FOLIA HISTOCHEMICA ET CYTOBIOLOGICA
Vol. 50, No. 2, 2012
pp. 292–303

ORIGINAL STUDY

VIA MEDICA

The influence of laparoscopic adjustable gastric banding and laparoscopic sleeve gastrectomy on weight loss, plasma ghrelin, insulin, glucose and lipids

Hady Razak Hady, Pawel Golaszewski, Robert Lukasz Zbucki, Jacek Dadan

1st Department of General and Endocrinological Surgery, Medical University of Bialystok, Poland

Abstract: The aim of this study was to assess the impact of laparoscopic gastric banding and laparoscopic sleeve gastrectomy on the concentration of ghrelin, insulin, glucose, triglycerides, total and HDL-cholesterol, as well as AST and ALT levels in plasma in patients with obesity. The research includes 200 patients operated using LAGB (34 men average age 37.0 ± 12.6 years and 66 women average age 39.18 ± 12.17 years) and LSG (48 men average age 47.93 ± 9.24 years and 52 women, 19 ± 9.33 years). The percentage of effective weight loss, effective BMI loss, concentration of ghrelin, insulin, glucose, triglycerides, total cholesterol, HDL-cholesterol, LDL-cholesterol, ALT, AST and HOMA IR values was taken preoperatively and at 7th day, 1 month, 3 and 6 months after surgery. Both after LSG and after LAGB, statistically significant reduction in BMI, serum insulin, glucose and HOMA IR was noticed in comparison to the preoperative values. Post LAGB, patients showed an increase of ghrelin, while LSG proved ghrelin decreased. Correlations between glucose and BMI loss, and between insulin and BMI loss in both cases are more favorable in the LSG group. Lipid parameters, AST and ALT have undergone declines or increases in the particular time points. Both techniques cause weight loss and this way lead to changes in the concentration of ghrelin, as well as to the improvement of insulin, glucose, cholesterol and triglycerides metabolism. They reduce metabolic syndrome and multiple comorbidities of obesity. *(Folia Histochemica et Cytobiologica 2012, Vol. 50, No. 2, 292–303)*

Key words: obesity, LSG, LAGB, metabolic parameters

Introduction

Obesity is an effect of a chronic imbalance between energy supply and its expenditure according to environmental, genetic or hormonal conditions. It is manifested by the excessive gathering of adipose tissue and leads to many serious coexisting diseases [1, 2].

As a global disease, obesity represents a serious health, psychosocial and socio-economic problem worldwide. The growing proportion of people with excessive body weight results in a higher predisposition to develop the diseases associated with obesity such as hypertension (HT), type 2 diabetes mellitus (T2DM), cardiovascular diseases (CVD), dyslipidemia, sleep apnea, osteoarthritis, steatosis, depressive disorders, and gastrointestinal cancers [1, 2].

WHO in 1997 put obesity on the list of social diseases, which have come to embrace an increasing number of areas of the world, especially over the past two decades [3–5]. In 2005, the population of adults (> 15 years old) with overweight was estimated at 1.6 billion, and those with obesity at 400 million. In Poland, it was noted that 1% of the population (over 300,000 people) had BMI > 40 kg/m^2, while in urban populations it was 2.8%, and in big cities 3% [6, 7].

Orexigenic and anorexigenic hormones play important roles in the regulation of energy balance, for example ghrelin, isolated for the first time by Kojima et al. in 1999 [8]. This is a 28-amino acid peptide released from X/A cells belonging to the system of scattered endocrine cells of the APUD series. The high-

Correspondence address: R.L. Zbucki,
1st Department of General and Endocrinological Surgery,
Medical University of Bialystok,
Sklodowskiej-Curie Str. 24a, 15–276 Bialystok, Poland;
tel.: + 48 85 746 86 72, fax: + 48 85 746 86 20;
e-mail: klchirog@umwb.edu.pl

est expression of ghrelin is observed in the stomach fundus and it gradually reduces from the body of the stomach to the colon [9]. Gastrectomy reduces ghrelin concentration in plasma by about 60%. What is more, ghrelin is synthesized in the pancreas, kidney, hypothalamus, placenta, pituitary and thyroid gland [10]. The regulation of ghrelin secretion has yet to be completely understood. However, it is known that its concentration in plasma reduces in patients with a positive energy balance, for example with obesity, while in anorexia it increases [11]. Moreover, certain hormones and nutrients affect ghrelin secretion, and ghrelin itself increases secretion of lactotropic and corticotropic hormones. It influences the endocrine part of the pancreas, inhibits insulin secretion [12] and thus affects the metabolism of glucose. Like leptin, ghrelin acts in an 'informant' role for the energy balance of the central nervous system [13, 14].

Metabolic syndrome is a collection of risk factors responsible for developing CVD and T2DM [15]. WHO determined that metabolic syndrome consists of metabolic disorders such as insulin resistance represented by one of the following: T2DM, impaired fasting glucose, impaired glucose tolerance or, in subjects with normal fasting glucose (< 110 mg/dl), glucose uptake below the lowest quartile for the background population in hyperinsulinomic and euglycemic conditions. One of the following additional criteria should also occur: antihypertensive medication and/or high RR (systolic ≥ 140 mm Hg or diastolic ≥ ≥ 90 mm Hg), plasma triglycerides ≥ 50 mg/dL, HDL cholesterol < 35 mg/dl in men or < 39 mg/dl in women, BMI > 30 kg/m^2 and/or waist hip ratio > 0.9 in men or > 0.85 in women, albuminuria ≥ 20 μg/min or albumin rate: creatinine ≥ 30 mg/g [16]. The American Heart Association recommends the ATP III classification (Adult Treatment Panel III), which includes the following factors: abdominal obesity (waist circumference > 102 cm in male patients and > 88 cm in female patients), aterogenic dyslipidemia (triglycerides ≥ 150 mg/dl), high blood pressure (≥ 130/ /≥ 85 mm Hg), insulin resistance ± glucose intolerance (≥ 110 mg/dl), proinflammatory state and prothrombotic state [17].

The surgical treatment of obesity, especially laparoscopic gastric banding (LAGB) and laparoscopic sleeve gastrectomy (LSG), is gaining wider interest. Recently, despite the fact that LSG was introduced later, it has gained popularity not only as a first step in the treatment of superobese patients or patients at high risk, but mainly as an isolated and definitive operation [18].

LAGB was first described in 1994 [19] and since then it has become more popular. LSG was first described in 1988 as part of a duodenal switch [20], and in 1993 as an isolated technique [21]. The number of LSG procedures in Europe and in the USA/Canada is increasing. In 2003–2008, a growth was observed from 0.0% to 4.0% (in USA/Canada) and to 7.0% in Europe. However, this popularity should be reviewed in the light of further research. A different situation pertains with LAGB — its applicability in Europe in 2003–2008 decreased from 63.7% to 43.2%, while in the USA/Canada it increased from 9.0% to 44.0% [22]. In Poland, LAGB has been performed since 1998, and LSG since 2005, and with each passing year, the application of these methods increases [6].

A growing number of publications have attempted an objective comparison of the different techniques from various points of view. Yet there are still few available publications describing LAGB and LSG according to the percentage of effective BMI loss (%EBL), and even fewer studies comparing the biochemical effects.

The aim of this study was to assess the impact of LAGB and LSG on the concentration of ghrelin, insulin, glucose, triglycerides, total and HDL cholesterol, as well as AST and ALT levels in patients with obesity. Moreover, our aim was to assess the impact of body weight loss on the comorbidities of obesity.

