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Research Article

The Impact of Bariatric Procedures on Local Gastrointestinal Hormones

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Abstract

Background: Many of the beneficial metabolic effects of bariatric surgery have been attributed to altered peptide hormone profiles, especially involving pancreatic and gut peptides. We aimed to assess the impact of sleeve gastrectomy (SG), one anastomosis gastric bypass (OAGB), and sleeve gastrectomy with loop bipartition (SGLB) on gastrointestinal tract hormones. **Methods:** A case series analysis was carried out at our institution from February 2018 to February 2021. This study included 3 groups subjected to different operations; each group consisted of 50 patients. **Results:** This study included 132 women (88%) and 18 men (12%). Mean age in SG, OAGB and SGLB were 33.5 SD3.89, 30.9 SD7.2, and 40.3 SD6.89 respectively. The percentage of change in Peptide YY levels two weeks postoperatively in SG, OAGB, and SGLB were 29.1%, 40.1%, and 65.6% respectively. In Glucagon-like peptide-1 were 19.3%, 34.1% and 32.8% respectively. However, the percent of change in Ghrelin level two weeks were 36.5%, 50%, and 50.6% respectively. Finally, the percent change in secretin hormone levels were 61.5%, 56.9%, and 46.3% respectively. **Conclusions:** Differences in gastrointestinal hormones that regulate energy and glucose homeostasis are a possible mechanism for more significant weight loss after SGLB and OAGB compared to SG.

Keywords: Bariatric; Ghrelin hormone; Secretin hormone; Glucagon-like peptide-1; Weight loss

Introduction

It is currently estimated that nearly 2 billion adults worldwide are overweight (defined by a body mass index [BMI] ≥25 kg/m2) and a further estimated 500 million are obese (BMI ≥30 kg/m2). It is well known that being overweight or obese carries an increased risk of type 2 diabetes, vascular disease, osteoarthritis, sleep apnea and malignancy[1]. Several therapeutic strategies have been proposed for treating obesity. Intensive lifestyles interventions achieve only 5-6% body weight loss[2] which is not able to be maintained for a long time, despite decreased cardiovascular risk. Many studies have shown that bariatric surgery is a very effective approach in reducing body weight. So far, bariatric surgery remains the most successful option in patients with a BMI ≥ 40 kg/m^2 [3].

There are two ways in which bariatric surgery promotes long-term weight loss. Bariatric procedures are either diversionary or non-diversionary, or a combination of the two. Diversionary procedures enhance weight loss by altering the structure of the digestive tract, allowing food to bypass portions of the small intestine. Diversionary procedures generally incorporate restrictive methods by reducing or limiting the capacity of the stomach for enhanced weight loss. The two combination diversionary and non-diversionary weight loss surgeries are Roux-en-Y gastric bypass (RYGB) surgery and duodenal switch surgery.

Non-diversionary procedures promote weight loss by making changes to stomach capacity. The two leading forms of non-diversionary weight loss surgery procedures are sleeve gastrectomy (SG) surgery and gastric band surgery (GBS) [4].

Many of the beneficial metabolic effects of bariatric surgery have been attributed to altered peptide hormone profiles, especially involving pancreatic and gut peptides. The absorption and digestion of nutrients requires a healthy gastrointestinal tract subjected to the control by nervous and hormonal influences. Several gut hormones are responsible for regulating appetite and satiety and they also control the movement of the gut and hence transit of food through the intestines[5].

In the current study, we aimed to assess the effects of bariatric procedures; SG, one anastomosis gastric bypass (OAGB) and sleeve gastrectomy with loop bipartition (SGLB), on gastrointestinal (GIT) hormones (Ghrelin, secretin, Peptide YY (PYY), Glucagon-like peptide (GLP-1)).

Methods

This prospective observational study was conducted at our department of General Surgery between February 2018 and February 2021. The study included 150 patients who were subdivded to three groups subjected to different operations (SG, OAGB and SGLB). Each group consisted of 50 patients. All patients were thoroughly evaluated by a multidisciplinary team (Nutritionist, Endocrinologist, Psychologist, and Surgeon) using a standardized protocol. Follow up was done after two weeks and after two months. The inclusion criteria were: age range from 20 to 50 years old, morbid obese patients surgically treated with BMI of 40Kg/m^2 or greater, and patients had BMI of 35 Kg/m^2 with comorbidities. Patients being away from our close follow up were excluded from the study.

