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# 3D-computer gastrovolumetry: a new method of visual estimation of a gastric tube for patients after sleeve gastrectomy

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*The aim of this study was to analyze the volume of the gastric tube using sleeve gastrectomy (SG) 3D-computed gastrovolumetry for patients after SG and to determine its correlation with the percentage of excess weight loss. Patients who underwent SG between 2015 and 2018 were followed prospectively and evaluated after the operation. The condition of the gastric tube was examined using 3D-computer tomography reconstruction and gastric volumetry. The gastric tube was distended by effervescent sodium bicarbonate given orally. Gastric volume (GV) was estimated with the software of the CT device. The relationship between GV and weight loss was analyzed. Assessment of anthropometric parameters and the condition of the gastric tube was performed 24 months after surgery. Forty-two patients (24 women, 18 men) with a mean age of 36.9 ± 10.9 years were studied. The mean values body mass index (BMI) before and after SG were 48.1 ± 11.1 kg/m$^2$ (from 35.3 to 81.5 kg/m$^2$) and 34.7 ± 8.5 kg/m$^2$ (from 26.7 to 61.3 kg/m$^2$), respectively. There was a statistically significant difference between BMI before and after RRS (Z = –5.58; P = 0.001), after RRS BMI was significantly smaller. Mean percentage of excess weight loss (%EWL) was 52.2 ± 20.7%. Mean GV was 288.7 ± 105.2 ml. The % EWL was inversely correlated with GV after SG (rs = –0.831; P = 0.001). 3D-computer gastrovolumetry is a good method to measure GV after SG. Post-operative weight loss inversely correlates with the GV.*

*Key words: obesity; sleeve gastrectomy; insufficient weight loss; weight regain after surgery; 3D-computer gastrovolumetry.*

## INTRODUCTION

According to the World Health Organization obesity has long been an epidemic worldwide, affecting people regardless the age, gender, race, or geographical localization. Being overweight is one of the key factors in the development of insulin resistance and later on the development of type 2 diabetes mellitus [1]. In addition, obesity associated with metabolic syndrome worsens the course of diseases of the musculoskeletal system, cardiovascular, respiratory, digestive tract, and reproductive system [2]. Numerous meta-analyses and randomized clinical trials have proven the benefits of bariatric surgery over conservative treatments for obesity and related metabolic disorders [3]. In many countries around the world bariatric surgery is part of national programs for the treatment of obesity and type 2 diabetes mellitus. At present, obesity surgery has been considered as a preoperative treatment stage of patients who are to have joint prosthetics, cardiac surgery, and even liver transplantation [4]. Bariatric surgery has made a major breakthrough in the last decade, and its popularity is growing every year [5]. This is confirmed by the increase in the number of operations on all continents. In 2003 there were 146,000 of them worldwide and in 2016 their number exceeded 685,000 [6]. For a long time, Roux-en-Y gastric bypass took on a leading position and was considered the "gold standard" in bariatric surgery [7]. However, today SG has rapidly come to the forefront as the most performed operation in the world [6].

SG is an effective and safe bariatric surgical procedure that reduces excess body weight and compensates for concomitant metabolic disorders, primarily type 2 diabetes mellitus [8]. However, as the number of operations performed increases, so does the number of patients with unsatisfactory results. There are publications in the literature which show that in the remote postoperative period up to 30% of patients experience weight regain after successful reduction [9]. In turn, Alvarez V. and co-authors [10] in their work described the impact on the outcome of the operation as multifactorial. They were conditionally divided into surgeon-dependent, patient-dependent, and combined. It is believed that sufficient volume of the gastric tube is 100 ml when performing SG, but during further observations dilatation of the reservoir is not a rare trait. There is still a debate in scientific circles about the expansion of the gastric tube: whether it is a physiological mechanism after surgery or the consequence of an unsatisfactory result. However, there are very few publications in the literature [11], although the volume of the gastric tube after SG can be one of the key factors of unsatisfactory results after surgery. Modern multislice computed tomography with the possibility of 3D modeling and digital determination of tissue volume has occupied one of the key places in hepatology, pulmonology, herniology, traumatology, and many other areas of medicine [12]. But it will play an even more important role in the near future because with each passing day the directions of its application are only expanding. In our opinion, its use for patients after SG will allow obtaining better and quantitative characteristics of the gastric tube.