Material and methods

Our center is a pioneer in bariatric surgery in north eastern Poland. In this study, we examined 200 obese patients who underwent LAGB (n = 100) and LSG (n = 100) between 2005 and 2009 with a six month follow-up. The group of patients with a gastric band included 34 men (average age 37.0 ± 12.6 years) and 66 women (39.18 ± 12.17 years). The group of patients after sleeve gastrectomy included 48 men, average age 47.93 ± 9.24 years and 52 women — 44.19 ± ± 9.33 years. Preoperative BMI in the LAGB group was 45.21 ± 3.96 kg/m^2 (average body weight 125.72 ± 15.9 kg); in the LSG group it was 52.15 ± 8.5 kg/m^2 (151.2 ± ± 25.19 kg) (Table 1).

Among patients classified for LAGB, T2DM was found in eight patients (8%), HT in 12 (12%) and sleep apnea in five patients (5%). In the group of patients classified for LSG, these disorders were found in, respectively, 39 (39%), 56 (56%) and 31 patients (31%) (Table 2). All patients complied with the criteria for bariatric treatment. Patients over 40 years old, and with T2DM, HT, CVD, after heart attacks, chronic obstructive pulmonary disease, sleep apnea, osteoarthritis and varicose veins, were qualified for LSG. LAGB was applied more frequently in female patients under 40 years of age, who were medially five years younger than the LSG group of patients. Men in this group were medially ten years younger. We preoperatively performed a number of tests, including abdominal ultrasound

Table 1. Baseline characteristics of obese patients

	LAGB (n = 100)	LSG (n = 100)
Gender: female/male (%)	66/34	52/48
Age: female/male (y)	37.0 ± 12.6/39.18 ± 12.17	47.93 ± 9.24/44.19 ± 9.33
Weight [kg]	125.72	151.2 ± 25.19
BMI [kg/m^2]	45.21 ± 3.96	52.15 ± 8.5
Ghrelin [pg/Ml]	661.98 ± 180.5	491.49 ± 176.27
Insulin [μU/L]	22.71 ± 6.17	42.9 ± 28.82
Glucose [mg/Dl]	105.63 ± 28.87	147.7 ± 61.64
Total cholesterol [mg/dl]	207.37 ± 14.09	213.08 ± 19.68
Triglycerides [mg/dl]	127.25 ± 27.52	166.3 ± 51.64
LDL [mg/dl]	148 ± 20.02	138.44 ± 35.31
HDL [mg/dl]	44.7 ± 10.04	42.48 ± 11.19
ALT [UI/L]	29.57 ± 22.32	29.47 ± 11.52
AST [UI/L]	27.17 ± 16.5	25.5 ± 12.35
Uric acid [mg/dl]	4.97 ± 1.23	5.78 ± 1.73
Urea [mg/dl]	32.17 ± 13.57	32.22 ± 7.77

and gastroscopy, to eliminate possible upper gastro-intestinal tract pathologies. Patients were consulted by an endocrinologist, a nutritionist, a psychologist and, for women, by a gynecologist. All procedures were performed laparoscopically using five trocars.

LAGB was performed typically through pars flaccida (in several cases with perigastric technique), reaching the posterior wall of the stomach with dissector. Afterwards the silicone ring was dragged and closed around the stomach near the angle of His, a 25–40 ml pouch was formed, and then it was combined with the subcutaneal port above the left costal arch.

LSG began with stomach estimation and localization of the crow's foot. Using harmonic scalpel or LigaSure®, major omentum was cut close to stomach wall and medially to gastro-omental vessels. Omentum was cut up to the left diaphragm branch and down 4–6 cm before pylorus. The first load separated the major curvature from the crow's foot, and the next separated it longitudinally from the body to the angle of His. Potential bleeding from line was continuously supplied with electrocoagulation or hemostatic suture. The stomach was reduced to a narrow tube. Then the proof test was performed. Finally, the drain to that region was applied. Patients after LAGB were usually hospitalized for one day, and after LSG for 2–3 days. All were discharged with the recommendation of a low energy, low sodium and semi liquid diet for the first two weeks, with the continuance of a low-fat and low carbohydrate diet, and of a control visit every month. All patients were examined preoperatively, and seven days, then one, three and six months after the surgery, fasting 10–12 hours, by taking a clot blood sample, which was then centrifuged to obtain serum. Changes in ghrelin, insulin, glucose, total cholesterol, LDL-cholesterol, HDL-cholesterol, triglycerides, ALT, AST, urea and uric acid were determined after the surgery, which could serve as a criterion for proper technique selection in order to achieve the most effective results in treating comorbidities. Ghrelin was determined using Ghrelin (Total) RIA KIT, (Millipore, Billerica, MA, USA). As the objective criteria, we considered %EWL, %EBL and HOMA-IR. HOMA IR was calculated using the formula: HOMA-IR = {[fast insulin [mU/mL] × fast glucose [mmol/l]} / 22.5 [23]. Percentage of effective weight loss (%EWL) and %EBL were calculated according to the guidelines from 2007 [24].

Statistical analysis was performed using Statistica 6.0 software for Windows. All values were given as mean ± SD. The Mann–Whitney test was used for examining the differences between preoperative and postoperative values. A value of $p < 0.05$ was considered to be significant [25].

Results

Having reviewed the material, it was found that a statistically significant reduction of BMI in patients undergoing LAGB began seven days after the operation (41.74 ± 3.83 kg/m^2) compared to the preoperative values (45.21 ± 3.96 kg/m^2). Similar observations concerned one, three and six months after the surgery (respectively 39.23 ± 3.91 kg/m^2, 35.59 ± 4.11 kg/m^2, 31.26 ± 5.31 kg/m^2).

Folia Histochem Cytobiol. 2012
10.5603/FHC.2012.0039

Table 2. Changes in BMI, plasma ghrelin, insulin, glucose, total cholesterol, HDL- and LDL-cholesterol, triglycerides, AST, ALT concentrations and HOMA IR seven days, one, three and six months post LAGB (**A**) and LSG (**B**) vs. preoperative condition (NS – not significant)

A

LAGB	Prior to surgery	7 days		1 month		3 months		6 months	
			p		p		p		p
BMI [kg/m^2]	45.21 ± 3.96	41.74 ± 3.83*	< 0.01	39.23 ± 3.91*	< 0.00001	35.59 ± 4.11*	< 0.00001	31.26 ± 5.31*	< 0.00001
Ghrelin [pg/Ml]	661.98± 180.5	649.61 ± 205.76	NS	875.67 ± 83.47*	< 0.05	929.3 ± 172.49*	< 0.05	798.99 ± 153.92	NS
Insulin [μU/L]	22.71 ± 6.17	13.44 ± 3.84*	< 0.05	12.38 ± 5.6*	< 0.05	9.52 ± 2.86*	< 0.01	9.2 ± 0.54*	< 0.01
Glucose [mg/dL]	105.63 ± 2 8.87	92.43 ± 10.84	NS	96.25 ± 5.5	NS	96.75 ± 6.18	NS	93.5 ± 1.7	NS
HOMA IR	6.83 ± 6.12	3.83 ± 2.12	NS	3.4 ± 1.94	NS	3.41 ± 2.09	NS	3.87 ± 1.74	NS
Total cholesterol [mg/dL]	207.37 ± 14.09	187 ± 20.39	NS	179.75 ± 11.2	NS	173.25 ± 4.6*	< 0.001	178.6 ± 8.32*	< 0.01
HDL [mg/dL]	44.7 ± 10.04	31.45 ± 14.73	NS	35.1 ± 5.14	NS	38.6 ± 6.05	NS	37.07 ± 9.95	NS
LDL [mg/dL]	148 ± 20.02	132 ± 33.85	NS	134.75 ± 9.63	NS	125 ± 10.96*	< 0.05	124.57 ± 2.89*	< 0.05
Triglycerides [mg/dL]	127.25 ± 7.52	109.84 ± 15.54	NS	105.67 ± 13.44	NS	94.4 ± 13.68*	< 0.05	81.5 ± 13.62*	< 0.05
AST [IU/L]	27.17 ± 16.5	31.5 ± 19.98	NS	18 ± 7.1	NS	15.75 ± 7.1	NS	17.83 ± 4.07	NS
ALT [IU/L]	29.57 ± 22.32	31.57 ± 17.38	NS	22 ± 13.59	NS	19.25 ± 12.09	NS	23 ± 11.28	NS

