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Review article

The advantages and disadvantages of sleeve gastrectomy; clinical laboratory to bedside review☆

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ABSTRACT

Sleeve gastrectomy is a surgical technique and a leading method in metabolic surgery. Sleeve gastrectomy gained ever-increasing popularity among laparoscopic surgeons involved in bariatric surgery and has proved to be a successful method in achieving considerable weight loss in a short time. There are some disparate effects that patients may experience after sleeve gastrectomy including a reduction in BMI, weight, blood pressure, stroke, and cancer and also a significant remission in obesity-related diseases including type 2 diabetes (T2D), Non-alcoholic fatty liver (NAFLD), cardiovascular disease, obstructive sleep apnea, and craniopharyngioma-related hypothalamic obesity as well as non-obesity-related diseases such as gout, musculoskeletal problems, ovarian disorders and urinary incontinence. The most common complications of sleeve gastrectomy are bleeding, nutrient deficiencies, and leakage. There are several studies on the impact of gender and ethnic disparities on post-operative complications. This study collects state of the art of reports on sleeve gastrectomy. The aim of this study was to analyze recent studies and review the advantages and disadvantages of sleeve gastrectomy.

1. Introduction

Obesity is one of the most critical risk factors of several life-threatening diseases. There are more than 1 billion overweight adults and at least 300 million obese, meaning that their BMI exceeds 30 kg/m [1]. According to recent investigations, the prevalence of obesity in adults has dramatically increased over the past ten years. Cancer death statistics show that one out of seven men, and one out of five women in the United States are obese [2]. Researchers have demonstrated that obese people in the identified classes (I, II, or III) are at the higher risk of obesity-related diseases, co-morbid conditions, lower quality of life (QOL), and increased mortality more than those in the normal range of BMI (18.5–24.9) [3,4]. Although having a healthy lifestyle seems to be an ideal option to lose weight, surgical treatment continues to be the most efficient and scientifically successful method for those with excessive amount of adipose tissue (class II or III). The gastric bypass, sleeve gastrectomy, adjustable gastric band, and biliopancreatic diversion with the duodenal switch are the most popular and common bariatric surgery (BS) procedures [5].

Sleeve gastrectomy is a new, safe, and efficient method for the treatment of obesity with higher survival rates among patients [6]. In this method, a large part of the stomach, which accounts for the regulation of appetite, is resected (Figure 1). Over the last years sleeve gastrectomy has captured remarkable surgical interest mainly because this technique does not require a gastrointestinal anastomosis or intestinal bypass (Figure 2). It is minimally invasive and is considered less technically challenging than laparoscopic Roux-en-Y gastric bypass (LRYGB). Sleeve gastrectomy avoids implantation of an artificial device around the stomach, whereas in laparoscopic adjustable gastric banding technique (LAGB) inflatable silicone device is placed around the top portion of the stomach to decrease food consumption.

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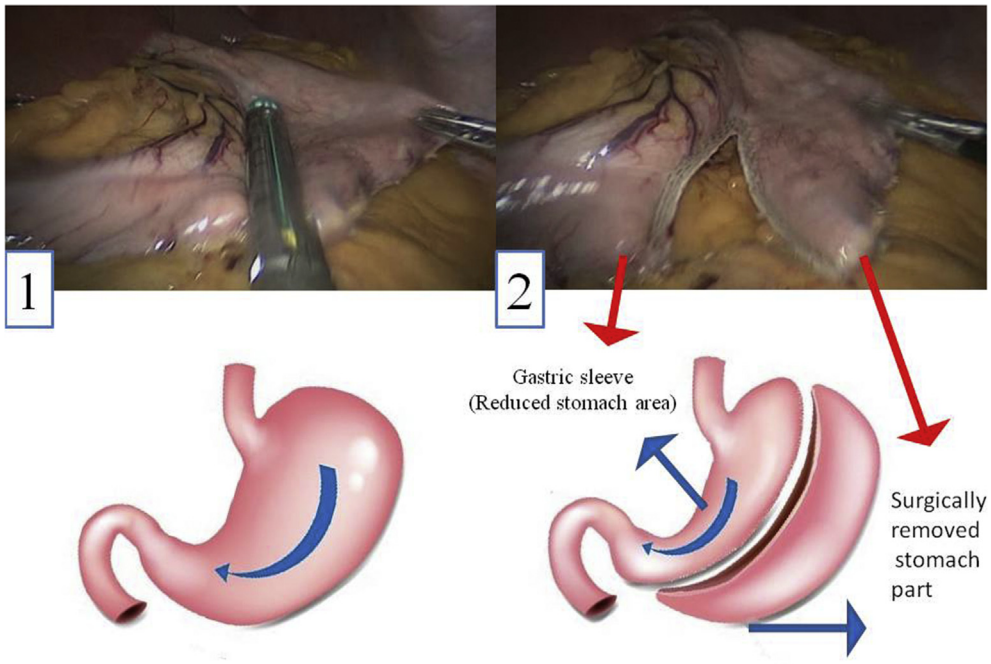

Figure 1. Vast part of stomach is resected in sleeve gastrectomy. 1) Stomach of patient with BMI of 42 before operation. 2) Around 80% of stomach fundus area is resected through laparoscopic technique. The figures were taken through the procedures of sleeve gastrectomy under supervision of Dr. Taha Anbara at Erfan Niayesh Hospital and consent was gathered from the patient.

