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A New Emerging procedure — Sleeve Gastrectomy

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1. Introduction

Laparoscopic Sleeve Gastrectomy (LSG) is an increasingly popular procedure for weight loss. Compared to other bariatric procedures, sleeve gastrectomy remains a relatively young stand-alone weight loss operation. However, despite being relatively new it has gained grounds not only in the west where bariatric surgery has been around for long but also in Asia where it is increasingly becoming the procedure of choice for weight loss [1, 2]. Its attractiveness is attributed not only to its significant weight loss outcome, but also the technical austerity of the operation as well as the significant improvement or remission of medical co morbidities.

1.1. History

Sleeve gastrectomy may be seen as an extension of the Magenstrasse and Mill procedure. The first open sleeve gastrectomy was performed in March 1998 by Doug Hess [3]. A year later, the first laparoscopic duodenal switch with a sleeve gastrectomy was reported on a porcine model [4]. LSG was first performed in 2000, by Gagner et al as part of a duodenal switch procedure and he subsequently also reported sleeve gastrectomy after BPD/DS as a salvage procedure for poor weight loss [5, 6]. Regan et al. then reported sleeve gastrectomy as a first step for sufficient weight loss prior to performing a more definite procedure such as Roux-en-Y bypass or duodenal switch in high-risk obese patients to decrease mortality and morbidity [7].

1.2. Indications

The NIH Consensus conference [8] in 1991 stipulated that patients with BMI equal to or exceeding $40kg/m^2$ or patients with high risk co-morbid conditions and BMI exceeding or equal to 35 kg/m^2 were candidates for bariatric surgery. For Asian patients, the BMI cut-off is $2.5kg/m^2$ lower [9]. More recently, the International Sleeve Gastrectomy Expert

Consensus Statement stipulated that laparoscopic sleeve gastrectomy (LSG) was a valid stand-alone procedure for patients with metabolic syndrome as well as patients with a BMI of 30 – 35 kg/m^2 in presence of associated comorbidities [10]. Obese patients with Child's A or B liver cirrhosis, inflammatory bowel disease or potential transplant recipients were also potential candidates for LSG [10]. LSG was also deemed suitable for morbidly obese patients in their adolescence as well as elderly morbidly obese patients. Medical tourism is on the rise and people traveling from far-fetched regions with minimal support may seek bariatric surgery and once stationed back in their remote locations may not have access to care needed for maintenance. A very low of long term complications is seen as an advantage to recommend this procedure.

1.3. Contraindications

LSG has been reported to increase the incidence of gastroesophageal reflux disease (GERD) [11]. A history of GERD is a relative contraindication for undergoing laparoscopic sleeve gastrectomy as their symptoms might worsen after surgery and these patients may be better served with other procedures e.g. gastric bypass [12].

Caution should be exercised in patients with concurrent Barrett's Esophagus. Performing a sleeve gastrectomy will decrease the amount of gastric tissue available for creation of a gastric tube after esophagectomy if there is malignant progression of the Barrett's Esophagus. LSG is preferred and favored over Roux-en-Y bypass in patients / regions at high risk of developing gastric cancer as performing the latter procedure will make endoscopic surveillance of the remnant stomach for cancer almost impossible.

2. The procedure

2.1. Preoperative considerations

The preoperative management does not differ from other bariatric procedures. Patients with a history of smoking should be encouraged to stop smoking. Dietary counseling should be mandatory and should address preoperative weight loss, immediate and long term diet recommendations after sleeve gastrectomy. Initiation of a low calorie diet prior to surgery should be considered as this helps shrink the large fatty liver and thus optimizes intra-abdominal operating space. Investigations to evaluate peri-operative risk, exclude other causes of obesity and those on long term follow up nutritional monitoring are a norm. A visit to a physiotherapist, psychologist, pulmonologist, anesthetist and other physicians should be considered on need basis. The role of a multidisciplinary team to manage these patients cannot be further emphasized [13].

