Research Article

Metabolic and symptomatic outcome after laparoscopic sleeve gastrectomy

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Abstract
Purpose: This study evaluates the metabolic & symptomatic outcome of laparoscopic sleeve gastrectomy (LSG) as a definitive procedure for morbidly obese patients considering the metabolic effects on hyperglycaemia and hyperlipidaemia and improvement of other obesity-induced co-morbidities. **Methods:** A prospective study conducted at Laparoscopic surgery unit in Minia University Hospital in the period from January 2012 to January 2015. 50 Morbidly obese adults (6 males and 44 females, age range: 22-46 years, mean age: 31.93 ± 6.39 years) admitted to the General surgery department are enrolled in this thesis. **Results:** All cases lost weight during the period of follow up (12 months) except one case (2%) which lost weight just during the first 6 months then stopped losing weight. Three cases (6%) lost weight but not efficiently with no cases of weight regain after losing weight during the period of follow up. Regarding the postoperative status of obesity-induced co-morbidities after 12 months, symptoms of knee osteoarthritis improved in all affected cases with the ongoing weight loss. Two cases of systemic hypertension showed controlled arterial blood pressure without medicaments within 6-12 months after surgery. Significant reduction in the levels of serum triglycerides and total cholesterol began 4 weeks after surgery ($p<0.001$) and continues throughout the period of follow up. Five cases had type II diabetes on oral hypoglycaemics. After surgery, postoperative fasting blood sugar (FBS) levels improved – in comparison to preoperative levels - with significant declining particularly three months after surgery ($P=0.001$), 6 months ($P<0.001$) and 12 months ($P<0.001$). Postoperative 2-hours postprandial blood sugar levels also improved – in comparison to preoperative levels - with significant declining particularly 6 months after surgery ($P=0.009$) and 12 months ($P<0.001$). At the end of study, remission of diabetes, defined by fasting blood sugar (FBS) <100 mg/dl with complete stoppage of diabetic medication, was seen in all these five patients. **Conclusion:** Benefits of LSG include not only an effective treatment of morbid obesity but also abolishing many of its related co-morbid conditions, including type II diabetes mellitus, osteoarthritis of weight bearing joints, hypertension and hyperlipidaemia.

Keywords: laparoscopic bariatric surgery, laparoscopic sleeve gastrectomy, morbid obesity, hyperlipidaemia

Introduction

Obesity is a major health problem affecting over 1.7 billion individuals worldwide, and although it was considered a disease of the western world, it seems to have expanded to the developing world, especially in urban settings[1]. It contributes to type II diabetes mellitus, ischaemic heart disease, hyper-tension, dyslipidaemias, obstructive sleep apnea, nonalcoholic steatohepatitis and polycystic ovary syndrome. Cancer risk is markedly increased, particularly for colorectal cancer[2].

The field of bariatric surgery is continually evolving. Many different operations have been tried and abandoned owing to the poor long-term weight loss and/or metabolic or mechanical complications. During the past decade, the use of laparoscopic sleeve gastrectomy (LSG) has gained popularity, and it has become widely accepted as a primary bariatric operation, as well as a first-stage operation for high-risk patients. Five-year data are now emerging that supports the durability of sleeve gastrectomy[3].

While LSG is generally considered a restrictive procedure, mechanisms of postoperative weight loss and improvement in comorbidities seen after may also be related to neurohumoral changes related to gastric resection. Metabolic mechanisms of action of LSG continue to be an active area of research[4].

Patients and methods:

After explanation of the purpose of the study and having written informed consents, fifty morbidly obese adults (6 males and 44 females, age range: 22-46 years, mean age: 31.93 ± 6.39 years) were admitted to the General surgery department to be enrolled in this thesis.

Exclusion criteria:

Patients with the following characteristics were excluded from the study:

1) BMI >55 kg/m^2.
2) Previous upper abdominal surgery.
3) Previous bariatric surgery.
4) Untreated psychosis.
5) Current drug or alcohol abuse.
6) Sweat eaters.

Initial assessment:

On admission, patients' age, sex and body mass index (BMI) were recorded. History of obesity induced co-morbidities (e.g. diabetes mellitus, hypertension, symptoms of gastro-oesophageal reflux, female hypofertility, backache or knee pain) and previous abdominal surgery was obtained. Thorough general and abdominal examination was done.

Investigations:

Laboratory tests included C.B.C., INR, prothrombin time and concentration, complete liver and kidney function tests, random blood sugar, fasting and postprandial blood sugar for diabetic cases, serum cholesterol and trigylcerides, thyroid function tests to exclude an endocrinal disorder causing obesity. Imaging studies included chest Xray, knee Xray and abdominal ultrasound. E.C.G., pulmonary function tests and endoscopic evaluation of the stomach were requested.