This study centers around the advantages and disadvantages of sleeve gastrectomy in a review of the literature. We tried to present reliable reports about sleeve gastrectomy as a definitive procedure for morbid obesity and to review the positive or negative operational effects of sleeve gastrectomy in different studies from 2014 to 2019.

2. RYGB and sleeve gastrectomy

RYGB and sleeve gastrectomy are currently the most popular bariatric techniques worldwide. While several studies from Switzerland, Finland, and the United States have reported no statistical significance between

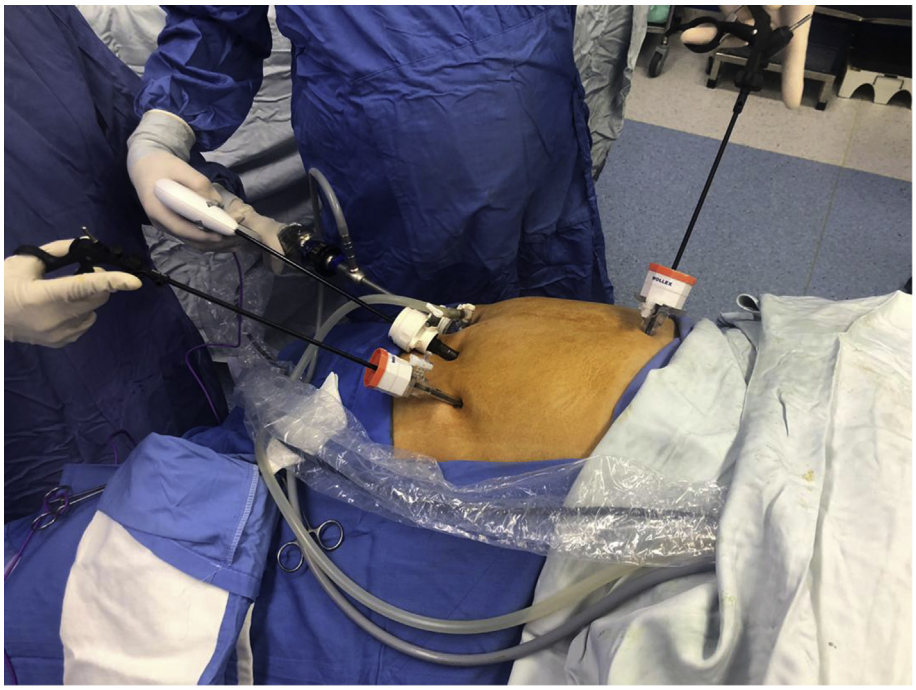

Figure 2. The laparoscopic technique. This procedure has quickly attracted considerable surgical interest because it does not require a gastrointestinal anastomosis or intestinal bypass and thanks to the laparoscopic technique. The figure was taken through the procedures of sleeve gastrectomy at Erfan Niayesh Hospital and consent was gathered from the patient.

RYGB and sleeve gastrectomy in regular and excessive weight loss (EWL) [7, 8, 9], a new and multicenter cohort study [10] showed that RYGB led to significant weight loss and further improvement in co-morbidities, especially metabolic disorders such as type 2 diabetes mellitus (T2DM) [11]. Some other studies introduced RYGB as a technically challenging and more complicated method than sleeve gastrectomy, with almost double the rate of complications [10].

3. Sleeve gastrectomy not only a malabsorptive procedure but also, a metabolic procedure

Bariatric surgery initially intended to change anatomy and to alter behavior subsequently, but now we understand that anatomical changes modulate physiology to change behavior [12]. It's no longer considered only mechanically restrictive and/or malabsorptive procedure; instead, is more considered metabolic procedure involving complex physiological changes [13]. Both restriction and hormonal modulation achieve weight loss following sleeve gastrectomy. Reduction in stomach size with sleeve resection restricts distention and increases the patient's satiety (decreasing meal portion size) [14]. This restriction is further facilitated by the natural band effect of the pylorus, which maintains intact during the sleeve gastrectomy. As early evidence suggests, sleeve gastrectomy surgery reduced the hunger feeling of patient. This might be attributed to the decreasing serum levels of ghrelin, a hormone produced mainly by P/D1 cells, which stimulates hunger feeling [6]. Gut Microbiota and its impact on the Gut-Brain axis also may cause a significant decrease in appetite [12].

4. The advantages of sleeve gastrectomy

4.1. Weight loss

A morbidly obese patient would experience a series of physical changes after sleeve gastrectomy, including a significant long-term weight loss (up to 80% EWL; Around 10 % less than RYGB), maintenance of EWL percentage in a long term, hunger reduction, satiety, food preference changes, and energy expenditure increase [3]. The reduction of BMI percentage is significantly associated with changes in plasma high sensitivity C-reactive protein (hs-CRP) [15].