2.2. Technique

a.   Positioning

It should be ensured that the operating table has the capacity to support the weight of the patient. The patient may be positioned supine or in French position with legs apart (Figure

1). The feet are secured to the foot board so that reverse trendeleburg position is possible. The arms should be well padded to prevent neurological injury should the arms be stretched out and secured to an arm board. Once the patient is strapped down, the table should be tilted to extremes to ensure that the patient is well secured and would not slip off the table (Figure 2).

Figure 1. French position

Figure 2. Patient secured on operating table

b. Decompression of the stomach

This can be achieved by insertion of orogastric tube, a hollow calibration tube by gastroscopy. We insert our disposable 38F calibration tube after positioning the patient and prior to draping. In doing so, we are able to empty the gastric contents prior to surgery and during surgery, to maneuver the calibration tube to size the sleeve. The insertion of a calibration tube is not without problems. If one faces resistance during insertion of it is better to use a gastroscope or colonoscope as calibration tube. There are reports of esophageal perforation resulting from improper handling of calibration tubes [14].

c. Port placement

5 ports are typically inserted for LSG in our patients. A 10-12 optical trocar is inserted 20 cm below the left costal margin along the midclavicular line to gain access to the abdominal cavity. Other techniques like the use of Veress needle and open Hassan technique may be used. A 5mm epigastric port is inserted for introduction of a liver retractor. For patients where the distance between the xyphoid and umbilicus is up to 35cm we insert an infra-umbilical 15mm port as the working port for the surgeon. If the distance is more or the patient has central obesity this port is changed to a 10-12mm port that is placed approximately 20cm from xyphoid to the left of the mid line. Two 5mm ports are inserted in the left and right hypochondria regions of the patient for assistant and surgeon (Figure 3).
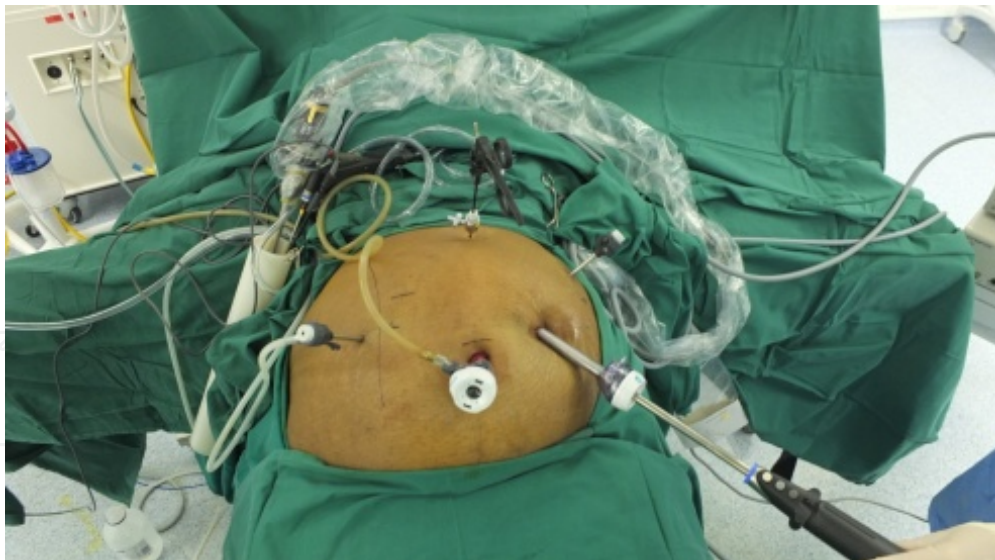

Figure 3. Port placement

d. Measurement of the Antral pouch:

Once pneumoperitoneum is established, a diagnostic laparoscopy is performed and hepatic steatosis assessed. The greater gastrocolic omentum is divided 5 cm from the pylorus with the

aid of an energy device (Figure 4). There is consensus among bariatric surgeons that the antral pouch should be measured 2-6cm from the pylorus along greater curve [10] as risk benefit ratio is best within these limits. However, some surgeons also believe that cutting too close to pylorus increases risk of leak and most would prefer to stay 4-6cm away. Michalsky D et al compared patients who underwent radical resection of antrum (resection 2.5cm from pylorus) versus those with preserved antrum (resection 6cm from pylorus), they found no difference in % excess weight loss, complications, gastric emptying and food retention between both groups [15].
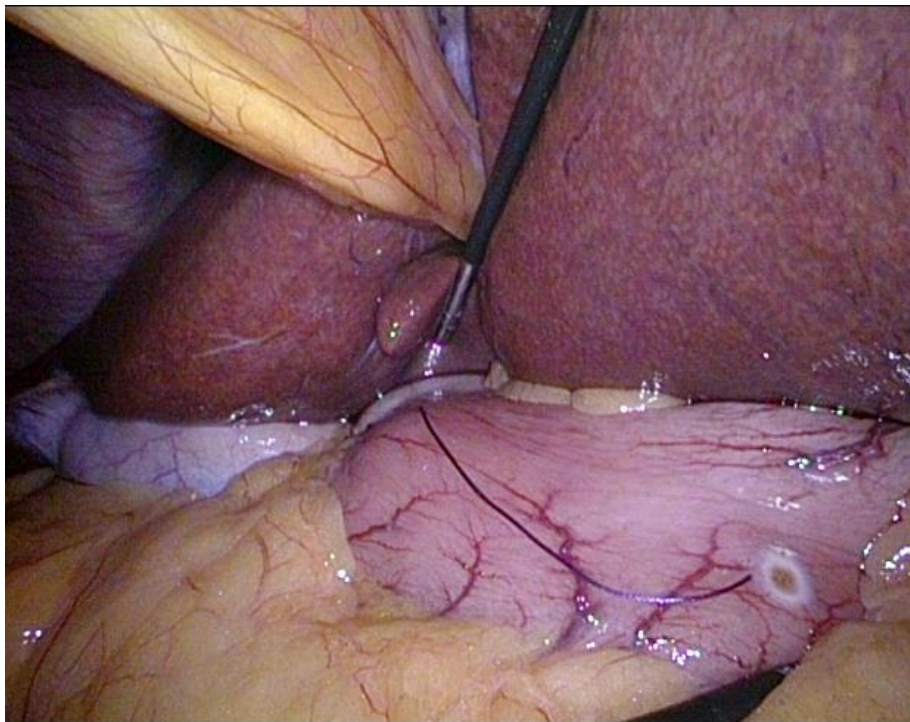

Figure 4. Measuring antral pouch

e. Devascularization:

In the lateral technique, the devascularization process is continued up the greater curve of the stomach to the short gastric vessels with the help of the assistant who maintains traction and exposure during this process (Figure 5a&b). Eventually, one reaches the left crus which is an important landmark of dissection (Figure 6). The left crus muscle is then routinely dissected and hiatus explored by some for a hernia, while others may differ. We selectively explore the hiatus of the symptomatic and endoscopically proven hiatus hernia as all our patients are evaluated for symptoms of reflux by questionnaire pre-operative and also have a gastroscopy performed. In patients with hiatus hernia, the hernia should be reduced and the defect repaired.
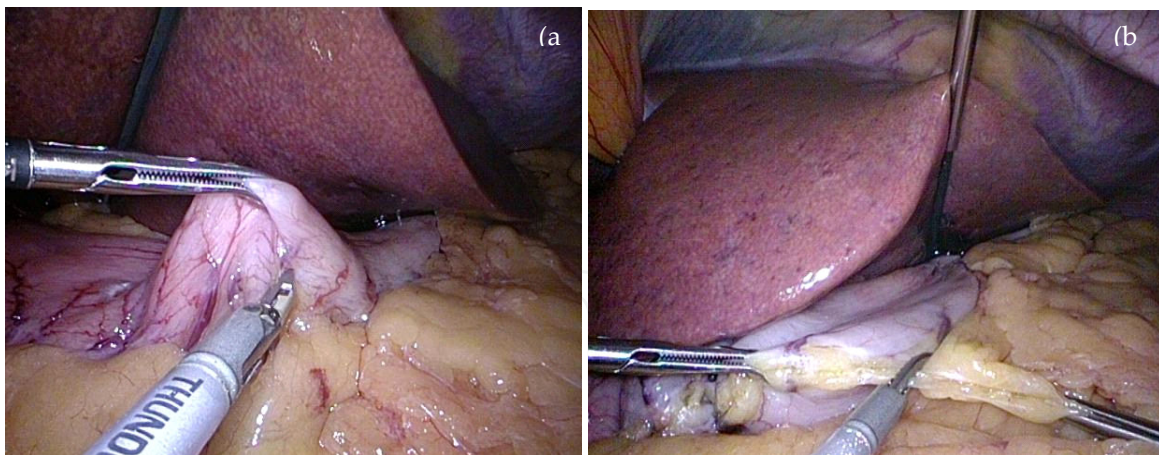
Figure 5. a) Gaining entry into lesser sac, (b) Division of gastro colic ligament
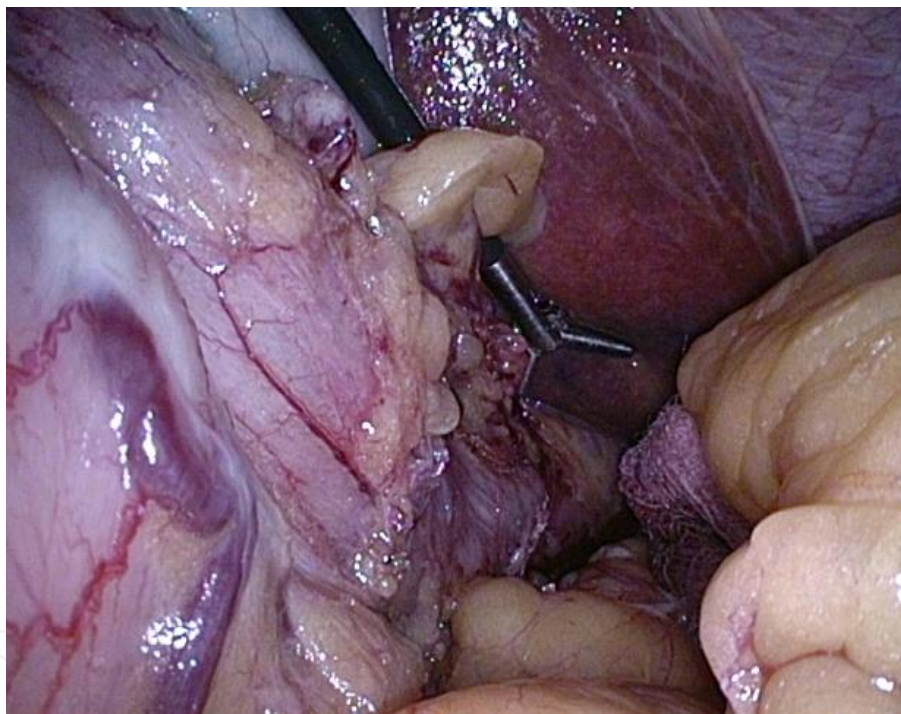

Figure 6. Exposure of left crus of diaphragm

In the medial approach, once the lesser sac is entered the process of stapling starts and devascularization is done only upon completion of sleeve. Dapri et al randomized 20 patients to each arm and looked at the technical outcomes of both medial and lateral approaches; they reported no difference in operative time, preoperative bleeding and hospital stay [16]

f.   Gastric tube calibration

The 38 Fr Bougie inserted preoperatively is then advanced into the stomach along the lesser curve. This serves as the border of transection with the linear staple with the remnant lesser