B

LSG	Prior to surgery	7 days		1 month		3 months		6 months	
			p		p		p		p
BMI [kg/m^2]	52.15 ± 8.5	48.23 ± 8.16	NS	45.81 ± 7.71*	< 0.01	42.72 ± 6.86*	< 0.00001	37.98 ± 4.97*	< 0.00001
Ghrelin [pg/Ml]	491.49 ± 176.27	410.17 ± 91.56*	< 0.05	395.57 ± 58.76*	< 0.05	380.01 ± 60.78*	< 0.05	389.08 ± 33.01*	< 0.05
Insulin [μU/L]	42.9 ± 28.82	21.4 ± 18.86*	< 0.05	19.31 ± 16.24*	< 0.01	16.69 ± 13.55*	< 0.01	16.01 ± 8,41*	< 0.05
Glucose [mg/dL]	147.7 ± 61.64	112.79 ± 26.56*	< 0.05	103.87 ± 12.06*	< 0.05	101.53 ± 10.5*	< 0.01	98,42 ± 7,8*	< 0.05
HOMA IR	12.22 ± 13.4	5.11 ± 4.09*	< 0.05	4.02 ± 3.2*	< 0.001	4.22 ± 3.48*	< 0.01	3,52 ± 2.52*	< 0.01
Total cholesterol [mg/dL]	213.08 ± 19.68	206.14 ± 12.74	NS	210.55 ± 28.95	NS	185.6 ± 11.36*	< 0.0001	182.22 ± 9.28*	< 0.0001
HDL [mg/dL]	42.48 ± 11.19	28.85 ± 5.97	NS	36.47 ± 10.62	NS	39.88 ± 9.15	NS	43.8 ± 8.77	NS
LDL [mg/dL]	138.44 ± 35.31	121.39 ± 25.06	NS	132.92 ± 26.98	NS	110.51 ± 22.37*	< 0.05	111.78 ± 9.12*	< 0.05
Triglycerides [mg/dL]	166.3 ± 51.64	151.57 ± 22.36	NS	122.64 ± 28.54*	< 0.01	118.43 ± 20.46*	< 0.01	116.45 ± 36.01*	< 0.01
AST [IU/L]	25.5 ± 12.35	31 38 ± 11.51	NS	24.8 ± 9.78	NS	19.35 ± 6.5	NS	22.1 ± 11.16	NS
ALT [IU/L]	29.47 ± 11.52	35.78 ± 12.22	NS	29.71 ± 11.29	NS	24.1 ± 9.68	NS	23.23 ± 11.16	NS

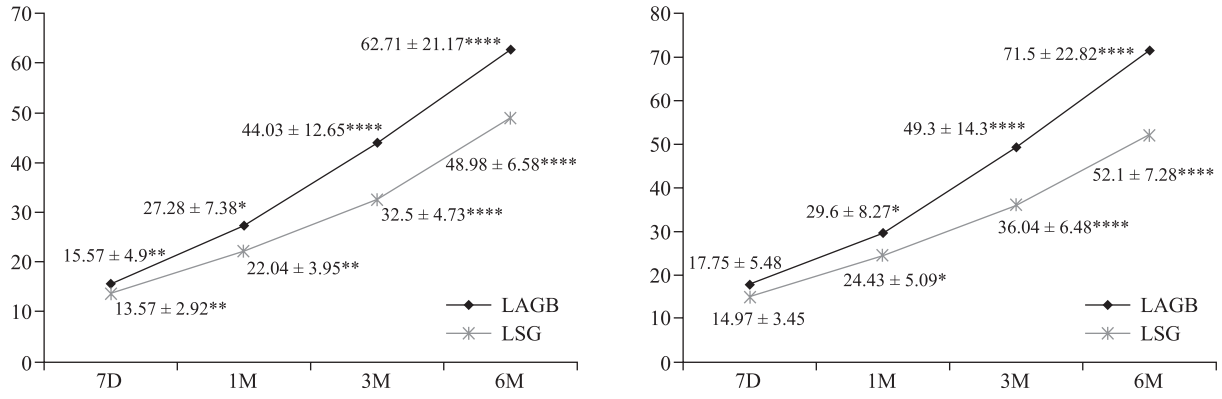

Figure 1. Comparison of %EWL (**A**) and %EBL (**B**) after seven days, one, three and six months in patients after LAGB and LSG. (*p < 0.01; **p < 0.05; ***p < 0.001; **** p < 0.00001)

During the six-month follow-up, %EWL and %EBL was observed in both groups of patients. Seven days after the surgery in the LSG group, we noted a %EWL 13.57 ± 2.92%; after one month — 22.04 ± ± 3.95%; after three months — 32.5 ± 4.73%; and after six months — 48.98 ± 6.58%. In the LAGB group, the %EWL was higher than in the LSG group seven days after the surgery (15.57 ± 4.9%), and remained at the same level after one month (27.28 ± ± 7.38%); three months (44.03 ± 12.65%); and six months (62.71 ± 21.17%). %EBL in the LSG group after seven days reached 14.97 ± 3.45% — p irrelevant, after one month — 24.43 ± 5.09%; after three months — 36.04 ± 6.48%; and after six months — 52.1 ± 7.28%. %EBL in different periods in the LAGB group amounted to 17.75 ± 5.48%, p irrelevant seven days after the surgery, 29.6 ± 8.27% after one month, 49.3 ± 14.3% after three months and 71.5 ± ± 22.82% after six months. %EWL and %EBL increased after both bariatric procedures during the whole of our follow-up (Figure 1).

Among all the analyzed parameters, the most significant differences in both groups of patients were observed in ghrelin. In the LSG group, we observed a statistically significant reduction of ghrelin seven days after the surgery (410.17 ± 91.56 pg/mL) compared to the preoperative period (491.49 ± 176.27). Further observation showed a statistically significant decrease of ghrelin after one, three and six months (respectively 395.57 ± ± 58.76 pg/mL, 380.01 ± 60.78 pg/mL, and 389.08 ± ± 33.01 pg/mL). However, in patients after LAGB, a statistically significant increase of ghrelin was observed one month and three months after the surgery (respectively 875.67 ± 83.47 pg/mL and 929.3 ± ± 172.49 pg/mL), compared to the preoperative period (661.98 ± 180.5 pg/mL). In this group of LAGB patients, a reduction after seven days (649.61 ± ± 205.76 pg/mL), and an increase after six months (798.99 ± 153.92 pg/mL), were statistically insignificant. Changes in concentration of ghrelin in individual follow-up are presented in Table 3.