4.2. Remission of mental problems

Higher preoperative depression, phobic anxiety, interpersonal sensitivity, and binge eating are associated with low postoperative weight loss in patients undergoing sleeve gastrectomy [16, 17]. Several studies have indicated that sleeve gastrectomy in morbidly obese patients has reduced mental problems [16], but further studies are needed to assess the preoperative prevalence of syndromic or subsyndromal atypical depression and its relationship with postoperative weight loss in bariatric surgery candidates [17, 18].

Due to the significant association of depression with obesity, it is one of the common disorders among individuals selected to undergo bariatric surgery. Different studies show that bariatric surgery might be associated with a modest reduction in clinical depression over the initial postoperative years [19]. Researchers found significant improvement in physical, psychosocial, and sexual QOL after bariatric surgery that as a result led to a considerable weight loss, whereas more mediocre improvement in physical, psychosocial, and sexual QOL has been reported in higher preoperative depression [4, 20]. Some other findings indicated significant improvement in psychological dimensions and eating behavior after sleeve gastrectomy. None of the psychological dimensions is associated with the percentage of EWL, which prompts the question of reliable psychological predictors. In clinical contexts, patients with low cognitive restraint would need individual support after bariatric surgery to be able to cope with their new anatomic conditions [16].

4.3. Improvement of clinical markers

Sleeve surgery has considerable regulatory impacts on a variety of clinical parameters, including serum lipid profile constituents, biochemical, histological, hematological, and inflammatory markers which all of them represent as health indexes. A summary of the sleeve gastrectomy effects on the majority of physiological parameters is presented in Figure 3.

4.3.1. Biochemical parameters

Biochemical parameters clinically represent organs' health levels. After sleeve gastrectomy, biochemical markers change respectively and some reports have given good news about the improvement of their serum levels. Improvement was found in the serum levels of Fasting Blood Sugar (FBS), alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALK), and γ-glutamyltransferase [21, 22, 23]. In several studies, mean TSH levels were decreased, whereas low free thyroxine (FT4) levels remained the same after surgery; however, TSH decrease was directly related to baseline TSH levels and not to EWL percentage. There were significant reductions in Urine albumin-to-creatinine ratio (ACR) as well [14]. In another study, one year after surgery normal serum levels of albumin and calcium in the sleeve gastrectomy patients were observed [24]. On the contrary, some researchers indicated that no significant changes in serum levels of glucose, albumin, blood urea nitrogen (BUN), Creatinine and eGFR can be observed six months after sleeve surgery [25]. In another study, a remarkable reduction in the serum levels of creatinine after bariatric surgery was observed, but no significant decrease in cystatin C levels was noted. No correlation was indicated between the UACR and BMI, adiponectin, leptin, resistin, or insulin resistance, while High-Molecular-Weight adiponectin increased and leptin levels reduced significantly [26]. Some studies also reported a sharp drop in the uric acid levels 13 months after bariatric surgery compared to baseline values, which led to a decrease in the incidence of gouty attacks [27]. According to different studies, the rs712221 polymorphism of ESR1 influences the reduction of the uric acid serum levels after bariatric surgery [28]. In fact, patients with the rs712221 genotype showed better glycemic control and more decrease in uric acid levels 12 months after surgery [28]. The general biochemical profile revealed discrepancies involving serum albumin, uric acid, creatinine, AST, and ALT to be higher in men [29].

4.3.2. Lipid disorders

Obese patients are severely involved in hyperlipidemia and other lipid disorders, which could be highly attributed to their unhealthy lifestyle. Sleeve gastrectomy has shown regulatory impacts on lipid markers after the operation (75% remission in lipid disorders). A considerable reduction can be observed in triglyceride [30], total cholesterol, VLDL cholesterol, and LDL cholesterol levels [31]. Although significant growth was observed in serum levels of HDL cholesterol [26, 31] and HDL functionality [32], some other studies showed no significant increase in HDL cholesterol serum levels after sleeve gastrectomy [26]. Surprisingly, in an interesting report in Brazil, HDL cholesterol levels became higher in females [29] and LDL cholesterol and total cholesterol were more tended to be different in men [29]; although the difference wasn't strictly significant. Considering the importance of this matter, more studies are needed to be done to clarify the association of gender with the co-morbidities after sleeve gastrectomy (See Gender and complications section).

4.3.3. Histological markers

Histological improvement, including fibrosis, steatosis, ballooning degeneration, and lobular inflammation was noticed in the non-alcoholic fatty liver activity score of patients after sleeve gastrectomy [33, 34, 35]. Several studies have demonstrated that the histological improvement was more considerable among those who underwent sleeve gastrectomy in comparison to those who underwent RYGB; however, it wasn't statistically significant [23].