An independent clinician was responsible for generating a random allocation sequence that kept hidden from all of the trial participants. Based on type of operation, the participants were assigned equally into three groups using a computer-generated block randomization technique. The type of treatment was masked for the patient (single blinded technique).

Sample size was calculated according to the following formula
(Mina Alvandipour et al., 2018).

$$N = \frac{2 \times (z_{\frac{\alpha}{2}} + z_{\beta})^2 \times (1 + (k-1)\,\rho)}{k \times \left[\frac{(\mu_1 - \mu_2)}{\sigma} \right]^2} = 20$$

where $\alpha = 0.05, \beta = 0.1, \mu_1 = 2, \mu_2 = 4, \sigma = 2, K = 4, \rho = 0.9$.

Then we added additional number (30) to guard against drop out.

The questionnaire included: name, age, sex, address, telephone number and date of the surgery, medical history, general examination.

Routine preoperative laboratory investigations included: complete blood count, liver function tests (total and direct bilirubin, AST, ALT, Alkaline Phosphatase, Serum Albumin and total proteins) , renal function tests (blood urea & serum creatinine), random and fasting blood glucose, serum electrolytes (Sodium, Potassium, total & ionized

Calcium), arterial blood gases, prothrombin time & concentration, serum triglycerides and cholesterol. Four GIT hormones were tested: 1- Secretin hormone. 2- Ghrelin hormone. 3- Peptide YY hormone (PYY). 4- Glucagon-like Peptide-1 (GLP1). The studied GIT hormones were tested preoperatively, then two weeks and two months postoperative.

Imaging investigations (plain chest x ray and abdominal ultrasound) and other investigations (pulmonary function tests, ECG, Echo-cardiography if indicated) were performed.

Preoperative Preparations:

Patients were completely informed about the risks of short- and long-term complications of all procedures. Informed consent was obtained from the patients.

Medical evaluation for operative risk assessment:

The importance of a detailed health history and examination by the bariatric surgeon and the multidisciplinary team was a critical part of the preparation for surgery. For all patients, prevention of thromboembolism was done by: Below knee elastic stocking or crepe bandage and daily injections of low-molecular-weight heparin together with sequential leg or foot compression and ambulation on the first postoperative day were the best prophylaxis for postoperative thromboembolism.

For all patients, antibiotics were given in higher doses to morbidly obese patients to obtain adequate serum and tissue levels. Patients took 3rd generation cephalosporin (cephatriaxone 1gm) with induction of anaesthesia and then one 1 gm/12 hours. All of the patients were asked to be on low caloric diet for 2 weeks preoperative. This regimen decreases intraabdominal fat (the gut fat in the mesentery and omentum) more than subcutaneous fat and decrease size of liver, thereby increasing operative access to the abdomen and helping to prevent the development of postoperative intraabdominal compartment syndrome.

Technique of operations:

SG:

In this procedure, the greater curve of the stomach starting at a point 2 to 6cm proximal to the pylorus all the way to the angle of His is freed of greater omentum and vessel secured. Over a 36 French orogastric bougie, a gastric tube is created by resecting the greater curve of the stomach using a cutting stapler along a line joining the initial point of dissection and the angle of His. The reservoir capacity of the stomach is reduced to 200ml. with the advantage of preserving most of the normal digestive stomach function [6].

OAGB:

In this procedure, the patient is positioned in a modified lithotomy. Similar to other contemporary bariatric procedures, OAGB is performed laparoscopically as other procedures, creation of a tubular gastric pouch from the lesser curvature is achieved. This is done by stapling the stomach from the body junction-antral junction toward the angle of His. Although there is a discrepancy regarding the starting point for gastric stapling, there appears to be a tendency to initiate at the level of or directly below the Crow's foot on the lesser curvature. An endoluminal bougie (36 French) is passed through to calibrate the pouch prior to complete resection. Following the formation of the gastric pouch, a jejunal loop, roughly 180 cm from the ligament of Treitz, is brought cephalad in an antecolic/antegastric fashion to create the loop gastrojejunostomy. A linear staple is used for stapling of the anastomosis, with a varying length of 30 to 60 mm. Completely hand-sewn anastomoses have been described[7].