During the entire six-month postoperative observation of patients after LAGB, statistically significant changes in plasma insulin were observed, not only seven days after the surgery (13.44 ± 3.84 μU/L) compared to the preoperative value (22.71 ± 6.17 μU/L), but also one month (12.38 ± 5.6 μU/L), three months (9.52 ± 2.86 μU/L) and six months after surgery (9.2 ± 0.54 μU/L). Analysis of changes in plasma insulin proved the results to be statistically significant. Seven days after the surgery, in patients after LAGB,

Table 3. Improvement of T2DM, hypertension and sleep apnea after LAGB and LSG in a six-month follow-up

	LAGB				LSG			
	Prior to surgery		6 months		Prior to surgery		6 months	
	n	%	n	%	n	%	n	%
Type 2 diabetes	8	8	4	50	39	39	21	53.84
Hypertension	12	12	7	58.33	56	56	26	46.28
Sleep apnea	5	5	3	60	31	31	16	51.61

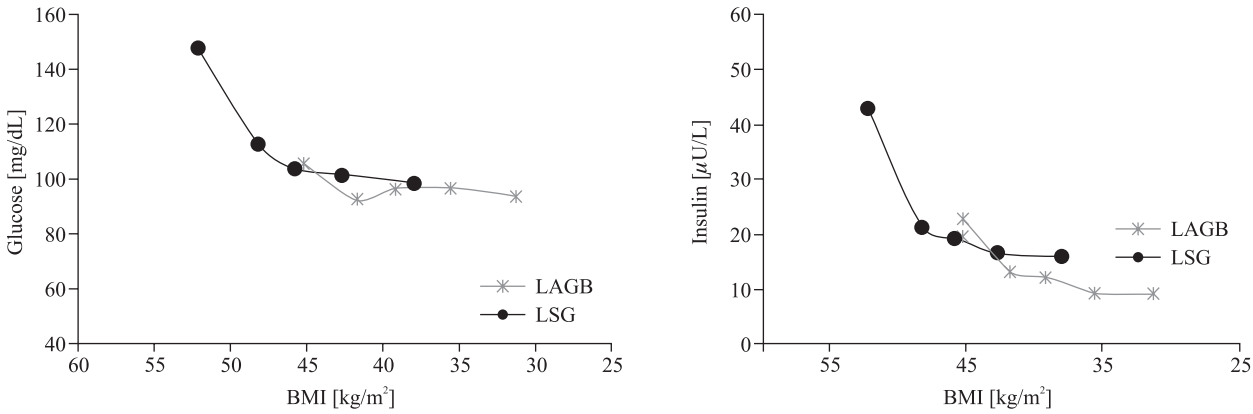

Figure 2. Correlation of BMI/plasma glucose (**A**) and BMI/plasma insulin (**B**) in patients after LAGB and LSG

insulin levels had halved (21.4 ± 18.86 μU/L) compared to the values before the surgery (42.9 ± 28.82 μU/L). Further measurements of the insulin in this group of respondents showed further decreases one month (19.31 ± 16.24 μU/L), three months (16.69 ± ± 13.55 μU/L) and six months after surgery (16.01 ± ± 8.41 μU/L) (Table 3).

All results of glucose in the LSG group were statistically significant compared to preoperative levels (147.7 ± 61.64 mg/dL). Seven days after the surgery, a decrease (112.79 ± 26.56 mg/dL) was observed, which also occurred after one month (103.87 ± 12.06 mg/dL), three months (101.53 ± 10.5 mg/dL) and six months after the operation (98.42 ± 7.8 mg/dL). In contrast to the LSG group, examined glucose values in patients after LAGB were statistically insignificant. After the analysis of all glucose data, we noticed that preoperative value (105.63 ± 28.87 mg/dL) had reduced seven days after surgery (92.43 ± 10.84 mg/dL). After one month (96.25 ± 5.5 mg/dL) and three months (96.75 ± 6.18 mg/dL) we observed an increase, and finally, after six months, a statistically significant reduction (93.5 ± 1.7 mg/dL).

Correlations between glucose and BMI loss (Figure 2A), and between insulin and BMI loss (Figure 2B) are both more favorable for LSG. Our study proved that HOMA IR rate was statistically significant in patients treated with the LSG technique, where we noticed the increase to 5.11 ± 4.09 seven days after the surgery, compared to the preoperative value (12.22 ± 13.4) and after one month to 4.02 ± 3.2. After three months, the parameter increased to 4.22 ± ± 3.48, but after six months it reduced to 3.52 ± 2.52. In patients after LAGB, the preoperative rate of HOMA IR (6.83 ± 6.12) decreased seven days after the surgery (3.83 ± 2.12) and after one month (3.4 ± ± 1.94). After three months, this level was maintained (3.41 ± 2.09) but it increased after six months (3.87 ± ± 1.74). All these results were statistically insignificant in the LAGB group.

The results of total cholesterol were different. In patients after LAGB, compared to preoperative values (207.37 ± 14.09 mg/dL), cholesterol level decreased seven days after the surgery (187 ± 20.39 mg/dL) and after one month (179.75 ± 11.2 mg/dL). Both results were statistically insignificant. However, the decrease after three months (173.25 ± 4.6 mg/dL) and a slight increase after six months (178.6 ± 8.32 mg/dL) were statistically significant. In the LSG group, the preoperative value (213.08 ± 19.68 mg/ /dL) had slightly decreased seven days after the surgery (206.14 ± 12.74 mg/dL) but increased after one month (210.55 ± 28.95 mg/dL). The further two results were statistically significant: a decrease after three months (185.6 ± 11.36 mg/dL), and a slight decrease after six months (182.22 ± 9.28 mg/dL). After examining changes in the concentration of triglycerides in the LSG group, we observed a statistically significant decrease of its value after one month (122.64 ± 28.54 mg/dL), three months (118.43 ± 20.46 mg/dL) and six months after the surgery (116.45 ± ± 36.01 mg/dL), compared to preoperative values (166.3 ± 51.64 mg/dL). The decrease of triglyceride values seven days after surgery (151.57 ± 22.36 mg/dL) was statistically insignificant. However, in the LAGB group, preoperative levels of triglycerides (127.25 ± ± 27.52 mg/dL) significantly decreased after three months (94.4 ± 13.68 mg/dL) and after six months (81.5 ± 13.62 mg/dL). The lowering of concentration after seven days (109.84 ± 15.54 mg/dL) and after one month (105.67 ± 13.44 mg/dL) was statistically insignificant.

All the results of HDL cholesterol from the LAGB and LSG groups were statistically insignificant. In the

LAGB group, compared to the preoperative value (44.7 ± 10.04 mg/dL), we found a significant reduction after seven days (31.45 ± 14.73 mg/dL). Subsequently, we observed an increase after one month (35.1 ± 5.14 mg/dL) and after three months (38.6 ± ± 6.05 mg/dL), and a decrease after six months (37.07 ± ± 9.95 mg/dL). In the group of patients after LSG, preoperative levels of HDL (42.48 ± 11.19 mg/dL) had also significantly decreased after seven days (28.85 ± ± 5.97 mg/dL). However, further observations showed an increase after one month (36.47 ± 10.62 mg/dL), three months (39.88 ± 9.15 mg/dL) and six months (43.8 ± 8.77 mg/dL).

After comparing preoperative values of another fraction of cholesterol, LDL cholesterol, in the LAGB group (148 ± 20.02 mg/dL), we noticed a decrease after seven days (132 ± 33.85 mg/dL), and an increase after one month (134.75 ± 9.63 mg/dL). The results were statistically insignificant. However, after three months (125 ± 10.96 mg/dL), and after six months (124.57 ± 2.89 mg/dL), the observed declines were found to be statistically significant. Further changes were statistically significant both after three months (110.51 ± 22.37 mg/dL) and after six months (111.78 ± ± 9.12 mg/dL). All measurements of ALT, in both groups of patients, were statistically insignificant.