curve forming the neo gastric pouch. One of the controversies lies in the optimal size of bougie to be used to size the sleeve. Baltazar uses a 32-French bougie with transection starting at 2-3 cm from the pylorus [17] as opposed to Gagner using a bougie of 60-French bougie and starting the transection at 10 cm away from the pylorus [6]. The bougie size does not affect mean excess weight loss in the short-term but weight loss is significantly different in calibrated sleeves compared to non calibrated sleeve [18]. The meta-analysis of Parikh et al did not show significant difference in %EWL outcomes between bougie <40 Fr and bougie ≥40 Fr up to 36 months (mean: 70.1% EWL; P=0.273) [19]. All panelists in the Expert consensus statement agreed that it was important to use a bougie to size the sleeve and the optimal size of the bougie should be between 32 to 36F [10]. The use of a bougie < 32F may increase postoperative strictures while using bougie of > 36F may bring about limited weight loss effects due to possible dilatation of the sleeve. The size to tube finally achieved will also depend on other factors like over sewing the staple line and whether ones' stapling is snug or lax in relation to the bougie.

g. Creating the gastric tube:

Linear transection of the stomach can be performed using 3.5mm, 3.8 mm or 4.1 mm staples height depending on the thickness of the stomach wall. Any serosal tears during stapling or excessive unexpected bleeding should be carefully evaluated as it may be signaling a poorly stapled area. As the incisura is a common area of narrowing and in indicted for being the cause of the high pressure system resulting in apical leaks in many patients, every effort should be made to stay away and prevent narrowing during stapling. We mark our stapling trajectory with a marker before commencing stapling as over enthusiasm often leads to disasters (Figure 7)

The use of staple-line reinforcement either through suturing or buttressing with biological or synthetic material is a hotly debated topic. Perioperative and postoperative bleeding is a concern for the staple line in sleeve gastrectomy and has been quoted to be between 0 to 14% [20]. Methods to contravene this include the over sewing the staple line with non-absorbable suture material, use of fibrin glue as well as the use of buttressing material along the suture line. Several authors have advocated the use of buttress material to reduce staple line bleeding and leak rates [21], while other reinforcement techniques do not reliably reduce staple line leaks in sleeve gastrectomy [22, 23]. D'Ugo et al. found that in 1162 undergoing LSG, the overall leak rate was 2.8%; Leak rate was lower in patients who had their staple line reinforced with bovine pericardium strips (0.3%) compared to those with synthetic polyester (7.8%) or no reinforcement (4.8%). Postoperative bleeding in patients who had staple line reinforcement was lower (3% vs. 13.7%) [24]

In summary it is suffice to state that current evidence supports the use of buttress material to decrease staple line bleeding [19]. However, buttress material may potentially lower leak rates as it increases burst pressure but the evidence is of poor scientific strength to make a recom-mendation for their routine use to prevent leaks [23].
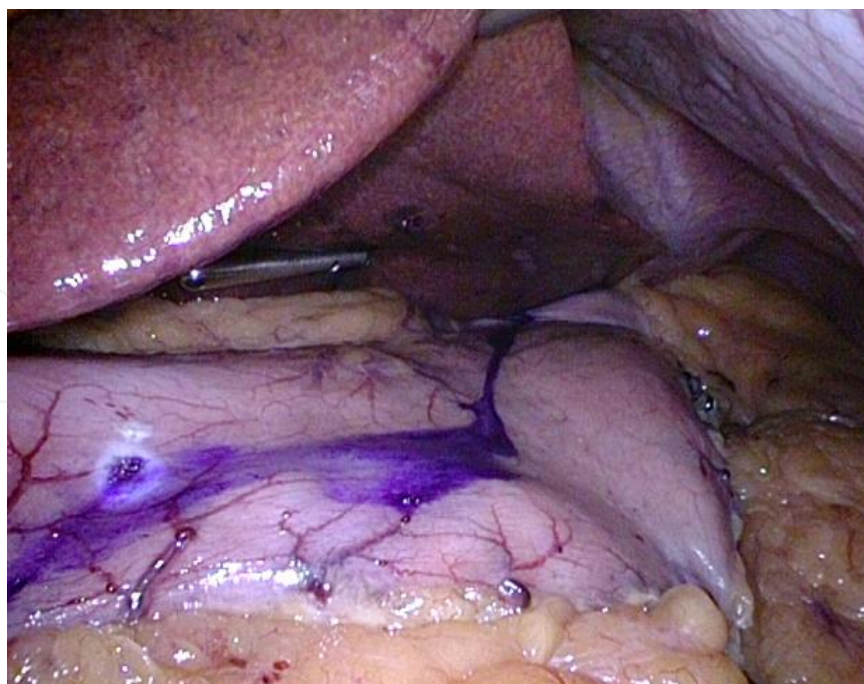
Figure 7. Marking prior to stapling