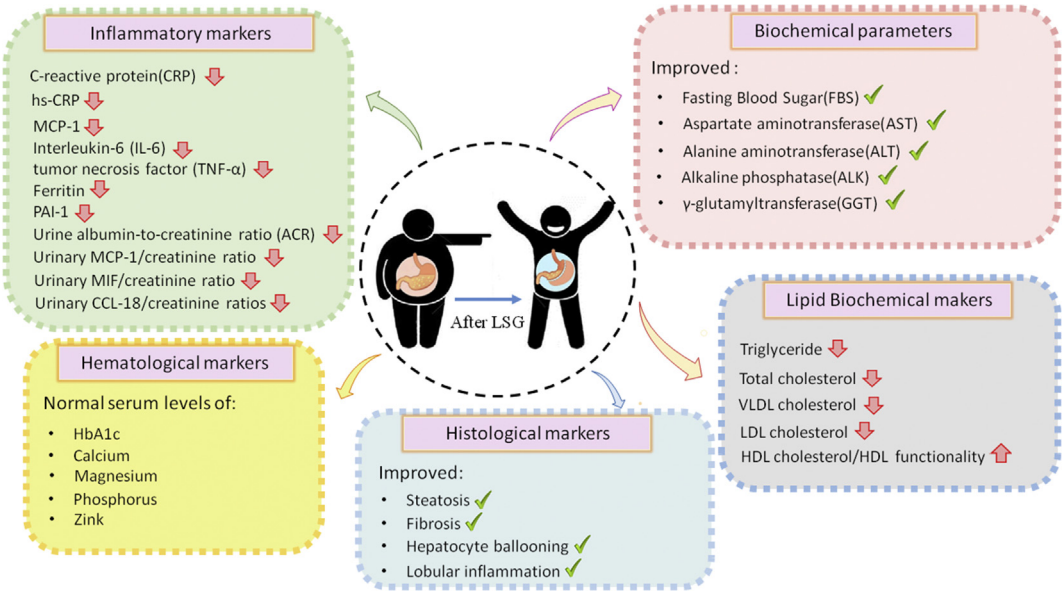

Figure 3. The details of changes in clinical markers and summary of the sleeve gastrectomy effects on the majority of physiological parameters.

4.3.4. Hematological markers

The close relationship between morbid obesity and alterations in the coagulation system was confirmed in several investigations [26, 36, 37]. Reduction in cardiovascular risk leads to a significant decrease in the thrombin generation; the critical process in hemostasis [36]. In a research, it was reported that after one-year post-surgery, patients were experiencing a normal serum levels of hemoglobin and calcium [24], as well as a significant decrease in serum levels of HbA1c and platelet [26]; however, in another study hemoglobin and hematocrit were less than normal for 28.6% and 25% of patients respectively, but ferritin, iron, and total iron-binding capacity remained the same a year after [37]. No complications with calcium, magnesium, phosphorus, and zinc level were observed, although magnesium increased significantly from baseline after a year [29]. HbA1c serum levels also went up in 30% of the samples after a year [37] but, not significantly remarkable, HbA1c tended to be higher in men [29]. Serum levels of ferritin were also considerably different among men [29].

4.3.5. Inflammatory markers

Observations showed more improved systemic and urinary inflammatory marker with a significant decrease in urinary MIF/creatinine, MCP-1/creatinine, and CCL-18/creatinine ratios [38] and also in the blood levels of MCP-1, interleukin-6 (IL-6), CRP, ferritin, and PAI-1 after sleeve gastrectomy [15, 39]. Researchers also indicated a significant reduction in hs-CRP and the urine albumin-to-creatinine ratio (ACR) as well [25]. The reduced levels of CRP and urinary cytokines suggest that bariatric surgery improves systemic and renal inflammatory status [38]. The serum concentrations of IL-6 and TNF-α were seen to decrease following the surgery in both RYGB and sleeve gastrectomy procedures [40]. Both techniques may improve the course of chronic diseases and the state of inflammation associated with obesity [40]. Sleeve gastrectomy has also shown to decrease albuminuria in patients with severe obesity and normal kidney function by affecting the regulation of inflammatory markers and reducing systemic inflammation [25].

4.4. Obesity-related disease resolution

4.4.1. Type 2 diabetes (T2D)

Recent studies showed that among obese patients (BMI from 27 to 43) with T2D, sleeve gastrectomy plus intensive medical therapy was more effective and practical in reducing the hyperglycemia than intensive medical therapy alone [13, 41, 42]. After sleeve gastrectomy, insulin sensitivity increased impressively, along with a significant reduction in FBS and HbA1c levels [24, 37]. This is mainly because of the decrease in the ghrelin serum levels as well as the increase in CCK (a neuropeptide that stimulates insulin secretion), GIP, GLP1, and GLP2 which plays a key role in diabetes resolution and metabolic control (Figure 4) [43,44]. Insulin resistance remission was also associated with serum uric acid decline in severely obese patients undergoing bariatric surgery [28].

4.4.2. Non-alcoholic fatty liver disease (NAFLD)

Obesity is a risk factor for NAFLD (Non-alcoholic fatty liver disease) and NASH (Nonalcoholic steatohepatitis). 85% of patients with NAFLD were improved after weight loss induced by sleeve gastrectomy and the biochemical improvement was found in serum levels of ALT, γ-glutamyltransferase, and AST [34, 35, 45]. The histological improvement was also noticed in the NAFLD activity score and individual components including steatosis, ballooning degeneration, and lobular inflammation. Fibrosis stage also showed significant improvement [34, 35]. Improvement in NAFLD activity score was various among different ethnics [46].