Operative technique:

All patients received a prophylactic dose of LMWH the night of the procedure, patient is placed on the operating table in the supine position with the operating surgeon standing between the legs of the patient. After creation of pneumoperitoneum, a total of 5 trocars are then inserted as seen in figure (1). Following retraction of the left lobe of the liver using a table-mounted Nathanson retractor, a window is dissected at the junction of the greater curvature and the greater omentum, 2-4 cm from the pylorus to gain entry into the lesser sac. This distance from the pylorus can be measured using an 'umbilical tape'. Division of the gastroepiploic, short gastric and posterior fundic vessels is done starting at this window all the way till the angle of His using the (ultracision Harmonic scalpel) (Harmonic; Ethicon Endosurgery, Cincinnati, OH, USA) (figure 2).

Once the dissection part is over, a 36 Fr bougie is introduced orally through the oesophagus to the pyloric channel. Gastric transection then begins 2 - 4 cm proximal to the pylorus using an Endo GIA™ stapler with 60-mm, green or gold cartridge. Once the bougie is reached, sequential firings along the border of the bougie complete the gastric transection.

Bougie must be held in position during this part of the procedure until completion of the stomach transection to avoid stapling across a displaced bougie. The entire staple line is then checked for bleeding points and to make sure that staples are well formed especially at the antrum where the stomach is thickest.

Transected stomach then is removed through one of the 12-mm port sites and methylene blue is injected through the bougie to assess the integrity of the staple line (figure 3). After exclusion of macroscopic leaks, the dye is removed from the stomach, as is the bougie and a 18 Fr tubal drain is inserted along the staple line. All trocar sites are closed with Vicryl (Ethicon).

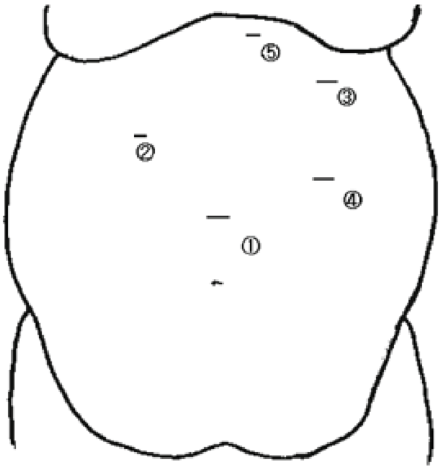


Figure (1): Ports site in LSG

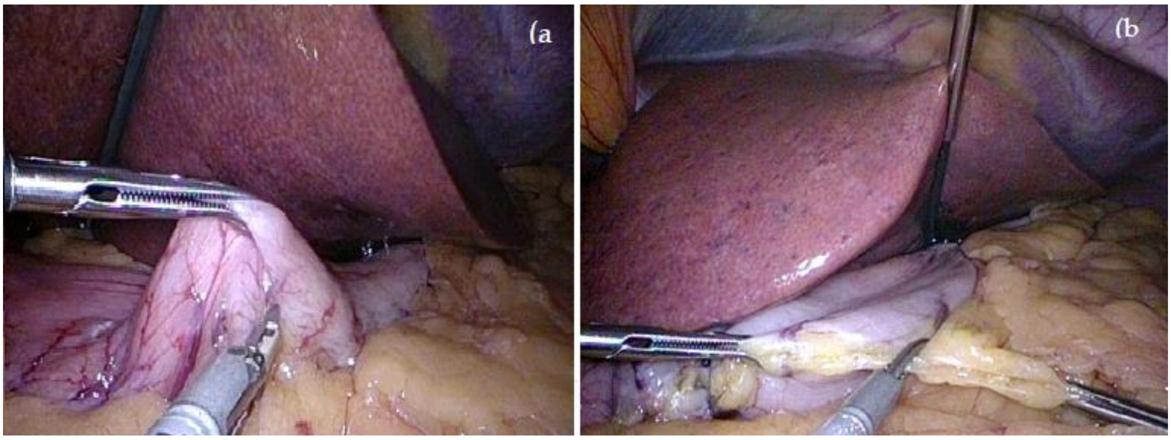


Figure (2): a) Gaining entry into lesser sac (b) Division of gastro colic ligament

Figure (3): Methylene blue test: clamping the distal stomach while injecting methylene blue

Results

Demographic data of the studied patients is shown in table (1). As shown in table (4) and figure (4), twenty five out of fifty patients (50%) had obesity-induced co-morbidities in the form of knee osteoarthritis (14 patients; 28%), type II diabetes mellitus (5 patients, 10%), systemic hypertension (2 patients, 4%), hypertension with knee osteoarthritis (2 patients, 4%) and female infertility (2 patients, 4%).

Table (2) shows the operative data of our patients; all patients were done laparoscopically and completed with no conversion except in one case (2%). No blood transfusion was needed in all cases and the operative time ranged from 60 minutes to 180 minutes (Mean ± SD= 84.6 ± 27.6 min). Time to resume oral intake after surgery ranged from 24 – 48 hours (mean ± SD= 37.44 ± 12). Patients were discharged from the hospital after a range of 3 to 6 days (mean ± SD= 4.5 ± 1.72).