In patients after LAGB, ALT increased seven days after the surgery (31.57 ± 17.38 IU/L) compared to the preoperative value (29.57 ± 22.32 IU/L). We observed a decrease after one month (22 ± 13.59 IU/L) and after three months (19.25 ± 12.09 IU/L). After six months, we noticed a slight increase (23 ± 11.28 IU/L), but it did not reach initial values. In the group of patients after LSG, after seven days an increase occurred (35.78 ± 12.22 IU/L) compared to preoperative values (29.47 ± 11.52 IU/L). In the further follow-up, we observed declines (29.71 ± 11.29 IU/L) after three months (24.1 ± 9.68 IU/L) and after six months (23.23 ± 11.16 IU/L). AST in patients after LAGB seven days after the surgery was higher (31.5 ± ± 19.98) than the preoperative value (27.17 ± 16.5 IU/L). After one month, we noticed a decrease (18 ± ± 7.1 IU/L), which occurred also after three months (15.75 ± 7.1 IU/L). After six months, as in the case of ALT, we observed an increase (17.83 ± 4.07 IU/L). In the LSG group, seven days after the surgery we recorded a higher (31.38 ± 11.51 IU/L) value than the preoperative value (25.5 ± 12.35 IU/L). A decrease was observed after one month (24.8 ± 9.78 IU/L) and three months (19.35 ± 6.5 IU/L), but after six months we noticed a growth (22.1 ± 11.16 IU/L). Afterwards, we observed a decrease after one month (24.8 ± 9.78 IU/L) and after three months (19.35 ± ± 6.5 IU/L), but an increase after six months (22.1 ± 11.16 IU/L). All measurements of AST were statistically insignificant in both groups.

Among the eight patients with T2DM from the LAGB group, an improvement was observed after six months in four patients, which is 50% of the diabetics in the preoperative group. In the LAGB group, hypertension improved in seven patients (58.33%) out of 12 diagnosed preoperatively. Sleep apnea improved in three patients (60%) from five diagnosed preoperatively. Diabetes, diagnosed preoperatively in 39 patients in the LSG group, improved in 21 patients (53.84%). From the group of 56 patients treated for hypertension, after six months an improvement after LSG was observed in 26 patients (46.28%). At the same time, from the group of 31 patients who before LSG complained of sleep apnea, in 16 (51.61%) a reduction of symptoms was observed. The results of the improvement of comorbidities in our patients are presented in Table 3.

Discussion

The occurrence of obesity is increasing alarmingly orldwide and is reaching epidemic proportions both in developed and developing countries. Treatment limiting the problem of obesity is an important response to this health, psychosocial and socio-economic challenge. Diseases associated with obesity such as HT, T2DM, CVD, dyslipidemia, sleep apnea syndrome, steatosis, gastro-esophageal reflux, peripheral edema, depression, depressive disorders, osteoarthritis and cancers are spreading [26, 27]. Eating habits are of major significance in obesity statistics, and they are closely related to the standard of living and economic status. The highest percentages of obese people are observed in the USA and Western Europe, which most publications respond to. However, recent results indicate a growing number of obese people in developing countries, or in those recently regarded as economically underdeveloped [5]. Poland is witnessing intense progress in bariatric surgery. This is connected with the increasing rate of obesity due to changing lifestyle and eating habits. It appears we are a part of a worldwide trend [6, 7].

Most publications have looked at bariatric procedures from one particular point of view. In our study, we tried to take into consideration a lot of metabolic effects. It is valuable to observe changes not only in one parameter, but also in the correlations of parameter groups. Therefore, in our study we present not only changes in ghrelin, but also in insulin, glucose and parameters of metabolic syndrome, in order to determine which bariatric technique leads to better results in reducing the effects of obesity. There have

been only a few articles published to date that have compared LAGB and LSG. We assumed that parameters of metabolic syndrome will decrease along with the reduction of body mass. We tried to determine whether there is any regular dependence of these parameters upon weight loss. We also asked the question of whether ghrelin — which according to the literature has a different concentration after each bariatric technique and which is produced outside the stomach, has an influence on weight loss, i.e. whether the cells outside the stomach compensate for the loss in ghrelin-producing cells after stomach resection. It has to be established whether such resection of fundus is effective or whether a nonresective reduction of gastric volume is enough [28, 29].

All bariatric procedures lead to a loss of body mass [30]. This applies to LAGB and LSG which have similar short-term results in terms of EWL, approximately 50–65%. The long term results of LAGB are less positive than those obtained after LSG, although the data after LSG is still poor [29, 31]. Our results of weight loss do not differ from the results of other bariatric centers. We observed a decrease of %EWL and %EBL which was maintained throughout the whole six-month follow-up. From this perspective, our results in the LSG group are similar to Armstrong and Malley's [32] as well as Karamanakos' [33] and in the LAGB group to Ponce's [34] and Jong's results [35]. Short-term observations of global studies indicate that the efficiency of both techniques is varied. In our follow-up, we obtained more favorable results in the LAGB group. Longer observations (> 1 year) indicate that further weight loss is more beneficial in the LSG group than in the LAGB group. It occurs after one or two or three years or even longer, but the largest effect can be observed one year and two years after the surgery [36–39].

LSG inhibits the production of ghrelin in 90% of cases, while LAGB only does so in 1% [40]. Age and sex do not influence the activity of ghrelin. Food intake plays the key role. Schindler et al. showed an increase in ghrelin level after LAGB simultaneous reduction of appetite, which is rather the result of changes in eating habits than changes in peripheral ghrelin concentrations [41]. Ghrelin concentration decreases more steeply after a meal rich in carbohydrates than one rich in fats. The effects of a high-protein meal as described in the literature often contradict each other in different sources [13, 42].

It has been found that despite the reduction of ghrelin levels, patients continue to lose body weight. This suggests that the relationship between ghrelin levels and weight loss is highly complex. Medical data leads to a consensus that an increase of ghrelin levels is induced by nonsurgical methods, such as low-calorie diet, lifestyle modification, regular physical activity, anorexic, or cardiac, cancer and liver cachexias. On the other hand, different bariatric procedures influence ghrelin levels differently. These discrepancies can be explained by different ways of dealing with the fundus in each bariatric procedure [43].

Comparing patients from both groups, we observed a significant difference in the average concentration of the only known peripheral orexigenic hormone. Here, it has to be noted that in respect to age we qualified older patients more usually to LSG than to LAGB [44], and according to gender, we qualified women to LAGB more usually than men. Women before LAGB were medially five years younger than the group before LSG, and men were medially ten years younger. Could this explain the differences in concentrations of ghrelin in different techniques?

Seven days after surgery, in both the LSG and the LAGB group, a reduction in plasma ghrelin was observed. In the LSG group, a decreasing tendency after one and three months maintained, but after six months a slight increase was noted, similar to the level after one month. We noticed a completely different course of changes in the LAGB group. After one month, a significant increase was noticed, and after three months the increase was maintained, although it was lower. After six months, it had started to reduce. It was significantly higher than preoperative values. In our follow-up, ghrelin levels differed slightly from the results obtained at other centers. A comparison of ghrelin levels by Langer et al. in patients who underwent LAGB and LSG has shown that the LSG evoked a significant decrease in ghrelin on the first day after surgery. Low levels were stable after one month and six months, while after the LAGB, after one month and after six months, an increase occurred. After the LSG, reduction of ghrelin was significant and permanent, as it was not after the LAGB. In addition, LSG resulted in a more significant decrease in body weight loss after one and after six months than LAGB [45]. Bohdjalian et al. [46] described declined ghrelin values after one, three and six months, and they noticed that those values were stable one year or even five years later, in terms of both total and acylated ghrelin.