4.4.3. Cardiovascular disease

Morbid obesity and the coagulation system have a clear relationship [26, 36, 37]. Sleeve surgery for weight loss has proven to remarkably increase life expectancy and reduce cardiovascular risk in morbidly obese patients [36]. Thrombin generation greatly decreased after weight loss but this reduction might be contributed to the reduction of cardiovascular risk that is generally associated with morbid obesity [36]. Even though post-operative death reports might be more than healthy obese subjects after sleeve gastrectomy (2.4% and 1.39%, respectively), the number of cardiovascular diseases, myocardial infarction, stroke, and systolic blood pressure (SBP) significantly reduced about ten years after sleeve gastrectomy [47]. No significant difference was detected in SBP and diastolic blood pressure (DBP) six months after bariatric surgery in some other investigations [22, 25].

4.4.4. Obstructive sleep apnea

Sleeve gastrectomy's direct impacts on obstructive sleep apnea led to improvement of respiratory disturbance which consequently improved sleep quality on morbidly obese patients after the operation [48]. Additionally, minimum oxygen saturation and rapid eye movement latency improved and the requirement for continuous positive airway

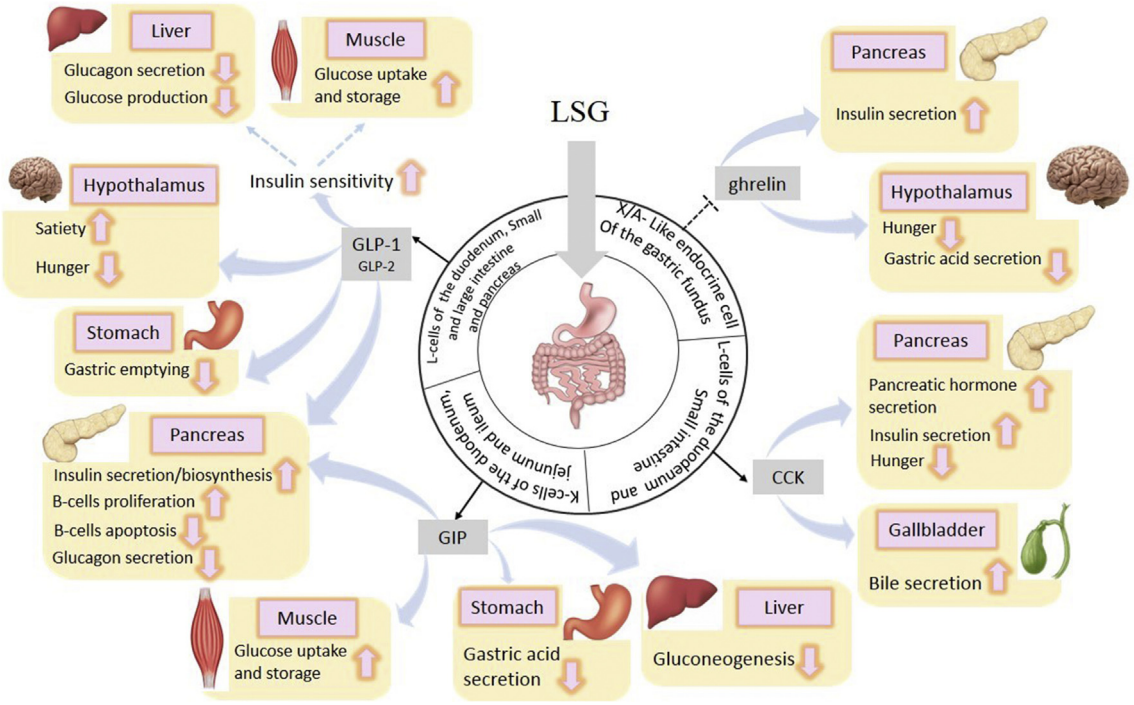

Figure 4. Clinical marker changes after sleeve gastrectomy.

pressure decreased [3]. For 85.4% of patients the resolution occurred with snoring after sleeve gastrectomy [49].

4.4.5. High blood pressure

Several reports have shown that high blood pressure is resolved after sleeve gastrectomy [23, 39]. Although the resolution of hypertension is the ideal goal, any improvement in hypertension may translate to reduced cardiovascular events or may be considered as a surrogate marker for morbidities like cardiovascular disease [50].

4.4.6. Stroke and heart attack

Obesity is associated with a higher rate of stroke incidence. The data showed that there was a 50 percent lower death rate among participants with bariatric surgery, which considerably reduced the risk of stroke and heart attack among them as well [51].

4.4.7. Craniopharyngioma-related hypothalamic obesity

Craniopharyngioma is a rare type of brain tumor and hypothalamic obesity is considered an adverse consequence of such tumors in the brain. Weight loss after RYGB, but not sleeve gastrectomy, was comparable between patients with craniopharyngioma-related hypothalamic obesity and control subjects [52] (see Table 1).