h.   Closure

The specimen is then delivered via the umbilical port (Figure 8). The staple line is then checked for any leaks; we do not routinely oversew the staple line. The 15mm port site is then closed with absorbable suture and the overlying skin stitched with a monofilament absorbable suture after local anesthesia is administered.

Figure 8. Resected stomach

3. Learning curve

Laparoscopic sleeve gastrectomy looks easy to perform, but yet is a technically demanding procedure; it has to learned through proctorship and mentorship. LSG can be safely and efficiently performed in a newly established bariatric center following a mentorship program. Proficiency seems to require 68 cases. The operative time and hospital stay may significantly decrease with experience early in the learning curve, as opposed to mortality and morbidity rates, conversion rate, and %EWL which will likely remain unchanged [25].

3.1. Post-operative care

For our team, a standardized post operative pathway not only ensures quality care for patients but also help juniors on call staff managing patients strategize management and know who to call when the need arises. We stratify patients based on their ASA grade and the anesthesia team will dictate their admission to intensive care, high dependency or general ward post-operatively. We have standard pain control protocol to prevent narcotic overdose and yet provide effective pain relief.

Clear fluids and ambulation are started on the day of surgery. Patients are reviewed by the dietician and post-operative diet reinforced prior to being discharged home. A phone consult is done 24-48hrs after discharge to reinforce hydration and to ensure patients are recovering well. The clinician nurse, surgical team and dietician review patients 1-2 weeks postoperatively as they slowly progress from clear feeds to soft diet within 4-6 weeks. We believe that the main pillars leading to the success of the sleeve is long term nutritional care. Nutrition relies on a professional medical team providing constant, ongoing patient support throughout all the bariatric process stages working side by side. Patients are regularly reviewed by the dieticians to re-enforce diet recommendations. Long-term, they are prescribed vitamin supplements as advocated by the American Society of Bariatric and Metabolic Surgery guidelines for post bariatric surgery patients [26]. Patients are educated on the need for regular follow up, alike other batriatric procedures. Keren D et al reported improved weight loss and better comorbidity outcomes for those with regular follow up. A total 119 patients were followed up for 30 months with the mean percentage of excess BMI loss being 82.08 ± 9.83 kg for the follow up group and 74.88 ± 8.75 kg for those without follow up [27].

3.2. Complications and management

Chang SH et al reported that the mortality rate for all bariatric procedures within 30 days was 0.08% (95% CI, 0.01%-0.24%); the mortality rate after 30 days was 0.31% (95% CI, 0.01%-0.75%) [28]. Mortality after LSG is exceedingly rare, the 30 days mortality being 0.11% and 1 year mortality of 0.21% [29]. The 30 day morbidity of sleeve gastrectomy is 5.61% which is higher in comparison to the laparoscopic adjustable gastric band of 1.44% but similar to that of the gastric bypass of 5.91% [29].

While the general complications of bariatric procedures remain unchanged among procedures, we will discuss important complications specific to sleeve gastrectomy. Staple line leakage, strictures, and gastrointestinal reflux are the most common complications after LSG.