Purpose - to analyze the volume of the gastric tube using 3D computed gastrovolumetry for patients after SG and to determine its correlation with the percentage of excess weight loss.

## METHODS

This work was based on the analysis of the treatment results of 42 patients who underwent SG in the conditions of the State Institution A.A. Shalimov National Institute of Surgery and Transplantology of the National Academy of Medical Sciences of Ukraine and State Scientific Institution Center for Innovative Medical Technologies of the National Academy of Sciences of Ukraine for the period from 2015 to 2018. Of these, 4 (9.5%) patients underwent surgery in other medical institutions.

Data evaluated (excluding age and gender) included: preoperative body weight, BMI, and excess body weight (EBW); after surgery evaluated body weight, BMI, percentage of excess body mass index loss (%EBMIL), percentage of excess weight loss, and percentage of total body weight loss (%TWL) at the 24 months after surgery. The body weight was measured in kilograms (kg), gastritis tube volume was measured in milliliters (ml).

The calculation of indicators was performed according to the formulas:

$$BMI = \frac{Body\ weight\ \ (kg)}{(Hight\ (m))2}$$

$$EBW = Body\ weight\ before\ operation - Ideal\ body\ weight$$

$$\%EBMIL = \frac{BMI\ before\ operation - current\ BMI}{BMI\ before\ operation - 25} x100\%$$

$$\%EWL = \frac{Body\ weight\ before\ operation - current\ body\ weight}{Body\ weight\ before\ operation - ideal\ body\ weight} \times 100\%$$

$$\%TWL = \frac{Body\ weight\ before\ operation - current\ body\ weight}{Body\ weight\ before\ operation} x100\%$$

To assess the effectiveness of surgical treatment of obesity, in relationship to the regression of excess body weight, there was used the classification of R.B. Reinhold based on %EWL. The results were evaluated as follows:

- % EWL <25 - poor result (group 1).
- % EWL ≥ 25 but <50 - acceptable result (group 2).
- % EWL ≥ 50 but <75 - good result (group 3).
- % EWL ≥ 75 - excellent result (group 4).

For visual assessment of the gastric tube after SG there was performed computer gastrovolumetry CT on the scanner TOSHIBA AQUILION ONE (utility model patent No. 119142 UA, Ukraine, A61B 6/03, No. application 2017 03596. Method of computer gastrovolumetry after SG of the stomach. information on the issuance of a patent 11.09.17, bulletin No. 17).

The method of computer gastrovolumetry was the following. The patient orally took 50 ml of 4% aqueous tartaric acid solution and 50 ml of 4% aqueous sodium bicarbonate solution. After 30 and 60 s, computed tomography of the abdominal organs was performed and the volume of the gastric tube was determined using 3D image modeling on a Vitrea workstation, version 7.3.

Statistical data processing was performed by using descriptive statistics methods with the help of the statistical analysis package SPSS, version 23. Descriptive statistics were performed to obtain demographic data. The statistical indicators of mean values (M), as well as the standard deviation (SD), are used in the work. For the nonparametric distribution, the statistical significance of the differences between the two dependent groups was evaluated by the Wilcoxon test (Z), and between the two independent groups, it was done by the Mann-Whitney test (U). The Spearman's ratio (rs) was used to determine the relationship between the indicators. The difference was considered statistically significant at $P < 0.05$.