Based on these results, some scientists have postulated that LSG should be the first choice in the treatment of superobesity [47, 48]. Based on our own experience and on the results from other centers, we can assume that the reduction in ghrelin levels may influence weight loss, but it is not the only factor which can determine the effectiveness of LSG in the treatment of obesity [49].

The test results are not fully explained when the interaction between ghrelin and insulin is taken into consideration. Saad et al. pointed out that insulin is a physiological and dynamic modulator of plasma ghrelin, and insulinemia mediates between nutrition status and energy balance and ghrelin levels in plasma [50]. Another study has confirmed that in obese patients, insulinemia and insulin are inversely associated with low ghrelin levels in plasma, and thus may have a feedback loop in the regulation of body weight [51].

Bariatric procedures causing loss of body weight improve glucose metabolism and reduce insulin resistance, which explains the results in remission of T2DM. In regard to the unquestionable impact of bariatric procedures on the T2DM [52], in which hyperinsulinemia is closely associated with insulin resistance [53], the LAGB is ambiguous. However, LSG provides tangible benefits, although in this case, we only studied the medium-term research. Moreover, Silecchia et al. documented resolution of insulin nondependent diabetes in 69.2%/76.9% and improvement in 15.4%/15.4% after 12/18 months in superobese patients after LSG [54]. In a retrospective study of 30 patients after LSG, DM resolution in 27% of patients was observed after two months and in 63% after six months. Patients with T2DM lasting < 5 years experienced more favorable results after bariatric treatment [55]. Rizzello et al. showed a rapid improvement of insulin, including insulin resistance after LSG not connected with EWL [56].

The relationship between insulin resistance and obesity has been examined and documented. Buchwald's meta-analysis found resolution in 78% and resolution/improvement in 87% of patients with T2DM after bariatric procedures. For example, in the LAGB group, over 50% of patients experienced a resolution. In terms of benefits in the resolution of T2DM and weight loss, LAGB is less effective than gastric bypass. This leads us to suppose that LSG would be found between these two, and would lead to more beneficial effects on diabetes than LAGB [57]. In a study comparing LAGB and LSG, Frezza et al. found that LSG provides a greater weight loss and better control of glucose at 12 and 18 months than LAGB, suggesting that resection of the stomach fundus plays an important, though as yet not completely explained, role [29].

Another comparison of both surgical techniques led to a statistically significant finding that in the LSG group resolution or remission of T2DM, HT and hyperlipidemia improved [58]. We also noticed that after LAGB and LSG, and having weight loss determined, there was an improvement in symptoms of metabolic syndrome components, but the effect was stronger after LSG. This results in reduction of the demand for previously used medications. Parikh et al. examined the effect of LAGB on %EWL in diabetics and the use of oral hypoglycemics in the postoperative period. They observed that after one year, %EWL decreased by 43%, and after two years by 50%, and that after one year 39% of the patients in this group required oral hypoglycemics, and after two years — 34%. After one year, 14% of patients required insulin, and after two years — 18% [59].

Furthermore, LSG and LAGB are comparable when T2DM and the metabolic syndrome remission after one year of observation are taken into consideration [60, 61]. Peterli et al. observed the reduction of plasma insulin and glucose levels seven days and three months after LSG, which was similar to the results after LGBP. Therefore, the authors suggest that the small intestine does not mediate significantly in improving glucose homeostasis [62].

On the other hand, Lee et al. compared the change in insulin resistance in patients after one, three and six months and 1one, two and three years after LAGB and LGBP. They found that both techniques led to lower insulin resistance, without a clear effect of exclusion of the duodenum and small intestine [63]. In their opinion, the improvement was related to weight loss, and not to the chosen surgical technique. Another comparison of patients after LAGB and LGBP shows significant impact of %EWL on improving insulin resistance after one year in both cases [64].

During our research, we found significant differences in insulin and glucose concentrations between groups of patients after LAGB and LSG. In both groups, we observed a statistically significant reduction in insulin. The most significant decrease occurred seven days and three months after the surgery. In both cases, we noted a decrease in glucose levels after seven days, while the effect was more visible and statistically significant in the LSG group. Glycemia after LSG decreased after a month, while in the LAGB group we noticed a slight increase in blood glucose compared to the measurement after seven days, which continued to increase after three months but decreased after six months. Insulin resistance expressed by HOMA IR among our patients showed more noticeable reduction seven days and one month after the surgery in the LSG group than in the LAGB group. Moreover, changes after six months in both groups were insignificant, but in the LAGB group a slight increase occurred, and in the LSG group a slight decrease.

As research indicates, in patients with second and third degree obesity, metabolic surgery has surpris-

ingly positive results in the reversibility of the consequences of metabolic syndrome, mainly through weight loss. But we also need to include preoperative levels of TG and diabetic status [65]. Although only a few publications have examined the effects of different surgical techniques on metabolic syndrome, we know already that both LAGB [66] and LSG [54] contribute to a noticeable improvement of the other components of metabolic syndrome, such as triglycerides, cholesterol and its fractions. In the case of LSG, long-term studies show that weight loss does not always improve lipid parameters [67]. As already stated, LSG has a similar effect on the metabolic syndrome as LGBP [68]. However, other studies have claimed that LGBP improves metabolic syndrome more significantly than LSG [69]. In our material, reduction of triglyceridemia was visible after seven days, but the highest decrease was observed after one month, and later it decreased much less rapidly. In addition, total cholesterol was reduced in both groups after six months. In both cases, within six months a gradual reduction of triglyceridemia occurred. In LAGB, a less significant decrease occurred after one month, while at the same time the decline was the highest after LSG. HDL after six months was characterized by similar changes in both cases, although it was more clearly visible after the LSG, especially after seven days and one month. The most significant change was noticeable after six months, when after LSG, HDL-cholesterol continued to increase, but decreased slightly after LAGB. Changes in LDL-cholesterol also were more visible after the LSG, especially after one and three months. The preoperative values of ALT were equal after LAGB and LSG. After seven days, one month and three months, those values significantly differed from each other, but after six months they were the same again. On the seventh postoperative day, ALT and AST values increased, which we believe was a result of the surgery.

Chen et al., in their study, attempted to demonstrate that there is a synergistic relationship between obesity, insulin resistance and ALAT. They suggest that such coexistence can be more clinically valuable in diagnosing insulin resistance than the metabolic syndrome [70].

Bariatric surgery has become the treatment of choice for morbid obesity and as the only one proven in the long-term control of weight loss. Moreover, the majority of patients with comorbidities have reached a complete recovery or improvement. It has also been noticed that in patients with a higher number of comorbidities, the impact of bariatric surgery was greater [71]. The weight loss after LSG is achieved in a restrictive way and by hormonal modulation. Restriction plays the most important role after LAGB. In our center, LAGB and LSG are currently the two most commonly applied bariatric techniques [72].

Examining the history of bariatric surgery, the constant development of technology and standards of treatment can be observed. It can be stated that this evolution leads to the reduction of the risk of postoperative complications and patient discomfort, which also considerably influence the effects of treatment. The application of SG as a sole and definitive treatment can be regarded as a significant development. Gastric resection was so for an integral part of one-step procedure [47].

Not only in terms of the potential metabolic benefits must an important remark be made regarding the recently described combination of sleeve gastrectomy and gastric banding as an initial treatment [73]. It would be useful to consider the effects of connection of restrictive and malabsorptive techniques. It seems that this method may have a justification, since the band protects against stretching the stomach, and resection of the gastric fundus with the ghrelin-producing cells reduces hunger. However, these arguments require clinical revision.