SGLB.

The procedure was performed by minimally invasive approach in French position with five ports (12 mm at umbilicus, 1 mm × 5 mm at right upper quadrant, 1 mm × 10 mm and 1 mm × 5 mm at left upper quadrant and 1 mm × 5 mm ports at epigastrium for liver retraction) as in our standard laparoscopic SG. The greater curvature of stomach including the posterior fundus was mobilized completely from pylorus to the angle of His exposing the left crus of diaphragm. The greater curvature of stomach was transected by a linear stapler (Echelon 60 Endopath Stapler and Cutter. 60 mm, Ethicon, Cincinnati, OH) from antrum (6 cm from pylorus) to angle of His with 38 Fr. calibration tube and the staple line was oversewn with suture. A loop gastroileostomy 250 cm from the ilececal valve was created at the dependent part of the antrum with 2 layers of handsewn suture but without division of the 1st part of duodenum. The resultant stomach tube has two outlets, one to the first part of duodenum through the pylorus and one to the terminal ileum through the gastroileostomy. The operation time was 189 min with minimal blood loss. The staple line and anastomosis was tested with methylene blue test at the end of the procedure [8].

Ethical Consideration:
Following the ethical guidelines, a written informed consent form was developed and attached to all sheets. The objectives of the study and full details were explained to every patient. Subjects were also assured. The aim of the study was explained to every patient.
The work has been reported in line with Consolidated Standards of Reporting Trials (CONSORT) Guidelines.

Statistical analysis:
Statistical presentation and analysis of the present study was conducted, using Mean, Standard Deviation, paired t-test was used to compare between related sample, Analysis of variance [ANOVA] was used for comparison among different times in the same group in quantitative data, paired Student T-test was used to compare between related sample. Linear Correlation coefficient was used for detection of correlation between two quantitative variables in one group and chi-square are computed for 2x2 tables in qualitative data by SPSS version 20. P-value <0.05 was considered significant.

Results

This study included 3 groups subjected to different operations; each group consisted of 50 patients. This study included 132 women (88%) and 18 men (12%). There is significant difference between the three operations in age (p value 0.002*), means of age in SG, OAGB and SGLB were 33.5 SD3.89, 30.9 SD7.2 and 40.3 SD6.89 respectively. There is no significant difference in weight in the three operations (P-value 0.054), means of weight in SG, OAGB and SGLB were 127.75 SD17.04, 136.8 SD26.42 and 148 SD26.8 respectively. There is no significant difference in BMI between the three operations (P-value 0.129), means of BMI in SG, OAGB and SGLB are 48.5 SD5.09, 49.6 SD8.72 and 54.3 SD10.27 respectively.

Percent of change in BMI two-weeks postoperatively in SG, OAGB and SGLB were 6.2%, 7.7% and 7.6% respectively. However, percent of change in BMI two-months postoperatively were 11.8%, 15.9% and 14.7% respectively. So, there is a significant change in BMI in the three operations two-weeks and two-months postoperatively (p value <0.001), as a result, OAGB achieved highest weight loss followed by SGLB (Table 1).

Table 2 showed that percent of change in Ghrelin level two-weeks postoperatively in SG, OAGB and SGLB were 36.5%, 50% and 50.6% respectively. Percent of change in Ghrelin levels two-months postoperatively were 36.5%, 50% and 49.4% respectively. There were statistically significant differences between the three operations regarding Ghrelin level two-weeks and two-months postoperatively (p value <0.001 and 0.005 respectively). As a result, ghrelin hormone dropped the highest in OAGB followed by SGLB and SG.

In the current study, means of preoperative levels of secretin in SG, OAGB and SGLB were 1.69, 1.45 and 3.63 respectively. Means of two-weeks postoperative levels were 0.65, 4.00 and 1.95 with percent of change 61.5%, 56.9% and 46.3% respectively and means of two-months postoperative levels were 0.83, 3.47 and 1.92 with percentage of change 49.1%, 58.2% and 52.9% respectively. As a result, secretin hormone level decreased in SG and SGLB and increased in OAGB.

Table 4 showed that percent of change in PYY level two-weeks postoperatively in SG, OAGB and SGLB are 29.1%, 40.1% and 65.6% respectively. These figures were significantly different from percent of change in PYY levels two-months postoperatively. Furthermore, PYY increased in SGLB followed by OAGB then SG.