## RESULTS

The age of patients ranged from 20 to 57 years, with a mean value of 36.9 ± 10.9 years (24 women and 18 men). Mean values before surgery: body weight – 143.8 ± 39.4 kg (from 95 to 270 kg), EBW – 77.8 ± 35.5 kg (from 39 to 193 kg), BMI – 48.1 ± 11.1 kg/m$^2$ (from 35.3 to 81.5 kg/m$^2$). This study included 14 (33.3%) patients with a BMI over 50 kg/m$^2$. Due to the high anesthetic risk, SG was performed as planned and as the first stage of obesity treatment. The first measurement of gastric tube volume was performed at the end of the operation, during a leak test with methylene blue. The mean value was 82.9 ± 11.8 ml (65-120 ml). All patients were constantly monitored by a multidisciplinary team with clear monitoring of indicators and general conditions. The frequency of visits was 3, 6, 9 and 12 months in the first year after surgery and every 6 months in the follow-up period.

In the vast majority of patients, there was a rapid loss of excess body weight during the first year after SG. However, after 1.5-2 years after the operation, the weight had a greater tendency to stabilize and the decrease was not so rapid. Assessment of anthropometric parameters and the condition of the gastric tube was performed 24 months after surgery. At the time of the study, the average body weight of patients after surgery was 103.8 ± 28.7 kg. The minimum figure was 72 kg, the maximum - 190 kg. In turn, the average BMI was 34.7 ± 8.5 kg/m$^2$ (range 26.7-61.3 kg/m$^2$). The difference between the average values of BMI before surgery and the corresponding indicator in the above-mentioned follow-up after surgery reached statistical significance ($Z = –5.58$; $P = 0.001$).

One of the visual indicators of the effectiveness of any bariatric operation taken the regression of body weight into account is %EWL and %EBMIL, which are 52.2 ± 20.7% (range 2.6-75.3%) and 60 ± 24,3% (range 3.6-89.7%), respectively.

The histogram shows the frequency distribution of patients depending on the %EWL (Fig. 1). Despite the fact that SG was planned as the first stage of obesity treatment (4 patients with BMI over 50 kg/m$^2$) and in the future, it was planned to perform the second stage in the form of malabsorption component (biliopancreatic diversion with duodenal switch or Roux-en-Y gastric bypass) the results of body weight regression confirmed the effectiveness of SG as an independent bariatric operation. Thus, BMI after surgery was in the range from 29.9 to 61.3 kg/m$^2$ with an average value of 41.9 kg/m$^2$. %EBMIL was 55.5 ± 22.9% (range 18.4-82%) and %EWL – 50.8 ± 20.3% (range 16.8-75.3%).

In this paper, to evaluate the effectiveness of the operation, we used the scale proposed by R.B. Reinhold. Depending on the value of %EWL all patients were conditionally divided into 4 groups, the frequency distribution is presented in the histogram (Fig. 2). Poor results were noted in 6 (14.3%) patients who were

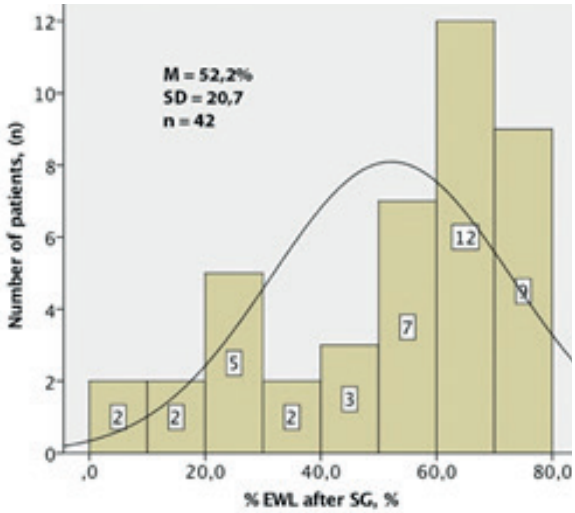


Fig. 1. Frequency distribution of patients by %EWL after SG

included in the first group. The mean values of %EWL, %EBMIL and %TWL were 14.6 ± 9.1, 17.2 ± 10.6, and 8.3 ± 5.2%, respectively.