4.5. Non-obesity-related diseases remission

The majority of diseases are not directly associated with obesity but patients might show improvement and remission on these conditions after sleeve gastrectomy (Table 2). Multivariable analysis showed that bariatric surgery was associated with a lower risk of renal failure, pneumonia, sepsis, urinary tract infection, and respiratory failure [53].

4.5.1. Gout

Obesity is a risk factor for the development of several inflammatory and immune-mediated conditions such as psoriasis, lupus, inflammatory bowel disease, and gout [53]. An increased incidence of early gouty attacks after bariatric surgery has been reported, but the data is sparse. The influence of weight loss surgery on the behavior of gout, beyond the immediate postoperative phase remains unclear. In a recent study, the incidence after a month up to a year was decreased significantly [27].

4.5.2. Musculoskeletal pain

Joint pain is a common musculoskeletal complaint of morbidly obese patients that can lead to gait abnormalities, perceived mobility limitations, and declining QOL but it cannot be considered as an obesity-related disease. Improvements in some, but not all, gait parameters, walking speed, QOL, and perceived functional limitations occurred three months after a bariatric procedure [54]. There was a higher frequency of multiple musculoskeletal pain complaints, including non-weight-bearing sites compared to historical controls before surgery which lowered remarkably at most sites following weight loss and physical activity [4]. Rapid and sustained increase of sclerostin and bone turnover markers (CTX and P1NP) also caused an increase in bone metabolism and resulted in more bone mineral density loss at all skeletal sites [55]. 100% resolved joint pain within 12 months after surgery was also observed in another study [4].

4.5.3. Ovarian disorders

Obese women are at higher risk for several pregnancy complications, such as preeclampsia, gestational diabetes, cesarean delivery (particularly for failure to progress), longer stages of labor (first and second), polyhydramnios, and difficulty in spinal and epidural placement. Above that, some studies among obese women revealed that there was a higher risk of neural tube defects and neonatal mortality in their newborn [56]. Several changes in female reproduction including the partial recovery of luteal function [57], enhanced sexual function [58], higher rates of fertility treatments and reduction in the risk of miscarriage, pregnancy complications, and fetal macrosomia [59] were also indicated in a couple of studies. Moreover, amenorrhea was resolved in all premenopausal females after sleeve gastrectomy in several investigations [49].

Polycystic ovary syndrome (PCOS) is the most common cause of female infertility. Visceral obesity and insulin resistance are the fundamental pathophysiological mechanisms behind PCOS [60]. Different researches showed that sleeve gastrectomy improved hirsutism and PCOS but more is required to figure out which technique (RYGB, sleeve

Table 1. Reduction in obesity-related comorbidities.

Author	Year	Type of Disease	Remission (Percent)	Excess weight loss (EWL)	Ref.
Peterli R	2018	morbid obesity	86.2% after one year	-	[8]
Capoccia D	2018	Diabetes mellitus	At two months 27% and at six months 63%	-	[79]
P. Sieber	2014	Type 2 diabetes	85% after five years LSG	After 1 year: 61.5%After 2 years: 61.1% and after 5 years 57.4%	[80]
Ruiz-Tovar J	2019	Insulin resistance in 59.2%, dyslipidemia in 23.5%, hepatic steatosis in 16%, and type 2 diabetes mellitus in 3.9% (of 51 patients)	76% after LSG	At 6 months and 1 and 2 years was 94.6%, 96.2%, and 92.9%, respectively	[81]
E. George	2012	Diabetes in obese patients	-	After 72, 84, and 96 months LSG:52%, 43%, and 46%	[82]
R. Paluszkiewicz	2012	morbid obesity and obesity-related comorbidities	–	At 12 months: 67%	[83]
I. Golomb	2015	Diabetes in obese patients	–	After the one year: 76.8% After the three year: 69.7% After the five year: 56.1%	[79]
V. Våge	2014	Morbid obesity and obesity-related diseases	80.7% after two years	—	[49]
W. Lee	2011	Type 2 Diabetes Mellitus	47% after 12 month	—	[84]
M. Milone	2013	Diabetes in obese patients	After three months: 62% After six months: 68% After 12 months: 87%	–	[85]
F. Abbatini	2012	Obese diabetic patients	After three months: 29/33 After 12 months: 29/33 After 36 months: 22/26 After 36 months: 10/13	–	[86]
A. Algooneh	2016	Non-alcoholic fatty liver disease (NAFLD)	56 % complete resolution of NAFLD after LSG	55.7% ± 23.0	[87]
J. Ruiz-Tovar	2017	Non-alcoholic fatty liver disease (NAFLD)	90 % complete resolution of NAFLD after LSG	–	[88]
M. Manco	2017	Obese Adolescents with Non-alcoholic fatty liver disease (NAFLD)	—	21.5% after 1 year	[89]
M. Iancu	2013	Coronary heart disease (CHD)	—	67.3 and 78.3 at six and 12 months	[90]
P. Major	2017	Cardiovascular disease	—	53.18% after one year	[91]
D. Gutierrez Blanco	2017	Cardiovascular disease	–	68.15% after one year	[92]
R. Wilhelm	2014	Hypertension	Hypertension resulotion:34% of patients	—	[50]
S. Mashaqi	2018	Obstructive sleep apnea (OSA)	Apnea-hypopnea index (AHI) resolution: 40 events per hour and seven events per hour after LSG (80%)	—	[93]
A. Christel	2016	Obstructive sleep apnea (OSA)	—	65.5 %	[94]

gastrectomy, or any other) would be a better option for the young infertile women [60].

