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# The Metabolic Effects of Laparoscopic Sleeve Gastrectomy: A Review

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## ABSTRACT

Bariatric surgery, as a whole, is the only proven modality to manage the severely obese. The laparoscopic sleeve gastrectomy (LSG) is the most recent tool in the armamentarium of bariatric surgery. Once used as the first-stage in a two-stage procedure for the super-obese patient, it is now used as a primary bariatric procedure. Involving the resection of the greater curvature of the stomach, it has been shown to achieve clinically significant excess weight loss and improvements in obesity-related co-morbidities. Its mechanism of action was originally classified as being a restrictive procedure, similar to laparoscopic gastric banding, but is now known to be far more complex. The pronounced effects of LSG on gut hormones such as ghrelin, PYY and incretins, allow this bariatric intervention to be adequately compared to the more historically classified malabsorptive procedures like the gastric bypass. In this review, we explore the metabolic effects and outcomes of LSG in producing significant weight loss and improving the factors associated with the metabolic syndrome.

*Keywords:* Bariatric Surgery; Gastrectomy; Metabolic syndrome; Diabetes Mellitus Type 2

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Implication for health policy/practice/research/medical education:
This study helps to understand the literature, experience and outcomes of a new exciting bariatric operation-Laparoscopic Sleeve Gastrectomy

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## 1. Context

The worldwide incidence of obesity is dramatically increasing; the World Health Organization has estimated that 1.7 billion adults are overweight (1). In the United States alone, approximately 1/3 of all adults are classified as obese (body mass index (BMI) > 30 kg/m2). Obesity, in addition with the associated factors of the metabolic syndrome (hypertension, dyslipidemia, and diabetes), put patients at increased risk of cardiovascular morbidity and mortality (2, 3). Bariatric surgery has been shown to be the most efficacious option for managing severe obesity (4). Not surprisingly, the field of bariatric surgery has grown remarkably over the past two decades with over 300, 000 procedures performed annually and is now the second most common abdominal operation (5, 6). As one would expect, the procedures themselves have evolved over the past 15 years. One procedure, in particular, has become increasingly popular; the Laparoscopic Sleeve Gastrectomy (LSG). Sleeve Gastrectomy (SG) did not begin as a stand-alone procedure. It was initially described by Marceau et al. as part of a larger bariatric operation- the biliopancreatic diversion with duodenal switch (BPD-DS) (7). Recognizing the less than consistent long-term weight loss results of a one-stage bariatric procedure in the super-obese patient, Regan et al. implemented LSG as part of a two-stage laparoscopic Roux-en-Y gastric bypass (RYGB) in this patient population (8). Building on this experience that LSG was both safe and effective, Baltasar et al. proposed LSG could employed as a primary bariatric procedure (9). As it is still a relatively new procedure, it continues to be evaluated by the medical community as more long-term information presents itself.

## 2. Evidence Acquisition

LSG has gained popularity as a primary bariatric procedure due to its comparative simplicity (10). It involves creating a "sleeve" of the stomach by resecting the majority of the greater curvature of the stomach, leaving a vertical tube of 60-80mL in capacity (11-13) compared to alternative bariatric procedures, LSG offers several advantages: 1) immediate restrictive weight loss; 2) maintained continuity of gastrointestinal anatomy; 3) avoidance of the dumping syndrome; 4) absence of an implantable foreign body; and 5) ease of operative technique with potential conversion to other bariatric procedures (14, 15). The disadvantages however, include: 1) irreversibility of the procedure; 2) possibility of a staple line leak and/or bleed; 3) higher operative risk compared to other restrictive procedures; 4) and paucity of long-term data on safety and efficacy (12, 14) .

### *2.1. Mechanism of Action*

Historically, bariatric surgery has been classified as restrictive (Gastric Banding), malabsorptive (BPD-DS), or a combination of both (RYGB). Restrictive procedures rely on reducing caloric intake and mechanically delaying gastric emptying as a means of producing clinically significant weight loss (16). LSG was, at first, presumed to rely on a similar strategy. However, Melissas et al. contradicted this notion by demonstrating that with LSG there was actually an acceleration of gastric emptying of solids; a change that is maintained long-term (16, 17). It was also hypothesized that due to the removal of the gastric fundus, food boluses would cause distention of the antrum, leading to decreased hunger drive and early satiety (17). This research raised the idea that other mechanisms of energy intake reduction, such as gut hormones, may further explain the effectiveness of LSG in weight reduction.