In the current study, percent of change in GLP-1 level two-weeks postoperatively in SG, OAGB and SGLB were 19.3%, 34.1% and 32.8% respectively. In comparison with percent of change in GLP 1 levels two-months postoperatively, there was a significant change in GLP1 level in the three operations two-weeks and two-months postoperatively. As a result, GLP-1 increased in OAGB followed by SGLB then SG (Table 5).

Table 6 showed the correlation between levels of hormones and weight loss two months postoperative. In SG, there was a significant negative correlation between weight loss and Secretin level (P-value 0.14*). In OAGB, there was a significant negative correlation between weight loss and Ghrelin level (P-value <0.001**) and significant positive correlation between weight loss and Secretin level (P-value 0.017**), PYY level (P-value 0.015*) and GLP 1 level (P-value 0.006*). In SGLB, there was a significant negative correlation between weight loss and Ghrelin level (P-value < 0.001**), Secretin level (P-value < 0.001**) and significant positive correlation between weight loss and PYY level (P-value < 0.001**) and GLP 1 level (P-value < 0.001**)

Table (1): Relation between BMI changes preoperative, two-weeks and two-months postoperative in the three operations

BMI	Type of Operation										
	Sleeve gastrectomy		Minigastric bypass		Sleeve gastrectomy with loop bipartition		ANOVA		Tukey's test		
	Mean	SD	Mean	SD	Mean	SD	F	P-value	S&M	S&L	M&L
Pre	48.44	5.08	49.70	8.62	54.47	10.35	2.297	0.111	0.844	0.093	0.334
Post 2wks.	45.44	4.87	45.89	8.51	50.3	9.92	1.698	0.193	0.977	0.166	0.338
% of change	6.2		7.7		7.6						
Post 2mon.	42.69	5.02	41.82	8.24	46.49	9.77	1.160	0.321	0.918	0.354	0.325
% of change	11.8		15.9		14.7						
Paired t-test											
Pre & Post 2wks.	<0.001**		<0.001**		<0.001**						
Pre & Post 2mon.	<0.001**		<0.001**		<0.001**						

Table (2): Levels of Ghrelin hormone in the three operations preoperative, two-weeks postoperative and two-months postoperative

Ghrelin (mg/dL)	Type of Operation										
	Sleeve gastrectomy		Minigastric bypass		Sleeve gastrectomy with loop bipartition		ANOVA		Tukey's test		
	Mean	SD	Mean	SD	Mean	SD	f	P-value	S&M	S&L	M&L
Pre	0.85	0.67	2.40	0.57	0.83	0.33	25.019	<0.001**	<0.001**	<0.001**	<0.001**
Post 2wks.	0.54	0.31	1.2	0.46	0.41	0.27	16.968	<0.001**	<0.001**	<0.001**	<0.001**
% of change	36.5%		50%		50.6%						
Post 2mon.	0.5	0.23	1.11	1.14	0.42	0.30	5.959	0.005*	<0.001**	<0.001**	<0.001**
% of change	41.2%		53.8%		49.4%						
Paired t-test											
Pre & Post 2wks.	<0.001**		<0.001**		0.036*						
Pre & Post 2mon.	0.003*		<0.001**		0.048*						

Table (3): Levels of Secretin hormone in the three operations preoperative, two-weeks postoperative and two-months postoperative

Secretin (mg/dL)	Type of Operation										
	Sleeve gastrectomy		Minigastric bypass		Sleeve gastrectomy with loop bipartition		ANOVA		Tukey's test		
	Mean	SD	Mean	SD	Mean	SD	f	P-value	S&M	S&L	M&L
Pre	1.69	0.67	1.45	0.45	3.63	1.06	22.979	<0.001**	0.290	<0.001**	<0.001**
Post 2wks.	0.65	0.22	4.00	0.77	1.95	0.98	202.526	<0.001**	<0.001**	<0.001**	<0.001**
% of change	61.5		56.9		46.3						
Post 2mon.	0.83	0.25	3.47	1.12	1.92	0.41	104.476	<0.001**	<0.001**	<0.001**	<0.001**
% of change	49.1		58.2		52.9						
Paired t-test											
Pre & Post 2wks.	<0.001**		<0.001**		0.017*						
Pre & Post 2mon.	<0.001**		<0.001**		0.004*						