Preoperative body mass index (BMI) ranged from 36.11 to 62.5 kg/m2 (Mean ± SD= 46.08 ± 7.09). As shown in figure (5), all cases lost weight during the period of follow up (BMI, range 23.83 - 49.8 kg/m2, mean ± SD= 30.26 ± 4.72) except one case (2%) which lost weight just during the first 6 months then stopped losing weight. Three cases (6%) lost weight but not efficiently (EWL % less than 50% at one year; 41.25%, 37.09% and 28.6%). In the period of follow up, there were no cases of weight regain after losing weight.

Table (3) shows the excess weight loss % for all cases. At 6 weeks it ranged from 12.5% to 40.1% (Mean ± SD= 29.75 ± 7.55). At 3 months, EWL% for all cases ranged from 22.6% to 70% (mean ± SD= 51.76 ± 9.81). At 6 months, EWL% for all cases ranged from 27.4% to 88.5% (Mean ± SD= 70.54 ± 12.53). After one year EWL % for all cases had a minimum of 28.6% and a maximum of 97.3% (Mean ± SD= 83.29 ± 14.91).

The lipid profile significantly improved after surgery. Before surgery, 20 patients have elevated levels of serum triglycerides and/or total cholesterol. Significant reduction in the levels of serum triglycerides and total cholesterol began as early as 4 weeks after surgery ($p<0.001$) and continued throughout the period of follow up (figure 6).

Regarding the postoperative status of obesity-induced co-morbidities (table 4, figure 7), symptoms of knee osteoarthritis improved in all affected cases with the ongoing weight loss. Two cases of systemic hypertension showed controlled arterial blood pressure without medicaments within 6-12 months after surgery. Two cases had knee osteoarthritis with systemic hypertension, one of them improved and the other case continue to be controlled on medications. Two females of our patients had a history of infertility prior to surgery, three months after surgery one of these ladies conceived.

Table (1). Demographic data of patients in our study

Gender	**Females**	44 (88%)
	Males	6 (12%)
Age (years)	**Range**	22 – 46
	Mean	31.93 ± 6.39
Preoperative BMI (kg/m^2)	**Range**	36.11 - 62.5
	Mean	46.08

Figure (4). Preoperative status of obesity-induced co-morbidities in the studied patients

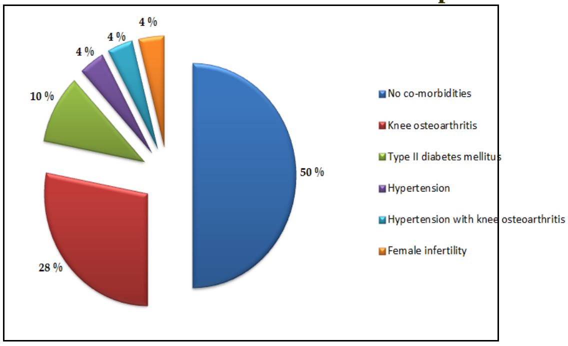


Table (2): Operative data

Operative data	**Descriptive statistics**
Operative time (min) **Range** **Mean ± SD**	 60–180 84.6 ± 27.6
Conversion	1 (2%)
Intraoperative need for blood transfusion	0
Intraoperative mishaps and complications	
None	45 (90%)
Entrapment of nasogastric tube in staple line	1 (2%)
Excessive pneumoperitoneum leak necessitating conversion	3 (6%)
Bleeding during gastrolysis	1 (2%)

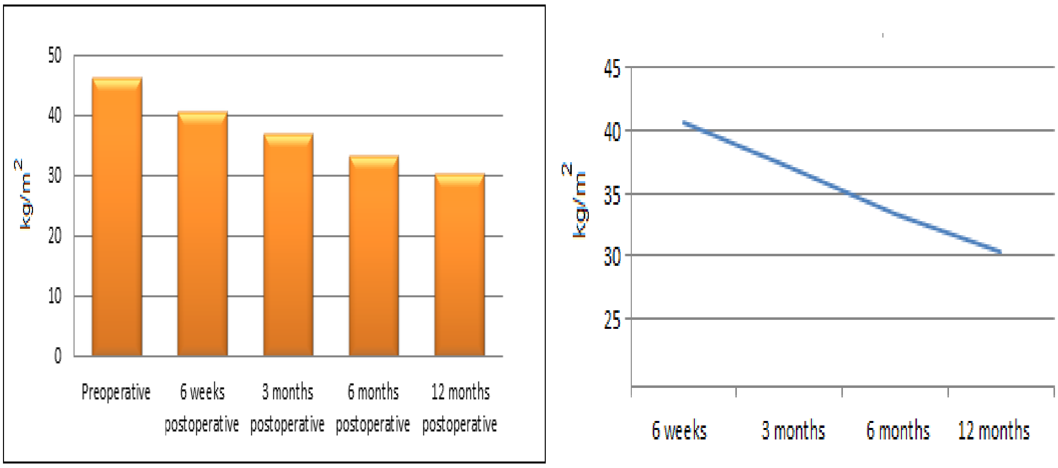


Figure (5): Pre and postoperative body mass index (BMI)