### *2.2. Gut Hormones*

#### *2.2.1. Ghrelin*

Ghrelin is a unique peptide with orexigenic, adipogenic and somatotrophic functions. Found in the pylorus of the stomach, it was originally identified by Kojima et al in 1999 (18). Ghrelin stimulation causes weight gain through hyperphagia, adiposity, and anabolic effects (19, 20). The physiological role of ghrelin in humans was further elicited by Cummings et al. who demonstrated a preprandial rise and postprandial fall in plasma ghrelin levels (21). Attributing the decline in ghrelin to the removal of the gastric fundus, Langer et al. showed a significant and maintained reduction in plasma ghrelin levels immediately after and 6 months post-LSG (22). Karamanakos et al. and Ramon et al. both prospectively evaluated the changes in fasting and postprandial ghrelin levels after RYGB and SG and found that only SG suppressed fasting and postprandial ghrelin levels significantly (23, 24).

#### *2.2.2. Peptide Tyrosine-Tyrosine*

Peptide tyrosine-tyrosine (PYY) is an anorectic hormone whose attenuated function, while fasting and after eating, is implicated in obesity (25). First identified by Tatemoto et al in 1980, this gut hormone is released into the circulation after meals (26). Batterham et al. showed that peripheral infusion of PYY in human subjects resulted in decreased caloric intake (27, 28). In respective prospective studies, both Karamanakos et al. and Ramon et al. found significantly increased levels of PYY post-LSG (23, 24). This clinically culminates in LSG patients having increased satiety and less hunger-drive after meals.

#### *2.2.3. Incretins*

Incretins are gut hormones that augment the release of insulin and promote pancreatic beta cell proliferation (29). Approximately 50% of insulin release following meals is due to the release of incretins, namely glucose-dependent insulin tropic polypeptide (GIP) and glucagon-like peptide 1 (GLP-1) (30). Despite being a purely gastric procedure, SG does in fact lead to an increased post-prandial release of distal gut hormones in a mechanism as yet to be determined (31).

### 2.3. Complications

There are several inherent risks associated with LSG. These risks include: 1) staple line disruption and subsequent leak; 2) bleeding requiring reoperation or transfusion; and 3) postoperative strictures requiring endoscopic or surgical intervention. In a systematic review of SG, Brethauer et al. identified 33 studies with detailed complication data. In these studies, there were 53 leaks (2.2%), 28 bleeding episodes (1.2%), and 15 postoperative strictures (0.6%), 15 Nonetheless, LSG is still considered a low morbidity procedure, with a mortality rate < 1% (32).

## 4. Results

### 4.1. Weight Loss

Bariatric surgery has consistently been shown to be more efficacious in managing severe obesity in comparison to pharmaceutical, diet or lifestyle regimens (33). Even so, the model of the Weight Wise Clinic in Edmonton, Alberta, has shown that a comprehensive medical, dietary and surgical approach can be effective and synergisitic (12). The average reduction in BMI for patients undergoing LSG is 8.75 kg/m2 at 6-months and 11.87 kg/m2 at 1-year. This is in comparison to laparoscopic gastric band and laparoscopic gastric bypass where the 6-month BMI reduction is 5.02kg/m2 and 10.82kg/m2 respectively and the 1-year BMI reduction is 7.05kg/m2 and 15.34kg/m2 respectively. As such, LSG is positioned between laparoscopic gastric band and laparoscopic gastric bypass for BMI reduction (34). A recent systematic review of sleeve gastrectomy reported an excess weight loss (%EWL) of 47% (35). However, there remains a wide range of reported weight loss in the literature; one review of 15 laparoscopic sleeve gastrectomy studies stated a %EWL between 33-90% (36). This high variability in reported weight loss could in part be due to the poor standardization of SG with differing inter-institutional agreement on operational technique (37). Nonetheless, this impressive weight loss has been shown to be sustainable in the long-term; Bohdjalian et al. demonstrated a mean %EWL of 55.0% at 5 years (38).

### 4.2. Type 2 Diabetes Mellitus

The effect of SG on Type 2 diabetes mellitus (T2DM) is quite impressive. In a recent systematic review, Gill et al. report a complete resolution of T2DM in 66.2% of patients undergoing SG (35). Resolution of diabetes is achieved with overall improvements in fasting glucose levels and HbA1c levels, leading to the cessation of all diabetic medications. The Stampede Trial at the Cleveland clinic, which compared SG and gastric bypass against medical management, showed that not only was there a significant reduction in overall oral hypoglycemic use, but at 1 year follow-up only 8% of SG patients required insulin (39). It is interesting that the resolution of T2DM does not significantly correlate with weight loss, lending strength to the argument that SG is not purely a restrictive procedure (40). Compared to duodenal switch and gastric bypass, Roslin et al. found that there was no significant difference in fasting glucose and insulin levels in those patients undergoing SG (41).