Table (4): Levels of Peptide YY hormone in the three operations preoperative, two-weeks postoperative and two-months postoperative

Peptide YY (mg/dL)	Type of Operation										
	Sleeve gastrectomy		Minigastric bypass		Sleeve gastrectomy with loop bipartition		ANOVA		Tukey's test		
	Mean	SD	Mean	SD	Mean	SD	F	P-value	S&M	S&L	M&L
Pre	312.04	128.91	235.75	119.39	264.50	105.06	1.660	0.200	0.096	0.395	0.580
Post 2wks.	440.5	177.54	393.5	103.59	768.67	295.51	9.444	<0.001**	0.427	<0.001**	<0.001**
% of change	29.1%		40.1%		65.6%						
Post 2mon.	486.75	176.23	495.2	211.18	801.50	249.53	7.240	0.002*	0.896	<0.001**	<0.001**
% of change	35.9%		52.4%		67%						
Paired t-test											
Pre & Post 2wks.	<0.001**		0.035*		0.003*						
Pre & Post 2mon.	<0.001**		0.026*		<0.001**						

Table (5): Levels of Glucagon-like Peptide 1 hormone in the three operations preoperative, two-weeks postoperative and two-months postoperative

Glucagon-like Peptide 1 (mg/dL)	Type of Operation										
	Sleeve gastrectomy		Minigastric bypass		Sleeve gastrectomy with loop bipartition		ANOVA		Tukey's test		
	Mean	SD	Mean	SD	Mean	SD	F	P-value	S&M	S&L	M&L
Pre	9.28	3.23	10.44	5.02	8.62	2.63	0.596	0.555	0.371	0.636	0.428
Post 2wks.	11.5	1.27	15.85	2.37	12.82	2.93	25.837	<0.001**	<0.001**	0.058	0.040*
% of change	19.3%		34.1%		32.8%						
Post 2mon.	11.38	1.26	14.94	2.35	12.05	2.49	18.841	<0.001**	<0.001**	0.298	0.035*
% of change	18.5%		30.1%		28.5%						
Paired t-test											
Pre & Post 2wks.	<0.001**		0.006*		0.025*						
Pre & Post 2mon.	<0.001**		0.019*		0.042*						

Table (6): Correlation between levels of hormones and weight loss two-weeks and two months postoperative

Type of Operation	Hormones	Weight loss post 2weeks.		Weight loss post 2months.	
		r	P-value	r	P value
Sleeve gastrectomy	Ghrelin	-0.448	0.004*	-0.082	0.617
	Secretin	-0.508	<0.001**	-0.391	0.014*
	Peptide YY	0.087	0.595	0.167	0.168
	Glucagon-like Peptide 1	0.040	0.805	0.271	0.113
Minigastric bypass	Ghrelin	-0.515	0.020*	-0.776	<0.001**
	Secretin	0.634	0.003*	0.527	0.017**
	Peptide YY	0.866	<0.001**	0.537	0.015*
	Glucagon-like Peptide 1	0.251	0.285	0.594	0.006*
Loop bipartition	Ghrelin	-0.391	0.059	-0.656	<0.001**
	Secretin	-0.649	<0.001**	-0.899	<0.001**
	Peptide YY	0.690	<0.001**	0.633	<0.001**
	Glucagon-like Peptide 1	0.919	<0.001**	0.671	<0.001**

Discussion

Bariatric surgery is one of the most effective treatments for achieving long-term weight loss in morbidly obese patients. Bariatric surgery causes weight loss through increased satiety and substantial decline of hunger. The understanding of neuroendocrine regulation of food intake and weight gain has significantly increased. The changes in these hormones following bariatric surgery can partly explain the mechanism behind weight loss achieved through these procedures [9].

In the current study, percent of change in BMI two-weeks postoperatively in SG, OAGB and SGLB were 6.2%, 7.7% and 7.6% respectively. However, percent of change in BMI two-months post-operatively are 11.8%, 15.9% and 14.7% respectively. OAGB achieved highest weight loss followed by SGLB. These results were in agreement with Le Roux et al., (2006) who found that after one-year follow-up period, BMI of patients underwent OAGB decreases from 49.8 to 36.8 [10]. Also, these results were in accordance with Ansar et al., (2020) who concluded that OAGB provides considerable weight loss for most patients. Moreover, initial lower BMI, absence of diabetes, and higher first month weight loss are independently associated with successful weight loss after 1 year [11].