Table (3): Percentage of excess weight loss (%EWL) for all cases (minimum, maximum and mean±SD)

	6 weeks postoperative	3 months postoperative	6 months postoperative	12 months postoperative
%EWL Range Mean ± SD	(12.5-40.1) 29.75 ± 7.55	(22.6-70) 51.76 ± 9.81	(27.4-88.5) 70.54 ± 12.53	(28.6-97.3) 83.29 ± 14.91
P value				
P2		**< 0.001***	**< 0.001***	**< 0.001***
P3			**< 0.001***	**< 0.001***
P4				**< 0.001***

Paired sample t test
*: significant difference at p value ≤ 0.05
P2: comparison with 6 weeks post-operative
P3: comparison with 3 months post- operative
P4: comparison with 6 months post- operative

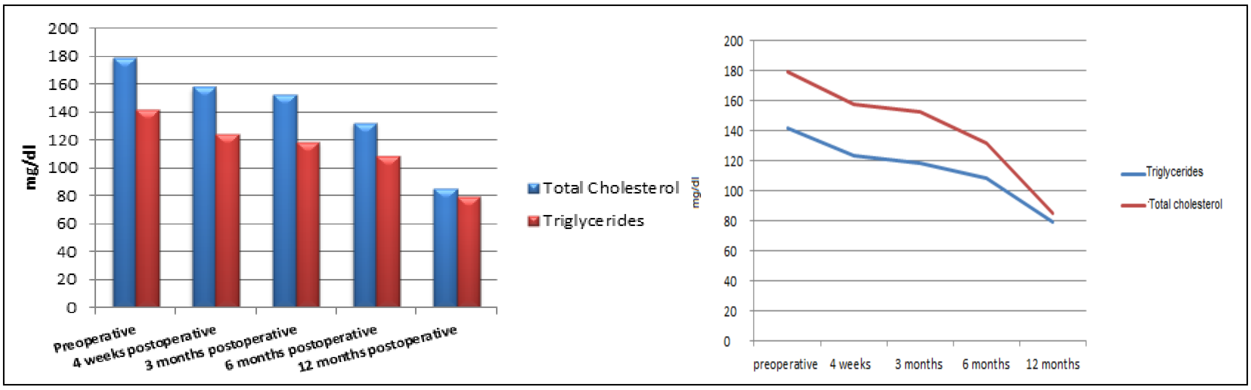


Figure (6): Pre and postoperative lipid profile

Table (4): Pre- and postoperative status of obesity-induced co-morbidities

Obesity-induced comorbidities		**Number of Cases**
Preoperative status	No co-morbidities	25 (50%)
	Knee osteoarthritis	14 (28%)
	Type II diabetes mellitus	5 (10%)
	Hypertension	2 (4%)
	Hypertension with Knee Osteoarthritis	2 (4%)
	Female Infertility	2 (4%)
Postoperative status (12 months)	No co-morbidities	25 (50%)
	The same	2 (4%)
	Improved	14 (28%)
	Cured	9 (18%)

Five cases in our study (10%) had type II diabetes mellitus on oral hypoglycaemic drugs. As shown in figure (8), postoperative fasting blood sugar (FBS) levels improved – in comparison to the preoperative levels - with significant declining particularly 3 months after surgery (P=0.001), 6 months (P<0.001) and 12 months (P<0.001), but non-significant declining at 1 month (P=0.87). Postoperative 2-hours postprandial blood sugar levels also improved – in comparison to preoperative levels - with significant declining particularly 6 months after surgery (P=0.009) and 12 months (P<0.001), but non-significant declining at 3 months (P=0.25) and 1month (P=0.061). At the end of study, remission of diabetes, defined FBS <100 mg/dl with complete stoppage of diabetic medication, was seen in all these 5 patients. Four patients in our study were hypertensive on antihypertensive drugs. At the end of the study two of them were off any medicaments for hypertension and the two other cases resumed antihypertensive treatment.

Regarding postoperative complications (figure 9), three cases were re-admitted to our hospital within the 1st postoperative 4 weeks; one case for chest infection that was treated medically, one case for repeated postoperative vomiting that was treated by nothing per os and IV fluids and one case for subacute femoro-popliteal deep venous thrombosis that was treated by full heparinization and bed rest.

One case (a 37 years old female) was readmitted 8 weeks after surgery complaining of fever, tachycardia and dyspnea. Leukocytosis (12.3 X 103 cell/mm3) and anaemia (Hb= 9.2 g/dl) were noted on initial re-admission labs. Emergency department abdominal ultrasound revealed minimal to mild free peritoneal fluid collection so abdominal CT scan with contrast was requested and revealed leakage of the upper portion of the staple line at the gastro-oesophageal junction with subphrenic collection.