### 4.3. Hypertension

Hypertension is yet another component of the metabolic syndrome, affecting nearly half of patients presenting for bariatric surgery (42). In a recent review, 58% of patients reported resolutions of their hypertension at 1-year follow up, with 75% of patients experiencing at least some improvement. This is in keeping with other bariatric surgeries, as Buchwald et al. reported that 78.5% of all surgical patients had resolution or improvement in their hypertension (43).

### 4.4. Hyperlipidemia

A retrospective analysis by Zhang et al. showed that there is improvement in patients' lipid profiles post-SG (44). They found significant improvements in high-density lipoprotein cholesterol (HDL) and triglycerides (TRIG) but no change in low-density lipoprotein cholesterol (LDL) and total cholesterol (TC). Videl et al. found that the changes in HDL and TRIG seen after LSG were comparable to those seen after gastric bypass (40). In general however, bariatric procedures such as RYGB and BPD-DS tend to better improve all the variables in the lipid profile (TC, LDL, HDL and TRIG), and thus are more successful in treating hyperlipidemia (43, 44).

### 4.5. Other Co-morbidities

Chopra et al. showed that in addition to diabetes and hypertension, LSG significantly improve asthma, obstructive sleep apnea and gastro esophageal reflux disease (GERD), in 90%, 90.74% and 45.92% of patients respectively (45). However, there still remains to be a consensus as to the effect of SG on GERD as studies have found conflicting evidence about whether it is an aggravating or alleviating factor (46). It can be postulated that improvements in the metabolic syndrome after SG should be reflected in a reduction in overall mortality (39). There is evidence that there is a modest reduction in long-term mortality following bariatric surgery, however this relationship has yet to be conclusively shown for SG (47).

## 5. Conclusions

LSG has emerged as an effective stand-alone procedure in the thriving world of bariatric surgery. It continues to produce results that can be compared to the gold standard, RYGB. The literature has moved away from labeling LSG as a purely restrictive procedure, as its interactions with gut hormones (ghrelin, PYY, and incretins) are now recognized. As more long-term data becomes available, the true value of this bariatric procedure will be fully recognized.

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## Authors' Contribution

Noah Switzer, Andrew Smith contributed to the inception and drafting of the manuscript. Daniel Birch and Shahzeer Karmali contributed in the inception, review and editing of the manuscript.

