue in order to confirm the relation between the volume of stomach resected with improvement of glycated haemoglobin and HDL concentration.

The issue of the volume of stomach resected after sleeve gastrectomy requires further studies due to the fact that available data are inconsistent. Differences may result from different operative techniques, different diameters of stomach tubes as sleeve calibration as well as from the proximity of charge placement from the tube or distance of first stapler placement from the pylorus. Another important aspect is the method of stomach volume measurement which is not standardized and different in different studies. The method proposed in this study is repeatable and does not require additional equipment – the measurement was performed using an insufflator necessary for the creation of pneumoperitoneum during laparoscopic surgery and the Veress needle which is confirmed to be a safe method of pneumoperitoneum creation. The susceptibility of stomach walls is an individual component which cannot be influenced.

Conclusions

The correlation between the volume of the stomach resected during laparoscopic sleeve gastrectomy and preoperative body mass, height and body surface was revealed. The lack of correlation with preoperative BMI

was observed. The correlation between the volume of stomach resected and bariatric results after a 1-year observation (%EWL, %EBL, %TWL) was not observed. Correlation between the volume of stomach resected during LSG with the percentage of HbA1C and HDL was observed in the 12-month follow-up. The lack of relation between glucose, total cholesterol, LDL, non-HDL and TG concentration was stated. LSG is an efficient method of obesity treatment, improves bariatric parameters and leads to positive changes in carbohydrate and lipid balance.

Data availability statement: *All data is available.*

Ethics statement: *The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the Medical University of Białystok.*

Author contributions: *Conceptualization: Hady Razak Hady, Writing: Patrycja Pawłuszewicz, Data curation: Patrycja Pawłuszewicz, Piotr Gołaszewski.*

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Supplementary material: *None.*

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