Percutaneous insertion of subphrenic drain under ultrasonographic control was done using local anaesthetic. After insertion of the percutaneous drain, the patient was kept under observation with parenteral antibiotics, TPN regimen and nothing per os. Follow up abdominal ultrasonography 48 after percutaneous drainage revealed no free or localized fluid collection.

The patient insisted on discharge upon her request despite our repeated warnings that her life may be endangered by such a decision. She then escaped follow up.

There was one case of port site infection treated by antibiotics on an outpatient basis. One case complained from severe reflux symptoms persisting for 3-6 months after surgery. She refused to have an oesophago-gastro-dudenoscopy and was sufficiently treated by proton pump inhibitors.

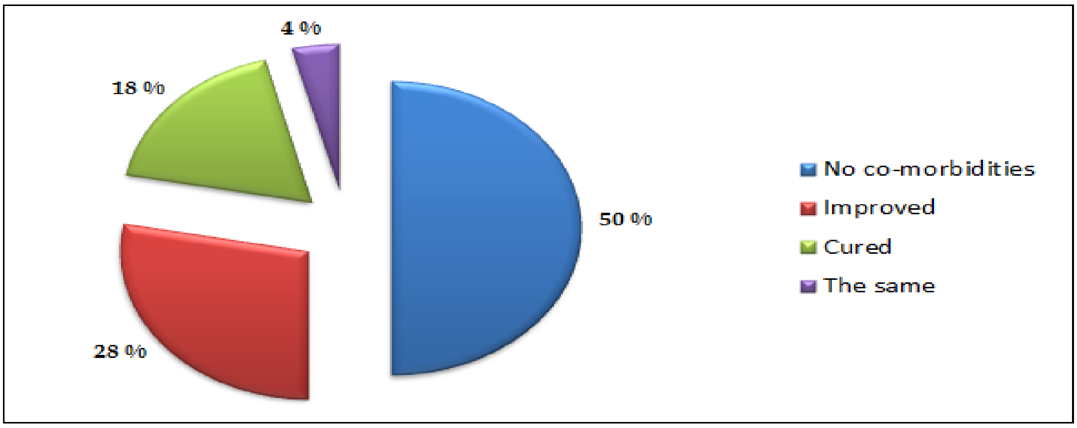
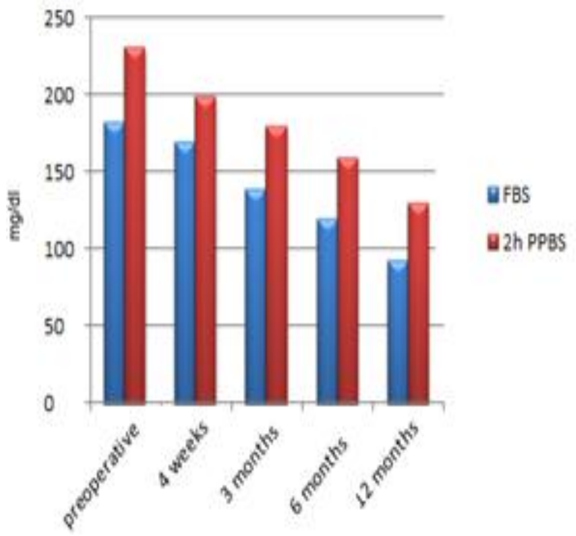


Figure (7): Post-operative status of obesity-induced co-morbidities



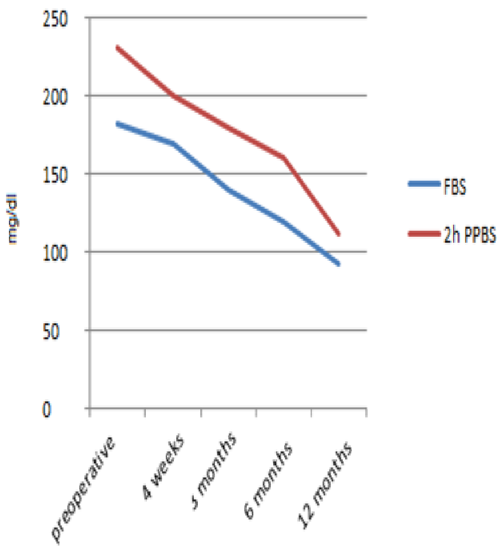


Figure (8): Pre and postoperative levels of fasting (FBS) and 2-hours postprandial blood sugar (2h PPBS) in the diabetic patients