One of the first publications discussing glucose homeostasis and weight loss in patients undergoing the sleeve + banding technique [74] was recently released. The developments it describes are promising, but due to the small number of patients and the short follow-up, they require further observation.

Conclusions

Both surgical techniques lead to weight loss, although in long-term follow-up, %EBL increases more effectively after LAGB.

According to our observations, and the opinions of other authors, we conclude that the improvement of metabolic parameters is a result of weight loss, and not a consequence of bariatric procedure. Ghrelin level after LSG is reduced due to the resection of the fundus and body of the stomach, which abates the consumption of carbohydrates and fats.

Bariatric treatment has a directly beneficial impact on patients' health status by reducing the symptoms of comorbidities such as T2DM, HT and sleep apnea. Both techniques contribute to the improvement or resolution of T2DM by reducing insulin resistance and glucose metabolism.

Acknowledgements

This study was supported by UMB grant No 3-40-632 L.

Disclosure of any commercial interest

The authors have no disclosure to make of any commercial interest in the subject of the study or in the source of any support.

References

1. Grundy SM. Multifactorial causation of obesity: implications for prevention. *Am J Clin Nutr.* 1998;67(Suppl):563S–572S.
2. Hill JO, Peters JC. Environmental contributions to the obesity epidemic. *Science.* 1998;280:1371–1374.
3. Hady RH, Zbucki RL, Luba ME et al. Obesity as social disease and the influence of environmental factors on BMI in own material. *Adv Clin Exp Med.* 2010;19:369–378.
4. Ogden CL, Yanovsky SZ, Carroll MD et al. The epidemiology of obesity. *Gastroenterology.* 2007;132:2087–2102.
5. Prentice AM. The emerging epidemic of obesity in developing countries. *Int J Epidemiol.* 2006;35:93–99.
6. Wylezol M, Pasnik K, Dabrowiecki S et al. Polish recommendations for bariatric surgery. *Videosurgery and other miniinvasive techniques.* 2009;4(Suppl 1):S5–S8.
7. Milewicz A, Jedrzejuk D, Lwow F et al. Prevelance of obesity in Poland. *Obes Rev.* 2005;6:113–114.
8. Kojima M, Hosoda H, Date Y et al. Ghrelin is a growth-hormone releasing acylated peptide from stomach. *Nature.* 1999;402:656–660.
9. Date Y, Kojima M, Hosoda H et al. Ghrelin, a novel growth hormone-releasing acylated peptide, is synthesized in distinct endocrine cell type in gastrointenstinal tracts of rats and humans. *Endocrinol.* 2000;141:4255–4261.
10. Muccioli G, Tschop M, Papotti M et al. Neuroendocrine and peripheral activities of ghrelin: implications in metabolism and obesity. *Eur J Pharmacol.* 2002;440:235–254.
11. Rigamonti AE, Pincelli AI, Corra B et al. Plasma ghrelin concentrations in elderly subjects: comparison with anorexic and obese patients. *J Endocrinol.* 2002;175:1–5.
12. Broglio F, Arvat E, Benso A et al. Ghrelin, a natural GH secretagogue produced by the stomach, induces hyperglycemia and reduces insulin secretion in humans. *J Clin Endocrinol Metab.* 2001;86:5083–5086.
13. Castańeda TR, Tong J, Datta R et al. Ghrelin in the regulation of body weight and metabolism. *Front Neuroendocrinol.* 2010;31:44–60.
14. Dadan J, Hady RH, Zbucki RL et al. The activity of gastric ghrelin positive cells in obese patients treated surgically. *Folia Histochem Cytobiol.* 2009;47:307–313.
15. Després JP, Lemieux I. Abdominal obesity and metabolic syndrome. *Nature.* 2006;444:881–887.
16. World Health Organization. Definition, diagnosis and classification of diabetes mellitus and its complications: report of a WHO Consultation. Part 1: diagnosis and classification of diabetes mellitus. Geneva, Switzerland: World Health Organization; 1999. Available at: http://whqlibdoc.who.int/hq/1999//WHO_NCD_NCS_99.2.pdf.
17. Grundy SM, Brewer HB, Cleeman JI et al. Definition of metabolic syndrome: report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. *Circulation.* 2004;109;433–438.
18. Iannelli A, Dainese R, Piche T et al. Laparoscopic sleeve gastrectomy for morbid obesity. *World J Gastroenterol.* 2008;14:821–827.
19. Morino M, Toppino M, Garrone C et al. Laparoscopic adjustable silicone gastric banding for the treatment of morbid obesity. *Br J Surg.* 1994;81:1169–1170.
20. Marceau P, Hould FS, Simard S et al. Biliopancreatic diversion with duodenal switch. *World J Surg.* 1998;22:947–954.
21. Johnston D, Dachtler J, Sue-Ling HM et al. The Magenstrasse and Mill operation for morbid obesity. *Obes Surg.* 2003;13:10–16.
22. Buchwald H, Oien D. Metabolic/bariatric surgery worldwide 2008. *Obes Surg.* 2009;19:1605–1611.
23. Wallace TM, Levy JC, Matthews DR. Use and abuse of HOMA modeling. *Diabetes Care.* 2004;27:1487–1495.
24. Deitel M, Gawdat K, Melissas J. Reporting weight loss 2007. *Obes Surg.* 2007;17:565–568.
25. Klingler A. Statistical methods in surgical research — a practical guide. *Eur Surg.* 2004;36:80–84.
26. Steinbrook R. Surgery for severe obesity. *N Eng J Med.* 2004;350:1075–1079.
27. Tice JA, Karliner L, Walsh J et al. Gastric banding or bypass? A systematic review comparing the two most popular bariatric procedures. *Am J Med.* 2008;121:885–893.
28. Pérez-Romero N, Serra A, Granada ML et al. Effects of two variants of Roux-en-Y gastric bypass on metabolism behaviour: focus on plasma ghrelin concentrations over a 2-year follow-up. *Obes Surg*. 2010;20:600–690.
29. Frezza EE, Wozniak SE, Gee L et al. Is there any role of resecting the stomach to ameliorate weight loss and sugar control in morbidly obese diabetic patients? *Obes Surg.* 2009;19:1139–1142.
30. Buchwald H, Avidor Y, Braunwald et al. E. Bariatric surgery: a systematic review and meta-analysis. *JAMA.* 2004;292:1724–1737.
31. Nocca D. Laparoscopic adjustable gastric banding and laparoscopic sleeve gastrectomy: which has a place in the treatment of diabetes in morbidly obese patients? *Diabetes Metab.* 2009;35:524–527.
32. Armstrong J, O'Malley SP. Outcomes of sleeve gastrectomy for morbid obesity: a safe and effective procedure? *Int J Surg.* 2010;8:69–71.
33. 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. *Ann Surg.* 2008;247:401–407.
34. Ponce J, Paynter S, Fromm R. Laparoscopic adjustable gastric banding: 1,014 consecutive cases. *J Am Coll Surg.* 2005;201:529–535.
35. de Jong JR, van Ramshorst B, Gooszen HG et al. Weight loss after laparoscopic adjustable gastric banding is not caused by altered gastric emptying. *Obes Surg.* 2009;19:287–292.
36. Himpens J, Dapri G, Cadičre GB. A prospective randomizeds between laparoscopic gastric banding and laparoscopic isolated sleeve gastrectomy: results after 1 and 3 years. *Obes Surg.* 2006;16:1450–1456.
37. Shi X, Karmali S, Sharma AM et al. A review of laparoscopic sleeve gastrectomy for morbid obesity. *Obes Surg.* 2010;20:1171–1177.
38. Sjöström L, Narbro K, Sjöström CD et al. Effects of bariatric surgery on mortality in Swedish obese subjects. *N Engl J Med.* 2007;357:741–752.
39. Himpens J, Dobbeleir J, Peeters G. Long-term results of laparoscopic sleeve gastrectomy for obesity. *Ann Surg.* 2010;252:319–324.