The second group included 8 (19%) patients. According to the Reinhold criterion, their result is interpreted as acceptable. However, if we look at the data of body weight regression, on the other hand, it can be called relatively satisfactory. %EWL was in the range from 25.3 to 48% with an average value of 35.9 ± 8.7% while the average value of %TWL was 19.8 ± 5.9% with a maximum value of 29.6%. That is, according to the criterion of %TWL in 4 patients, the result after SG can be interpreted as satisfactory.

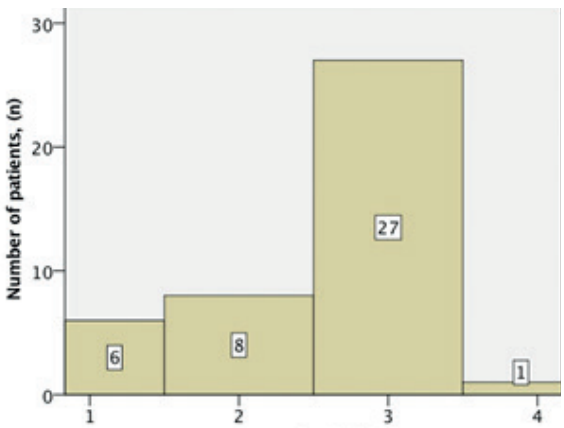


Fig. 2. Frequency distribution of patients by groups according to the Reinhold criterion

Most patients have a good result. Thus, in the third group among 27 (64.3%) patients the average values of %EWL and %TWL were 64.5 ± 7.4% (from 50.8 to 73.7%) and 33.3 ± 5.9% (from 22.1 to 47.2%), respectively. One patient entered the fourth group and he had the best results of body weight regression, %EWL - 75.3% and %TWL - 42.9%.

Despite the imperfection of the Reinhold classification for 28 patients (66.7%), the postoperative outcome was considered satisfactory. The chemical reaction in the stomach led to gas formation, thus improving the visualization and the ability to estimate the volume of the gastric tube (Fig. 3). According to 3D computer gastrovolmetry, the volume of the gastric tube was recorded in the range from 150 to 498 ml, with an average value of 288.7 ± 105.2 ml. In the first group, according to the Reinhold test, we obtained the average value of the volume of the gastric tube 480.5 ± 11.8 ml. This value is expected, given the low regression of body weight. At that time, in 28 (66.7%) patients with satisfactory results after surgery, the average value of the volume of the gastric tube was 234.2 ± 50.7 ml. The difference between the mean values of the volume of the gastric tube in a patient with unsatisfactory and satisfactory results reached statistical significance (U = 42.5; P = 0.001). During intraoperative measurement, the mean volume of the gastric tube was 82.9 ± 11.8 ml, and at the time of the study, this value

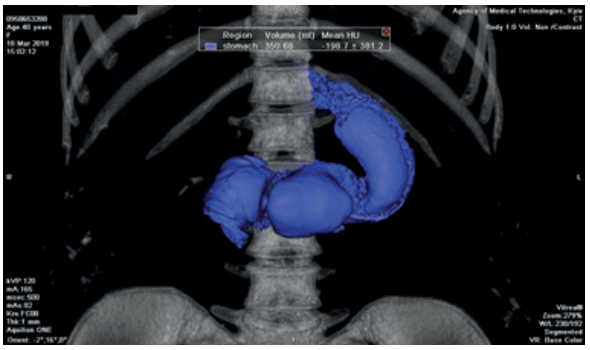

Fig. 3. 3D-computer gastrovolumetry of the patient after 26 months after SG (volume of the gastric tube - 350.68 ml, %EWL - 45.8% and %TWL - 19.3%)

increased to 288.7 ± 105.2 ml. This difference reached statistical significance (Z = –5.65; P = 0.001).