As regard changes in levels of GIT hormones in the current study, there is a progressive increase in postprandial GLP-1 and PYY in the three operations two-weeks and two-months postoperatively. These results were in agreement with Korner et al., (2009) who conducted several prospective studies on RYGB and it was found that there was an increase in postprandial plasma levels of PYY and GLP-1. This increase has been reported to occur as early as two days after bypass suggesting that the exaggerated response to the intervention and not to weight loss and is likely related to more rapid delivery of glucose to distal small intestine. He also showed that over time after bypass, there was a further increase in both fasting and postprandial PYY levels that may reflect adaptive changes within the gut [12].

Also, the results were in accordance with Martinussen et al., 2019 [13], who observed increased postprandial level in GLP-1 levels postoperative compared to pre-surgical state following many different bariatric procedures including SG and RYGB.

In the present study, it was found that GLP-1 increased in OAGB followed by SGLB then SG. This result was in line with Arakawa et al., (2020) who found that increases in postprandial PYY and GLP-1 levels in the blood were observed primarily after gastric bypass (GB) and transiently after SG [14]. Anatomic changes after GB accelerates nutrient delivery to the distal intestine and likely stimulates secretion of these hormones. Furthermore, chronically high gastric emptying rates after GB have also been shown to induce adaptive changes such as an increase in enteroendocrine cell number, villous height, and surface area [15,16]. GB has been shown to induce higher and sustained postprandial PYY and GLP-1 compared to SG up to 1 year follow up [17,18].

In the current study, it was found that Ghrelin hormone decreased in the three operations and it was dropped highest in OAGB followed by SGLB and SG. This result was in line with Cummings et al., (2002) who demonstrated a profound reduction in ghrelin in patients after GB. They also found an increase in plasma ghrelin levels after weight loss induced by caloric restriction, suggesting that GB bypass itself is associated with decreased levels of circulating ghrelin. However, a study carried out by Sharma et al., (2019) found a significant weight loss and decrease in BMI at three and six months postoperatively after SG. This difference may be attributed to in the current study we did not study the rhythm of ghrelin after two months [19].

In the study conducted by Meek et al., (2016)[20], patients with RYGB had a significant decrease in ghrelin levels after 6 months, an effect which was comparable to that seen post-gastrectomy. The authors concluded that the RYGB reduced ghrelin levels due to the exclusion of the gastric fundus, with reduced or absent contact between ghrelin-producing mucosal cells and ingested nutrients. Similar effects have been seen by other groups. In the study of (Tabasi et al., 2019) showed that SG may decrease circulating acylated ghrelin concentrations possibly due to the removal of ghrelin producing cells in the stomach [21].

In conclusion, differences in gastrointestinal hormones that regulate energy and glucose homeostasis are a possible mechanism for greater weight loss after SGLB and OAGB compared to SG.

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References

1. Bouter KE, van Raalte DH, Groen AK, Nieuwdorp M. Role of the gut microbiome in the pathogenesis of obesity and obesity-related metabolic dysfunction. Gastroenterology. 2017; 152:1671-8.
2. Bombak A, Monaghan LF, Rich E. Dietary approaches to weight-loss, Health At Every Size® and beyond: rethinking the war on obesity. Social Theory & Health. 2019; 17:89-108.
3. Tronieri JS, Wadden TA, Chao AM, Tsai AG. Primary care interventions for obesity: Review of the evidence. Curr Obes Rep. 2019; 8:128-36.
4. Fernandez Jr. AZ. Bariatric Surgery. In: Opara EC, Dagogo-Jack S, editors. Nutrition and Diabetes: Pathophysiology and Management. 2nd ed. CRC Press, Boca Raton; 2019. p. 149.
5. Larraufie P, Roberts GP, McGavigan AK, Kay RG, Li J, Leiter A, et al.,