40. Gagner M, Deitel M, Kalberer TL et al. The second international consensus summit for sleeve gastrectomy, March 19–21, 2009. *Surg Obes Relat Dis.* 2009;5:476–485.
41. Schindler K, Prager G, Ballaban T et al. Impact of laparoscopic adjustable gastric banding on plasma ghrelin, eating behaviour and body weight. *Eur J Clin Inv.* 2004;34:549–554.
42. De Vriese C, Delporte C. Ghrelin: A new peptide regulating growth hormone release and food intake. *Int J Biochem Cell Biol.* 2008;40:1420–1424.
43. Fruhbeck G, Diez Caballero A, Gil MJ. Fundus functionality and ghrelin concentrations after bariatric surgery. *N Eng J Med.* 2004;350:308–309.
44. Wölnerhanssen BK, Peters T, Kern B et al. Predictors of outcome in treatment of morbid obesity by laparoscopic adjustable gastric banding: results of a prospective study of 380 patients. *Surg Obes Relat Dis.* 2008;4:500–506.
45. Langer FB, Reza Hoda MA, Bohdjalian A et al. Sleeve gastrectomy and gastric banding: effects on plasma ghrelin levels. *Obes Surg.* 2005;15:1024–1029.
46. Bohdjalian A, Langer FB, Shakeri-Leidenmühler S et al. Sleeve gastrectomy as sole and definitive bariatric procedure: 5-year results for weight loss and ghrelin. *Obes Surg.* 2010;20:535–540.
47. Sammour T, Hill AG, Singh P et al. Laparoscopic sleeve gastrectomy as a single-stage bariatric procedure. *Obes Surg.* 2010;20:271–275.
48. Basso N, Casella G, Rizzello M et al. Laparoscopic sleeve gastrectomy as first stage or definitive intent in 300 consecutive cases. *Surg Endosc.* 2010;25:444–449.
49. Tymitz K, Engel A, McDonough S et al. Changes in ghrelin levels following bariatric surgery: review of the literature. *Obes Surg.* 2011;21:125–130.
50. Saad MF, Bernaba B, Hwu CM et al. Insulin regulates plasma ghrelin concentration. *J Clin Endocrinol Metab.* 2002;87:3997–4000.
51. McLaughlin T, Abbasi F, Lamendola C et al. Plasma ghrelin concentrations are decreased in insulin-resistant obese adults relative to equally obese insulin-sensitive controls. *J Clin Endocrin Metabol.* 2004;89:1630–1635.
52. Spanakis E, Gragnoli C. Bariatric surgery, safety and type 2 diabetes. *Obes Surg.* 2009;19:363–368.
53. Kim SH, Reaven GM. Insulin resistance and hyperinsulinemia. *Diabetes Care*. 2008;31:1433–1438.
54. Silecchia G, Boru C, Pecchia A et al. Effectiveness of laparoscopic sleeve gastrectomy (first stage of biliopancreatic diversion with duodenal switch) on comorbidities in super-obese high-risk patients. *Obes Surg.* 2006;16:1138–1144.
55. Rosenthal R, Li X, Samuel S et al. Effect of sleeve gastrectomy on patients with diabetes mellitus. *Obes Relat Dis.* 2009;5:429–434.
56. Rizzello M, Abbatini F, Casella G et al. Early postoperative insulin-resistance changes after sleeve gastrectomy. *Obes Surg.* 2010;20:50–55.
57. Buchwald H, Estok R, Fahrbach K et al. Weight and type 2 diabetes after bariatric surgery: systematic review and meta-analysis. *Am J Med.* 2009;122:248–256.
58. Omana JJ, Nguyen SQ, Herron D et al. Comparison of comorbidity resolution and improvement between laparoscopic sleeve gastrectomy and laparoscopic adjustable gastric banding. *Surg Endosc.* 2010;24:2513–2517.
59. Parikh M, Ayoung-Chee P, Romanos E et al. Comparison of rates of resolution of diabetes mellitus after gastric banding, gastric bypass, and biliopancreatic diversion. *J Am Coll Surg.* 2007;205:631–635.
60. Vidal J, Ibarzabal A, Nicolau J et al. Short-term effects of sleeve gastrectomy on type 2 diabetes mellitus in severely obese subjects. *Obes Surg.* 2007;17:1069–1074.
61. Fried M, Ribaric G, Buchwald JN et al. Metabolic surgery for the treatment of type 2 diabetes in patients with BMI < 35 kg/m^2: An integrative review of early studies. *Obes Surg.* 2010;20:776–790.
62. Peterli R, Wölnerhanssen 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 prospective randomized trial. *Ann Surg.* 2009;250:234–241.
63. Lee WJ, Lee YC, Ser KH Improvement of insulin resistance after obesity surgery: a comparison of gastric banding and bypass procedures. *Obes Surg.* 2008;18:1119–1125.
64. Ballantyne GH, Wasilewski A, Saunders JK. The surgical treatment of type II diabetes mellitus: changes in HOMA insulin resistance in the first year following laparoscopic Roux-en-Y gastric bypass (LRYGB) and laparoscopic adjustable gastric banding (LAGB). *Obes Surg.* 2009;19:1297–1303.
65. Batsis JA, Romero-Corral A, Collazo-Clavell M et al. The effect of bariatric surgery on the metabolic syndrome: a population-based, long-term controlled study. *Mayo Clin Proc.* 2008;83:897–907.
66. Cunneen SA. Review of meta-analytic comparisons of bariatric surgery with a focus on laparoscopic adjustable gastric banding**.** *Surg Obes Relat Dis.* 2008;4(Suppl 1):S47–S55.
67. Sjöström L, Lindroos AK, Peltonen M et al. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *N Engl J Med.* 2004;351:2683–2693.
68. Vidal J, Ibarzabal A, Romero F et al. Type 2 diabetes mellitus and the metabolic syndrome following sleeve gastrectomy in severely obese subjects. *Obes Surg.* 2008;18:1077–1082.
69. Iannelli A, Anty R, Schneck AS et al. Inflammation, insulin resistance, lipid disturbances, anthropometrics, and metabolic syndrome in morbidly obese patients: a case control study comparing laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy. *Surgery.* 2010;149:364–370.
70. Chen PH, Chen JD, Lin YC. A better parameter in predicting insulin resistance: obesity plus elevated alanine aminotransferase. *World J Gastroenterol.* 2009;28;15:5598–5603.
71. Elder KA, Wolfe BM. Bariatric surgery: a review of procedures and outcomes. *Gastroenterology.* 2007;132:2253–2271.
72. Magee CJ, Barry J, Arumugasamy M et al. Laparoscopic sleeve gastrectomy for high-risk patients: weight loss and comorbidity improvement — short-term results. *Obes Surg.* Published online 10 July 2010.
73. Agrawal S, Dessel E, Akin F et al. Laparoscopic adjustable banded sleeve gastrectomy as a primary procedure for the super-super obese (Body mass index > 60 kg/m^2). *Obes Surg.* 2010;20:1161–1163.
74. Miguel G, Azevedo J, Neto C et al. Glucose homeostasis and weight loss in morbidly obese patients undergoing banded sleeve gastrectomy: a prospective clinical study. *Clinics.* 2009;64:1093–1099.

Sumbitted: 25 May, 2011
Accepted after reviews: 23 November, 2011