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## References

1. Buchwald H, Ikramuddin S, Dorman RB, Schone JL, Dixon JB. Management of the metabolic/bariatric surgery patient. *Am J Med*.2011;**124** (12):1099-105
2. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute scientific statement: Executive Summary. *Crit Pathw Cardiol*.2005;**4** (4):198-203
3. Isomaa B, Almgren P, Tuomi T, Forsen B, Lahti K, Nissen M, et al. Cardiovascular morbidity and mortality associated with the metabolic syndrome. *Diabetes Care*.2001;**24** (4):683-9
4. Sjostrom L, Lindroos AK, Peltonen M, Torgerson J, Bouchard C, Carlsson B, et al. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *N Engl J Med*.2004;**351** (26):2683-93
5. Buchwald H, Oien DM. Metabolic/bariatric surgery Worldwide 2008. *Obes Surg*.2009;**19** (12):1605-11
6. Markar SR, Penna M, Karthikesalingam A, Hashemi M. The impact of hospital and surgeon volume on clinical outcome following bariatric surgery. *Obes Surg*.2012;**22** (7):1126-34
7. Marceau P, Biron S, Bourque RA, Potvin M, Hould FS, Simard S. Biliopancreatic Diversion with a New Type of Gastrectomy. *Obes Surg*.1993;**3** (1):29-35
8. Regan JP, Inabnet WB, Gagner M, Pomp A. Early experience with two-stage laparoscopic Roux-en-Y gastric bypass as an alternative in the super-super obese patient. *Obes Surg*.2003;**13** (6):861-4
9. Baltasar A, Serra C, Perez N, Bou R, Bengochea M, Ferri L. Laparoscopic sleeve gastrectomy: a multi-purpose bariatric operation. *Obes Surg*.2005;**15** (8):1124-8
10. Gagner M, Deitel M, Kalberer TL, Erickson AL, Crosby RD. The Second International Consensus Summit for Sleeve Gastrectomy, March 19-21, 2009. *Surg Obes Relat Dis*.2009;**5**(4):476-85
11. Braghetto I, Korn O, Valladares H, Gutierrez L, Csendes A, Debandi A, et al. Laparoscopic sleeve gastrectomy: surgical technique, indications and clinical results. *Obes Surg*.2007;**17**(11):1442-50
12. Gill RS, Switzer N, Driedger M, Shi X, Vizhul A, Sharma AM, et al. Laparoscopic sleeve gastrectomy with staple line buttress reinforcement in 116 consecutive morbidly obese patients. *Obes Surg*.2012;**22** (4):560-4
13. Karmali S, Johnson Stoklossa C, Sharma A, Stadnyk J, Christiansen S, Cottreau D, et al. Bariatric surgery: a primer. *Can Fam Physician*.2010;**56** (9):873-9
14. Brethauer SA, Hammel JP, Schauer PR. Systematic review of sleeve gastrectomy as staging and primary bariatric procedure. *Surg Obes Relat Dis*.2009;**5** (4):469-75
15. Chen B, Kiriakopoulos A, Tsakayannis D, Wachtel MS, Linos D, Frezza EE. Reinforcement does not necessarily reduce the rate of staple line leaks after sleeve gastrectomy. A review of the literature and clinical experiences. *Obes Surg*.2009;**19** (2):166-72
16. Melissas J, Koukouraki S, Askoxylakis J, Stathaki M, Daskalakis M, Perisinakis K, et al. Sleeve gastrectomy: a restrictive procedure? *Obes Surg*.2007;**17** (1):57-62
17. Melissas J, Daskalakis M, Koukouraki S, Askoxylakis I, Metaxari M, Dimitriadis E, et al. Sleeve gastrectomy-a "food limiting" operation. *Obes Surg*.2008;**18** (10):1251-6
18. Kojima M, Hosoda H, Date Y, Nakazato M, Matsuo H, Kangawa K. Ghrelin is a growth-hormone-releasing acylated peptide from stomach. *Nature*.1999;**402** (6762):656-60
19. Wren AM, Small CJ, Abbott CR, Dhillo WS, Seal LJ, Cohen MA, et al. Ghrelin causes hyperphagia and obesity in rats. *Diabetes*.2001;**50** (11):2540-7
20. Wu JT, Kral JG. Ghrelin: integrative neuroendocrine peptide in health and disease. *Ann Surg*.2004;**239** (4):464-74
21. Cummings DE, Purnell JQ, Frayo RS, Schmidova K, Wisse BE, Weigle DS. A preprandial rise in plasma ghrelin levels suggests a role in meal initiation in humans. *Diabetes*.2001;**50**(8):1714-9
22. Langer FB, Reza Hoda MA, Bohdjalian A, Felberbauer FX, Zacherl J, Wenzl E, et al. Sleeve gastrectomy and gastric banding: effects on plasma ghrelin levels. *Obes Surg*.2005;**15** (7):1024-9
23. Karamanakos SN, Vagenas K, Kalfarentzos F, Alexandrides TK. Weight loss, appetite suppression, and changes in fasting and postprandial ghrelin and peptide-YY levels after Roux-en-Y gastric bypass and sleeve gastrectomy: a prospective, double blind study. *Ann Surg*.2008;**247** (3):401-7
24. Ramon JM, Salvans S, Crous X, Puig S, Goday A, Benaiges D, et al. Effect of Roux-en-Y gastric bypass vs sleeve gastrectomy on glucose and gut hormones: a prospective randomised trial. *J Gastrointest Surg*.2012;**16** (6):1116-22
25. le Roux CW, Batterham RL, Aylwin SJ, Patterson M, Borg CM, Wynne KJ, et al. Attenuated peptide YY release in obese subjects is associated with reduced satiety. *Endocrinology*.2006;**147** (1):3-8
26. Tatemoto K, Mutt V. Isolation of two novel candidate hormones using a chemical method for finding naturally occurring polypeptides. *Nature*.1980;**285** (5764):417-8
27. Batterham RL, Cohen MA, Ellis SM, Le Roux CW, Withers DJ, Frost GS, et al. Inhibition of food intake in obese subjects by peptide YY3-36. *N Engl J Med*.2003;**349** (10):941-8
28. Batterham RL, Cowley MA, Small CJ, Herzog H, Cohen MA, Dakin CL, et al. Gut hormone PYY(3-36) physiologically inhibits food intake. *Nature*.2002;**418** (6898):650-4
29. Scott WR, Batterham RL. Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy: understanding weight loss and improvements in type 2 diabetes after bariatric surgery. *Am J Physiol Regul Integr Comp Physiol*.2011;**301** (1):R15-27
30. Laferrere B. Do we really know why diabetes remits after gastric bypass surgery? *Endocrine*.2011;**40**(2):162-7
31. Romero F, Nicolau J, Flores L, Casamitjana R, Ibarzabal A, Lacy A, et al. Comparable early changes in gastrointestinal hormones after sleeve gastrectomy and Roux-En-Y gastric bypass surgery for morbidly obese type 2 diabetic subjects. *Surg Endosc*.2012;**26** (8):2231-9
32. Sakran N, Goitein D, Raziel A, Keidar A, Beglaibter N, Grinbaum R,