We used a scatter plot to illustrate the correlation between gastric tube volume and %EWL (Fig. 4). The results of the study showed that there is a significant bilateral strong inverse relationship between the volume of the gastric tube and the %EWL (rs = –0.831; P = 0.0001). In other words, as the volume of the gastric tube increases, the %EWL decreases.

## DISCUSSION

Unfortunately, there is still no clear definition of what is a satisfactory or unsatisfactory result after surgery. In recent decades there have been attempts to analyze various indicators to assess the effectiveness of a bariatric operation, but consensus has not yet been found [13].

Undoubtedly an important factor in assessing a treatment is the analysis of regression of body weight. Thus, Biron and, et al. [14] divided patients into two groups: the first group – patients with morbid obesity (BMI before surgery over 50 kg/m$^2$), the second – with a BMI in the range of 35-50 kg/m$^2$. For obese patients, the satisfactory result of the operation was considered to be BMI <35 kg/m$^2$, while in patients with morbid obesity when BMI <40 kg/m$^2$.

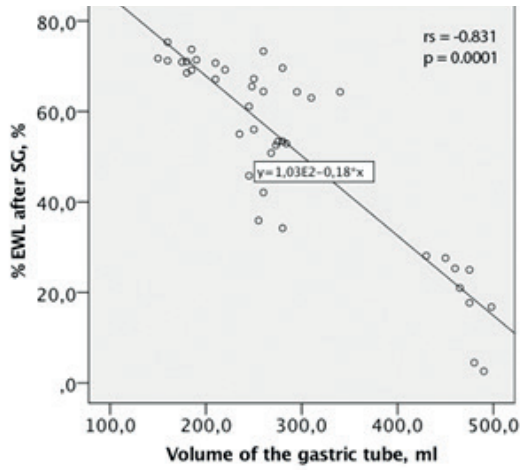


Fig. 4. Diagram of the relationship between the volume of the gastric tube and %EWL

There are publications in the literature in which in order to define the operation effectiveness there was used the mark by the scale "The Bariatric Analysis and Reporting Outcome System" (BAROS). As you know, the minimum value on this scale is "-7.2", and the maximum - "9". A satisfactory result is considered when the value is more than 3 points [1]. Brolin [13] proposed to evaluate the effectiveness of bariatric surgery by combining the analysis of %EWL and parameters of compensation of concomitant pathology. %EWL is the criterion most often used to assess body weight regression. A satisfactory result is stated in the case when it is more than 50% [14]. However, in our study, a wide range between the minimum and maximum value of %EWL attracts attention, although the average value fully meets the criterion of a satisfactory result.

It is not often that %TWL is used to evaluate the results after surgery. It should be noted that van de Laar, et al. [15] emphasize that %EBMIL and %EWL significantly depend on the initial anthropometric values and the assessment of these indicators is not very justified in the analysis of groups of patients with different baseline BMI values. While %TWL is deprived of this influence and therefore can more accurately characterize regression of body weight after operation in heterogeneous groups. The result is considered unsatisfactory in the case when the %TWL <20%.

For the purpose of a more accurate analysis of %EWL we applied categorization of indicators, transferred quantitative value into a qualitative one. Based on the definition of a satisfactory result at %EWL more than 50%, we conditionally divided the patients included in this study into a group with satisfactory and a group with unsatisfactory results. The group with unsatisfactory results included 14 (33.3%) patients who were in groups 1 and 2 according to the Reinhold criterion. To the group with a satisfactory result 28 (66.7%) patients from groups 3 and 4, respectively. The purpose of this division is to analyze the volume of the gastric tube according to 3D-computer gastrovolumetry

depending on the result.