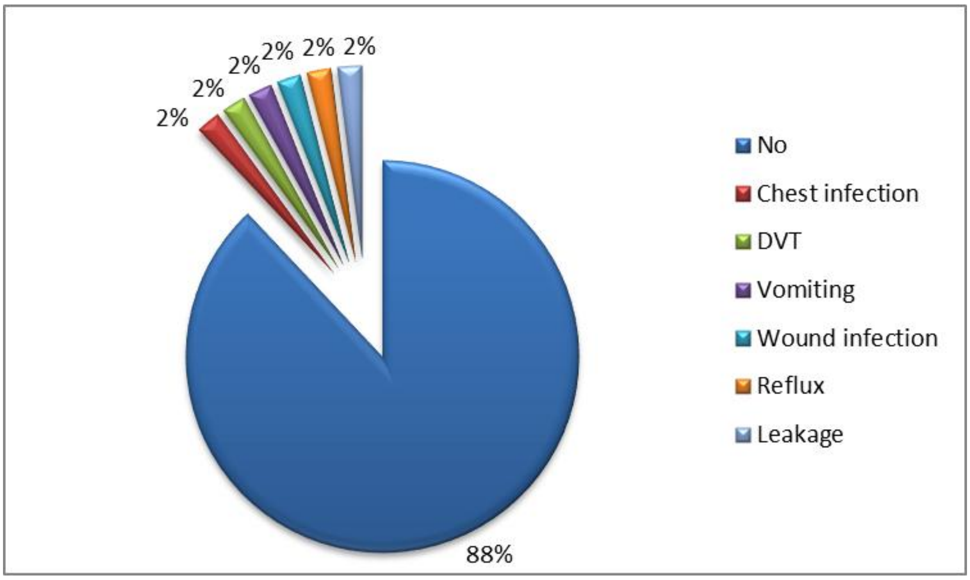
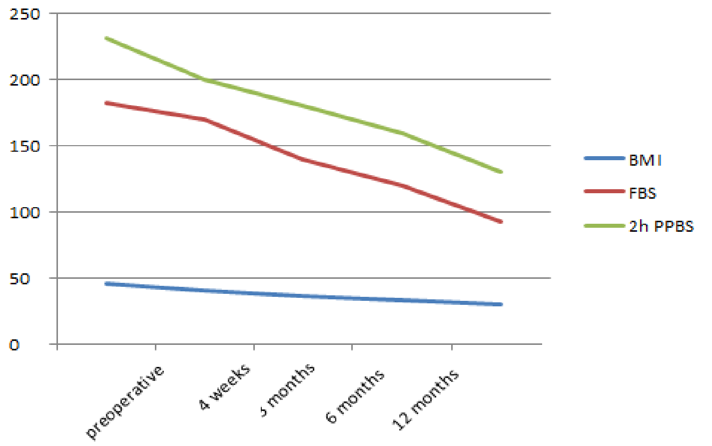


Figure (9): Postoperative Complications

Our results proved a positive correlation between weight loss and levels of FBS (correlation coefficient= 0.98) and a positive correlation between weight loss and levels of 2h PPBS (correlation coefficient= 0.99). This means that after operation, when body weight decreased the levels of FBS and 2h PPBS also decreased (figure 10).

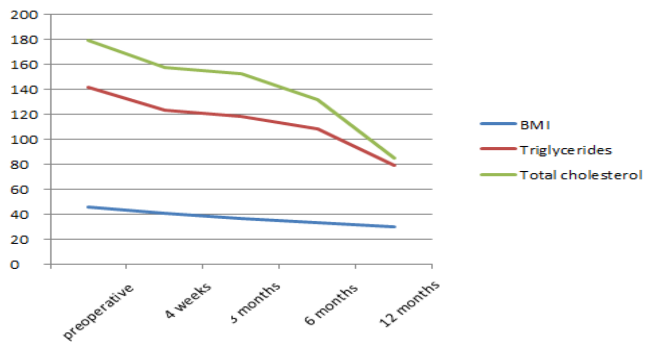
A positive correlation between weight loss and levels of serum triglycerides (corr-elation coefficient= 0.95) and a positive correlation between weight loss and levels of total cholesterol (correlation coefficient= 0.93) as shown in (figure 11).



Correlation coefficient

	BMI	FBS	2h PPBS
BMI	1		
FBS	0.979512	1	
2h PPBS	0.994411	0.986317	1

Figure (10): Positive correlation between weight loss and postoperative blood sugar levels



Correlation coefficient

	BMI	Triglycerides	Total cholesterol
BMI	1		
Triglycerides	0.952065	1	
Total cholesterol	0.925043	0.994128891	1

Figure (11): Positive correlation between weight loss and postoperative lipid profile

Discussion

According to the World Health Organization, global obesity rates have steadily risen and nearly doubled since the 1980s, posing a major public health crisis and contributing to premature death [4]. While obesity prevention continues to be the focus of many federal and public health initiatives, those who already suffer from obesity or morbid obesity often have unsuccessfully tried conventional methods of losing weight, including diet and exercise therapy, behavioural modification, and pharmacology[5].

Bariatric surgery is now recognized not only as clinically effective intervention for weight control, but also as metabolic surgery and is gaining popularity as evidence shows it resolves many comorbid conditions, such as type II diabetes mellitus, hypertension, obstructive sleep apnea, and dyslipidemia. [6].