4.5.4. Pregnancy and fertility

Despite the increased fertility rate among patients following BS, pregnancy within 18 months is not recommended. it is mainly because of the adverse consequences affecting both mother and the fetus. Ideally, stabilizing the weight after sleeve gastrectomy needs to be considered before pregnancy in patients [59].

4.5.5. Urinary incontinence

Epidemiological studies document obesity as an important risk factor for urinary incontinence. Over the last two decades, the incident urinary incontinence has increased by 30%–60% for each unit in BMI [61]. There might be a stronger association between increasing weight and prevalent stress incontinence than the association of increasing weight with urge incontinence and overactive bladder syndrome [61]. Surgical weight loss is considered the most practical and effective technique to reduce urinary incontinence symptoms (Up to 73% of patients after sleeve gastrectomy) and should be applied as the first-line treatment in these patients [61].

4.5.6. Cancer

Obesity is one of the most influential risk factors for cancer [62]. Sleeve gastrectomy is associated with a significant reduction in cancer incidence and mortality. The cancer-protective role of sleeve surgery is considered the strongest for female obesity-related tumors; however, the underlying mechanisms may involve both weight-dependent and weight-independent effects [63]. In a research among Swedish patients, researchers found an unexpectedly higher prevalence of cancer in female underwent bariatric surgery than obese men [64]. Understanding the precise metabolic mechanisms preventing cancer by metabolic surgery can widen our horizon of how obesity, diabetes, and metabolic syndrome are associated with tumorigenesis and growth [63].

5. The disadvantages of sleeve gastrectomy

5.1. Intra-operative complications

Bleeding, leakage, and gastric fistulae are the most common intra-operative complications and post-operative complications after sleeve gastrectomy [53]. The majority of publications are focused on the post-operative effects rather than intra-operative leaks and bleeds. The methods using for detecting intra-operative staple line bleeds are not standardized but present rather a different challenge in which bleeds are often undocumented or considered as a nuisance and are routinely treated with cauterization, sutures, sealants, and clips or might be self-resolved by the application of pressure along the staple line. Very few studies have addressed the impact of intra-operative leaks and bleeds on other complications or factors such as operative time, cost, and length of stay [65]. A research group reported that while bleeds did not affect

Table 2. The most common postoperative complications of SG.

Complication	Frequency % (Mean ± SD)	Population (Aggregate)	Author, Year	Ref.
Leakage	1.27% ± 0.99	6242	Sammour, 2017; Hoogerboord, 2014; Duran, 2019; Alizadeh, 2019; Sakran, 2016;	[95] [96] [24] [97] [98]
Hemorrhage	1.77% ± 0.32	6994	Hoogerboord, 2014; De Angelis, 2016; Goitein, 2015; Gagner, 2013; Thereaux J, 2019; Sammour, 2010; Sakran, 2016;	[99] [100] [96] [101] [102] [95] [98]
Kidney stones	1.45 ± 0.35	869	Peterli, 2017; C.lienke, 2015;	[103] [104]
Choleystectomy (For newly acquired gallstones)	3 ± 0.7	868	Peterli, 2017; Wood, 2019;	[103] [105]
Insufficient weight loss	2.35 ± 0.35	255	Dang, 2019; Peterli, 2017;	[10] [103]
Splenic injury	0.30 ± 0.1	630	Gagner, 2013; Gibson, 2015;	[101] [107]
Liver injury	3.60 ± 3.40	583	Gagner, 2013; Sweeny, 2019;	[101] [108]
Portal vein thrombosis	0.852 ± 0.76	5238	Gagner, 2013; Salinas, 2014; Duran, 2019; Moy, 2008; Sakran, 2016;	[101] [109] [24] [110] [98]
Venous thromboembolism	0.16 ± 0.12	975	Gagner, 2013; Genco, 2017; Magee, 2010;	[101] [111] [112]
Respiratory failure	3.16 ± 1.29	239	Moy, 2008; Duran, 2019; Stroh, 2009;	[110] [24] [113]
Abscess	0.36 ± 0.33	3167	Thereaux J, 2019; Sakran, 2016;	[102] [98]
Sleeve stricture	0.40 ± 0.30	3167	Thereaux J, 2019; Sakran, 2016;	[102] [98]
Choledocholithiasis	5.15 ± 4.45	1543	Thereaux J, 2019; Mishra, 2016;	[102] [114]
Nondysplastic Barrett's esophagus	15.16 ± 2.04	254	Genco, 2017; Soricelli, 2018;	[115] [116]
Pneumonia	3.65 ± 2.85	257	Duran, 2019; Cuomo, 2019;	[24] [117]
Sepsis	0.80 ± 0.08	262	Duran, 2019; Stroh, 2009;	[24] [113]
Infection	1.33 ± 0.61	379	Moy, 2008; Duran, 2019; Stroh, 2009;	[110] [24] [113]
Minor complications	7% ± 3	196	Thereaux J, 2019; Hoogerboord, 2014;	[102] [96]
Mortality	0.33 ± 0.33	865	Gagner, 2013; Magee, 2010;	[101] [112]
Nutritional Deficiency				
Vitamin D	30.5 ± 0.50	1064	Peterli, 2017; M. Koffman 2005;	[103] [118]
Vitamin B12	30.5 ± 5.50			
Iron	17.85 ± 4.15	140	Peterli, 2017; Sallé, 2010;	[103] [119]
Zink	7.40 ± 6.59	140	Peterli, 2017; Sallé, 2010;	[103] [119]
Folate	13.65 ± 4.35	1064	Peterli, 2017; M. Koffman 2005;	[103] [118]