Important role of the GLP-1 axis for glucose homeostasis after bariatric surgery. Cell Rep. 2019; 26:1399-408.
6. Chaim EA, Ramos AC, Cazzo E. Mini-gastric bypass: description of the techniquue and prelminary results. Arq Bras Cir Dig. 2017; 30:264-6.
7. Aleman R, Lo Menzo E, Szomstein S, Rosenthal RJ. Efficiency and risks of one-anastomosis gastric bypass. Ann Transl Med. 2020;8(Suppl 1):S7. doi: 10.21037/atm.2020.02.03.
8. Mui WL, Lee DW, Lam KK. Laparoscopic sleeve gastrectomy with loop bipartition: A novel metabolic operation in treating obese type II diabetes mellitus. Int J Surg Case Rep. 2014; 5:56-8.
9. Vincent RP, le Roux CW. Changes in gut hormones after bariatric surgery. Clin Endocrinol (Oxf). 2008;69:173-9.
10. Patriti A, Facchiano E, Gullà N, Aisa MC, Annetti C. Gut hormone profiles following bariatric surgery favor an anorectic state, facilitate weight loss, and improve metabolic parameters. Ann Surg. 2007; 245:157-8.
11. Ansar H, Zamaninour N, Pazouki A, Kabir A. Weight loss after one anastomosis gastric bypass-mini gastric bypass (OAGB-MGB): Patient-related perioperative predictive factors. Obes Surg. 2020; 30:1316-23.
12. Korner J, Inabnet W, Conwell IM, Taveras C, Daud A, Olivero-Rivera L, et al., Differential effects of gastric bypass and banding on circulating gut hormone and leptin levels. Obesity (Silver Spring). 2006; 14:1553-61.
13. Martinussen C, Bojsen-Møller KN, Dirksen C, Svane MS, Kristiansen VB, Hartmann B, et al., Augmented GLP-1 secretion as seen after gastric bypass may be obtained by delaying carbohydrate digestion. J Clin Endocrinol Metab. 2019;104:3233-44.
14. Arakawa R, Febres G, Cheng B, Krikhely A, Bessler M, Korner J. Prospective study of gut hormone and metabolic changes after laparoscopic sleeve gastrectomy and Roux-en-Y gastric bypass. PLoS One. 2020; 15:e0236133. doi: 10.1371/journal. pone. 0236133.
15. Mumphrey MB, Patterson LM, Zheng H, Berthoud HR. Roux-en-Y gastric bypass surgery increases number but not density of CCK-, GLP-1-, 5-HT-, and neurotensin-expressing enteroen-docrine cells in rats. Neurogast-roenterol Motil. 2013; 25:e70–9.
16. Cavin JB, Couvelard A, Lebtahi R, Ducroc R, Arapis K, Voitellier E, et al., Differences in alimentary glucose absorption and intestinal disposal of blood glucose after Roux-en-Y gastric bypass vs sleeve gastrectomy. Gastroenterology. 2016; 150:454–64.
17. Yousseif A, Emmanuel J, Karra E, Millet Q, Elkalaawy M, Jenkinson AD, et al., Differential effects of laparoscopic sleeve gastrectomy and laparoscopic gastric bypass on appetite, circulating acyl-ghrelin, peptide YY3-36 and active GLP-1 levels in non-diabetic humans. Obes Surg. 2014; 24:241–52.
18. Casajoana A, Pujol J, Garcia A, Elvira J, Virgili N, de Oca FJ, et al., Predictive value of gut peptides in T2D remission: Randomized contr-olled trial comparing metabolic gastric bypass, Sleeve gastrectomy and greater curvature plication. Obes Surg. 2017; 27:2235–45.
19. Sharma G, Nain PS, Sethi P, Ahuja A, Sharma S. Plasma ghrelin levels after laparoscopic sleeve gastrectomy in obese individuals. Indian J Med Res. 2019; 149:544-7.
20. Meek CL, Lewis HB, Reimann F, Gribble FM, Park AJ. The effect of bariatric surgery on gastrointestinal and pancreatic peptide hormones. Peptides. 2016; 77:28-37.
21. Tabasi M, Ashrafian F, Khezerloo JK, Eshghjoo S, Behrouzi A, Javadinia SA, et al., Changes in gut microbiota and hormones after bariatric surgery: a Bench-to-Bedside review. Obes Surg. 2019; 29:1663-74.