In the present study, patients' age ranged from 22 to 46 years (Mean ± SD= 31.93± 6.39). These age limits have been standard in most studies. Luppi and colleagues studied 130 patients that underwent LSG with 28 patients (21.5%) being 60 years old or older. At 12 months postsurgery, older patients had EWL% of 49% compared to 60% in the younger group [7]. In a recent multi-institutional study, Qin and co-workers found that the age group > 65 years had an increased risk for overall and medical complications. Notably, age was not significantly associated with surgical complications [8].

On the other hand, extremely obese teenagers may be operative candidates if traditional methods of weight loss have been exhausted. Al-Qahtani et al. presented an analysis about clinical efficacy and safety outcomes of LSG in 74 preadolescent children (ages 5–12) and 115 adolescents. Their short-term data showed that LSG is effective in reducing weight in this age group, however, long-term follow up and more studies are still needed to assess the durability of weight loss with age progress and the maturation to adulthood [9].

Female patients represented the main population of this study (88%), which is similar to the most recent published studies [10][11]. This distribution cannot be just explained by the higher incidence of obesity among females but it seems that female obese patients are more subjected to psychological problems and are more concerned than men about the cosmetic aspects.

This study tries to illustrate the efficacy of laparoscopic sleeve gastrectomy (LSG) in the treatment of morbidly obese individuals emphasizing on the metabolic and symptomatic outcomes. In our study, LSG was found to be an effective and safe tool for reducing weight in morbidly obese individuals. We achieved significant reduction of BMI that began in the first few weeks after surgery (P<0.001 at 6 weeks) and continued throughout the 12 months period of follow up. Excess weight loss % for all cases at 6 weeks it ranged from 12.5% to 40.1% (mean ± SD= 29.75 ± 7.55) and after one year, EWL % for all cases had a minimum of 28.6% and a maximum of 97.3% (mean ± SD= 83.29 ± 14.91).

On the settings of short-term follow up, Dey and co-workers found similar results with the median EWL% being 50.3% at the end of 6 months [12]. Diamantis and co-workers found similar results on long-term follow up, the mean EWL% was 62.3%, 53.8%, 43%, and 54.8% at 5, 6, 7, and 8 or more years after LSG, respectively [10].

Regarding the mechanism of weight loss and according to the surgical literature, LSG is considered a restrictive procedure because reduced size of the stomach after surgery causes early satiety and reduced oral intake [13]. However, increasing evidence suggests that LSG induces weight loss through other physiological alterations, not just restriction, including increased intraluminal stomach pressure, which causes early satiety; increased gastric emptying for faster small-bowel transit time; and neurohormonal changes, including the reduction of both fasting and meal-stimulated ghrelin production and increased glucagon-like peptide-1 (GLP-1) and peptide YY (PYY) intestinal hormones that increase satiety [6].

One interesting feature of SG is temporary absence of hunger following the procedure. While most gut hormones are considered anorectic because they suppress the appetite, ghrelin is known as the only orexigenic (appetite-stimulating) gut hormone. With SG, loss of appetite, despite a patient's restricted hypocaloric intake, is explained by the elimination of the majority of ghrelin-producing cells by resecting and removing most of the stomach especially the fundus [14].

Another interesting mechanism of weight loss after SG has been highlighted in a very recent study that investigated the anatomical integrity of vagal innervation of the gut and the 'vagal gut-brain communication' following SG. A key function of abdominal vagal afferent signaling is participation in the control of food intake through responding to gastrointestinal stimuli [15]. Sensory information from the stomach is conveyed to the brainstem via gastric vagal afferents, the central terminals of which enter the brainstem via the tractus solitarius and synapse on the nucleus tractus solitarius (NTS) neurons [16].

The dorsal and the ventral gastric branches of vagus are transected during SG, producing sprouting of vagal afferents synapsing in the NTS. This sprouting of induces hyperexcitation of NTS synapses with a consequent hyperexcitation of the hindbrain feeding circuits resulting in decreased food intake and subsequent body weight loss. Future studies are required to fully describe this phenomenon [15].

A recent study about the effects of LSG on knee pain in morbidly obese females showed that LSG is an efficient and safe procedure to help remission of overall knee pain of female patients during the first 6 months [17]. Our study showed similar results, osteoarthritis of the knee was the most frequent comorbidity encountered in the present study (28%). Knee stiffness and pain significantly improved by the end of the study in all the affected patients with the need of analgesics being lesser than that before surgery.

Regarding the metabolic effects of LSG, significant reduction in the levels of serum triglycerides and total cholesterol was noticed as early as 4 weeks after surgery ($p<0.001$) and continues throughout the period of follow up (12 months).