Traditional X-ray examination of the gastric tube with iodine-containing water-soluble contrast agent or even barium sulfate makes it very difficult to estimate the volume of the gastric tube. That's why we used computed tomography with 3D reconstruction to solve this problem. The results of the study showed that the data of body weight regression decreases with increasing volume of the gastric tube. Over time, the volume of the gastric tube increases, even in the case of the formation of a narrow tube during surgery. 3D-computer gastrovolumetry allows to carrying out of qualitative and quantitative characteristics of the state of the gastric tube after SG. Objective measurement of the gastric tube is important to assess long-term clinical outcomes and to select a possible follow-up strategy for revision surgery. In this project, we proposed a simple radiological volume model for the evaluation of the gastric tube after SG. In addition, we found a direct relationship between an increase in the volume of the gastric tube and a decrease in weight loss after surgery. Confirmation of the results requires further research in the long term.

## CONCLUSIONS

1.3D-computer gastrovolumetry allows to carrying out of qualitative and quantitative characteristics of the state of the gastric tube after sleeve gastrectomy.

2. 3D-computed gastrovolumetry is an effective method of examining the volume of the gastric tube after sleeve gastrectomy.

3. An inverse correlation has been established between gastric tube volume and the percentage of excess weight loss.

4. 3D-computed gastrovolumetry data can be used to select the method of revisional surgery in patients with unsatisfactory results.

*Prospects for further research are planned to work on the study of volumetric methods in other variants of bariatric surgery, as well as the study of ways to optimize the performance of volumetry in patients after SG.*

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*The authors of this study confirm that the research and publication of the results were not associated with any conflicts regarding commercial or financial relations, relations with organizations and/or individuals who may have been related to the study, and interrelations of co-authors of the article.*

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**3D-КОМП'ЮТЕРНА ГАСТРОВОЛЮМЕТРІЯ – НОВИЙ СПОСІБ ВІЗУАЛІЗАЦІЇ ШЛУНКОВОЇ ТРУБКИ У ПАЦІЄНТІВ ПІСЛЯ РУКАВНОЇ РЕЗЕКЦІЇ ШЛУНКА**

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Мета нашого дослідження – оцінити стан шлункової трубки за допомогою комп'ютерної томографії з 3D-реконструкцією і визначити кореляцію зі зниженням маси тіла. У це проспективне дослідження ввійшли 42 пацієнти (24 жінок, 18 чоловіків) віком 36,9 ± 10,9 років, яким була виконана рукавна резекція шлунка (РРШ) за період з 2015 по 2018 рр. Стан шлункової трубки досліджували за допомогою 3D-комп'ютерної гастроволюметрії. Шлункова трубка розширювалася після прийому содового бікарбонату через рот. За допомогою програмного забезпечення виконували 3D-реконструкцію і вимірювали об'єм шлункової трубки. Отримані результати зіставляли зі зниженням маси тіла. Антропометричні параметри і стан шлункової трубки оцінювали через 24 міс після операції. Середні значення індексу маси тіла (ІМТ) до та після РРШ становили 48,1 ± 11,1 кг/м$^2$ (від 35,3 до 81,5 кг/м$^2$) та 34,7 ± 8,5 кг/м$^2$ (від 26,7 до 61,3 кг/м$^2$) відповідно. Між ІМТ до та після РРШ відзначено статистично достовірну різницю (Z = –5,58; P = 0,001). Середнє значення відсотка втрати надлишку маси тіла (%ВІМТ) сягало 52,2 ± 20,7%, середнє значення об'єму шлункової трубки – 288,7 ± 105,2 мл. Між обсягом шлункової трубки та %ВІМТ існує достовірний двобічний зворотний зв'язок (rs = –0,831; P = 0,001). 3D-комп'ютерна гастроволюметрія – ефективний метод діагностики стану шлункової трубки після РРШ.

Ключові слова: ожиріння; рукавна резекція шлунка; недостатня втрата маси тіла; рецидив маси тіла; 3D-комп'ютерна гастроволюметрія.

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