operative time in their sleeve gastrectomy operation, they did disrupt the momentum of the operation [66]. Various studies support the premise that intra-operative staple line leaks and bleeds are primarily associated with stapler misfires [65].

5.2. Early complications

A variety of complications can happen in the post-operative period. The most common complications among patients during this time include

pulmonary emboli, hemorrhage, chest infections, abscess, incisional hernia, relaparoscopy for retained drain, anatomic leakage, wound infections, gastroesophageal reflux disease (GERD), and rhabdomyolysis in men [5, 49, 67]. Also, dumping usually occurs around an hour after eating and presents with symptoms of bloating, flushing, diarrhea, and light-headedness [67].

5.3. Nutritional and metabolic complications

The most common micronutrient deficiencies are of vitamin B12, iron, calcium, and vitamin D [67]. Other micronutrient deficiencies that can lead to severe complications include thiamine, folate, and fat-soluble vitamins [67, 68]. Investigations show that sleeve gastrectomy mostly led to health improvements three years after surgery and at year five, the nutrient levels reverted toward the baseline values [37]. These observations draw attention to the necessary clinical monitoring in the first five years. According to a prospective study, patients experienced fewer nutrient deficiencies after sleeve gastrectomy than the deficiencies they experienced after LRYGB [69].

5.4. Insufficient weight loss

Catheline *et al.* realized that 77% of patients who had a follow up greater than 18 months showed significant weight loss; however, 23% of patients had insufficient weight loss (defined between 35 to 40 kg/m^2 by BMI), progressive weight regain, or persistence of co-morbidities [42, 70]. In insufficient weight loss cases, a second-stage operation like relaparoscopic sleeve gastrectomy or gastric bypass can be proposed [70]. Based on different studies, just a small proportion of patients with insufficient weight loss, about 2.5 %, required a second operation [70, 71, 72].

5.5. Gender and complications

LDL cholesterol and total cholesterol levels were more different in males [29]. Over the last years, some investigations have proven that women are more addicted to sweets than meat products. During reproductive ages, women are naturally susceptible to iron deficiency and anemia [73]. Men, on the other side, tend to be heavier with larger muscle mass that may increase surgical time and general postoperative complications including rhabdomyolysis [74]. More studies are needed to find out the relationship between gender and the co-morbidities of sleeve gastrectomy.

5.6. Ethnic disparities and complications

Although the race and ethnicity are not independently associated with the likelihood of proceeding with bariatric surgery, studies showed that Asians compared with Caucasians are most susceptible to the metabolic complications of obesity at a much lower body mass index [75]. Studies among Indian patients have also demonstrated a higher risk of obesity-related diseases and NAFLD at a much lower body mass index [46]. African-Americans populations showed higher rates of remission compared to European-Americans patients [76]. Coleman *et al.* indicated that White and Hispanic people experienced more EWL in comparison with Black populations, and Blacks were also more susceptible to post-operative complications compared to White and Hispanics [77]. In another study, the acute renal failure in Hispanic subjects was considerably higher compared to Blacks [78].

6. Conclusion

The surveyed pieces of the literature suggest that sleeve gastrectomy is a safe and efficient technique with no mortality and co-morbidities resolution and less complication. Simple anatomical alterations of the gastrointestinal tract have both intentional and unintentional consequences. The more we learn about these alterations, the more it becomes evident to us that metabolic surgery is more than just a means of weight loss. Whether it can be recommended as a treatment for obesity-related co-morbidities such as NAFLD and cancer remains in controversy. Studying these operations not only helps to improve the effects of surgery, but also gives wider insights into understanding integrated physiology to harness the benefits of surgery without using the scalpel. For further studies, we suggest using rodent models with a series of benefits that make bariatric surgery procedures possible. Rodents are small and breed quickly, making the research possible on large numbers with complex diseases. Applying the knowledge of the gut-brain axis mechanism of action and implementing the data on the physiological bases of food intake regulation in clinical practice may allow for the more functional management of the obesity epidemic.

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