In a retrospective analysis of 45 patients who underwent LSG from June 2004 to June 2008, Zhang and colleagues reported 12 months postoperative significant improvement in high-density lipoproteins (HDL) levels, triglyceride (TG) levels, total cholesterol/HDL ratio and TG/HDL ratio [18].

The data of a large systematic literature search conducted from English language studies published from 2000 to 2012 supports our results; the mean levels of pre and postoperative cholesterol were 194.4 ± 12.3 mg/dl (range 178–213) and 181 ± 16.3 mg/dl (range 158–200), respectively. Based on this systematic review, LSG has a significant effect on hyperlipidemia in the form of resolution or improvement in the majority of patients [19].

More recently, the percentage of remission of hypertension, hyperlipidaemia, and obstructive sleep apnea within one year after LSG surgery was found to be 68%, 35%, and 62%, respectively [6].

Resolution of hyperlipidaemia obviates the risk of hypertension and stroke as supported by a recent prospective cohort study during which 80% of patients discontinued all antidiabetic medications and hypertension resolved in 67% of patients with dyslipidemia resolved in 100% of patients nine months postsurgery. 10-year coronary heart disease risk, risk of stroke and risk of fatal stroke significantly decreased after surgery [20].

The relationship between obesity and diabetes may be interrelated to insulin resistance and failure of the pancreas to meet the ever higher demand for insulin production. In the present study, five cases (10%) had type II diabetes mellitus on oral hypoglycaemic drugs.

We found significant improvement of the postoperative levels of FBS and 2-hours postprandial blood sugar in comparison to preoperative levels and at the end of the present study, remission of diabetes, defined by FBS <100 mg/dl with complete stoppage of diabetic medication, was seen in all these 5 patients.

The results of Wahal and co-workers support our results; they performed a study on 10 patients with BMI 30–35 kg/m2 and type II diabetes mellitus that underwent LSG. Six patients were on oral hypo-glycemic agents and four were on insulin as well as oral therapy. At 3-months follow-up, all 6 patients on oral therapy were off any anti-diabetic medication and insulin could be stopped in all four patients [21]. Other investigators have recently reported a resolution rate of 85% for Type II diabetes mellitus in these patients. [22].

In a more recent study, Palikhe and co-workers compared between the effect of LSG and that of anti-diabetic intensive medical treatment (IMT) comprising of low calorie diet, exenatide, metformin and if required insulin on 31 patients with type II diabetes showed improved glycemic outcomes after LSG with resolution of diabetes and hypertension in 36% and 29 % of patients respectively while none in the IMT group. With the quality of life (QOL) score improved in LSG as compared to IMT [23].

LSG is gaining ground among the bariatric procedures as a safe procedure for treating type II diabetes mellitus in obese diabetics. The mechanism behind type II diabetes mellitus remission following LSG has not been clearly defined. It has been postulated that decreasing oral intake and decreasing insulin resistance instead of increase in insulin secretion is the reason behind remission. The effect of weight loss and diabetes mellitus remission could be related to elicitation of the "ileal break" mechanism [24].

Two of the well-studied gut-derived peptides are glucagon-like peptide-1 (GLP-1) and peptide YY (PYY). Both are secreted from L cells in the distal small bowel in response to nutrient intake [25]. Multiple studies have shown that obese individuals have decreased basal and postprandial PYY levels as well as a decreased postprandial GLP-1 response. Patients after LSG experience a more expedited nutrient transport into the distal ileum, eliciting an augmented postprandial secretion of GLP-1 and PYY [24].

GLP-1 initiates what is known as the incretin effect, which increases insulin secretion while inhibiting glucagon release, thereby leading to better glucose hemostasis. PYY a hormone co-secreted with GLP-1 from the distal intestine after meals to increase the insulin sensitivity [24].

In sleeve gastrectomy patients, ghrelin levels was markedly reduced and remained low for several months after the operation. Ghrelin not only increases one' appetite but also has counter insulin effects which causes increased insulin resistance. A decrease in ghrelin levels hence, would partly explain improved glucose homeostasis in post LSG patients [26].

Most authors agree that the effect of LSG in resolution of type II diabetes mellitus is not due to solely one hormone, but the added effects of appetite suppression and regulation of foregut (e.g. ghrelin) and hindgut (e.g. GLP-1) hormones resulting in improved glucose control overall[27]. Suppo-rted by this growing body of evidence in the literature, the American Diabetes mellitus Association (ADA) has recently endorsed bariatric surgery for the treatment of type II diabetes mellitus in patients with BMI of 35 kg/m^2 or greater [28].

Conclusion

Our study concluded that LSG is effective in achieving weight loss, symptomatic resolution of obesity-related co-morbidities and improvement of the metabolic profile of patients namely the blood sugar level and lipid profile. More studies may be needed to evaluate the long-term effects of LSG on weight loss and glucose homeostasis.

We hope that our results can open the gate for metabolic surgery in patients with normal BMI to control various aspects of the metabolic syndrome such as cardiac events and polycystic ovary syndrome.

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