et al. Gastric leaks after sleeve gastrectomy: a multicenter experience with 2,834 patients. *Surg Endosc.*2012

33. Maggard MA, Shugarman LR, Suttorp M, Maglione M, Sugerman HJ, Livingston EH, et al. Meta-analysis: surgical treatment of obesity. *Ann Intern Med.*2005;**142** (7):547-59
34. Hutter MM, Schirmer BD, Jones DB, Ko CY, Cohen ME, Merkow RP, et al. First report from the American College of Surgeons Bariatric Surgery Center Network: laparoscopic sleeve gastrectomy has morbidity and effectiveness positioned between the band and the bypass. *Ann Surg.*2011;**254** (3):410-20
35. Gill RS, Birch DW, Shi X, Sharma AM, Karmali S. Sleeve gastrectomy and type 2 diabetes mellitus: a systematic review. *Surg Obes Relat Dis.*2010;**6** (6):707-13
36. Shi X, Karmali S, Sharma AM, Birch DW. A review of laparoscopic sleeve gastrectomy for morbid obesity. *Obes Surg.*2010;**20** (8):1171-7
37. Victorzon M. An update on sleeve gastrectomy. *Minerva Chir.*2012;**67** (2):153-63
38. Bohdjalian A, Langer FB, Shakeri-Leidenmuhler S, Gfrerer L, Ludvik B, Zacherl J, et al. Sleeve gastrectomy as sole and definitive bariatric procedure: 5-year results for weight loss and ghrelin. *Obes Surg.*2010;**20** (5):535-40
39. Schauer PR, Kashyap SR, Wolski K, Brethauer SA, Kirwan JP, Pothier CE, et al. Bariatric surgery versus intensive medical therapy in obese patients with diabetes. *N Engl J Med.*2012;**366** (17):1567-76
40. Vidal J, Ibarzabal A, Romero F, Delgado S, Momblan D, Flores L, et al. Type 2 diabetes mellitus and the metabolic syndrome following sleeve gastrectomy in severely obese subjects. *Obes Surg.*2008;**18** (9):1077-82
41. Roslin MS, Dudiy Y, Weiskopf J, Damani T, Shah P. Comparison between RYGB, DS, and VSG effect on glucose homeostasis. *Obes Surg.*2012;**22** (8):1281-6
42. Sarkhosh K, Birch DW, Shi X, Gill RS, Karmali S. The impact of sleeve gastrectomy on hypertension: a systematic review. *Obes Surg.*2012;**22** (5):832-7
43. Buchwald H, Avidor Y, Braunwald E, Jensen MD, Pories W, Fahrbach K, et al. Bariatric surgery: a systematic review and meta-analysis. *JAMA.*2004;**292** (14):1724-37
44. Zhang F, Strain GW, Lei W, Dakin GF, Gagner M, Pomp A. Changes in lipid profiles in morbidly obese patients after laparoscopic sleeve gastrectomy (LSG). *Obes Surg.*2011;**21** (3):305-9
45. Chopra A, Chao E, Etkin Y, Merklinger L, Lieb J, Delany H. Laparoscopic sleeve gastrectomy for obesity: can it be considered a definitive procedure? *Surg Endosc.*2012;**26** (3):831-7
46. Chiu S, Birch DW, Shi X, Sharma AM, Karmali S. Effect of sleeve gastrectomy on gastroesophageal reflux disease: a systematic review. *Surg Obes Relat Dis.*2011;**7** (4):510-5
47. Shah M, Simha V, Garg A. Review: long-term impact of bariatric surgery on body weight, comorbidities, and nutritional status. *J Clin Endocrinol Metab.*2006;**91** (11):4223-31