3.2.1. Leak

Staple line leaks can be divided into acute (< 7 days), early (1-6 weeks), late (after 6 weeks) and chronic (after 12 weeks) [10]. The risk of a leak after LSG was quoted to be 2.4% with 89% of these leaks occurring in the proximal third of the stomach near the angle of His [30]. The pathophysiology of post sleeve is multifactorial and include

a. Tissue Ischemia from

    i.   Excessive devascularisation resulting in ischemia of tissue near angle of His

    ii.   Removal of fat pad at angle of His

b. Faulty stapling technique

    i.   Use of improper staple height leading to poor B formation of staples

    ii.   Stapling across esophageal fibers at gastroesophageal junction muscle fibers

c. Functional or anatomical obstruction of gastric tube further increasing intra-gastric pressure of an already elevated pressure system. The sleeve is considered a high pressure tube because there are anatomical sphincters at both ends i.e. the lower esophageal sphincter and the pylorus. This can be contributed by

i.   Creation of a gastric tube that is not cylindrical shape as shown in the last three drawing of figure 9 results in a high pressure being built at the proximal most corner of the staple line based on Laplace Law and thus higher chances of leak at the proximal 1/3rd of the tubular stomach
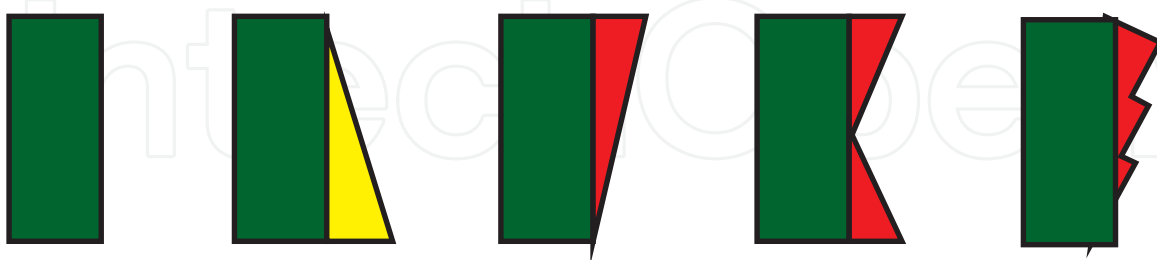

Figure 9. Possible shapes of sleeve created by improper stapling

ii.   A staple line that is spiral shaped can result in functional obstruction of the sleeve and a high pressure system develops

iii.   Stapling too close to the incisura results in anatomical narrowing, a preventable cause of leak

iv.   Post sleeve gastrectomy the tubular sleeve can acquire various shapes-"S" or "L" shape that can potential result in a high pressure system.

A detailed discussion of leak management is beyond the scope of this chapter. The diagnosis of a leak can be made clinically where patients have fever, tachycardia and abdominal pain. The diagnosis can be confirmed with a computerized tomography scan of the abdomen and pelvis or a oral contrast study like gastrograffin meal (Figure 10) The management of the patients with suspected leaks depends first, on whether these patients are haemodynamically stable. In patients who are well with small contained leaks, non-operative management with percutaneous radiological drainage, endoscopic stenting and supportive therapy with antibiotics and total parenteral nutrition has been demonstrated to be effective [31]. In patients who are septic and suspected to have contained or uncontained leaks, immediate operation for washout and drainage of the contaminated field is indicated. These patients will need nutritional support via total parenteral nutrition (TPN), or enteral nutrition via a feeding jejunostomy inserted at time of emergency surgery (preferred option) or naso-jejunal feeding tube. The following interventions (Figure 11) have been described as options in management of simple sleeve leak but they have to be individualized to circumstances and resources at individual centers. For more complex leaks with pleural, bronchial and pulmonary fistulae, detailed discussion with the thoracic surgeon is needed prior to intervention.

Figure 10. CT scan showing collection and leak of contrast from a proximal sleeve leak

1.   Simple suture repair

2.   Suture repair with omental patch+/-pyloroplasty

3.   El Hassan et al. described a novel method of cannulating a leak site via endoscopy and laparoscopy with a T tube in patients presenting with early leaks, therefore converting the leak site into a controlled fistula together with wide drainage of the abdominal cavity [32].
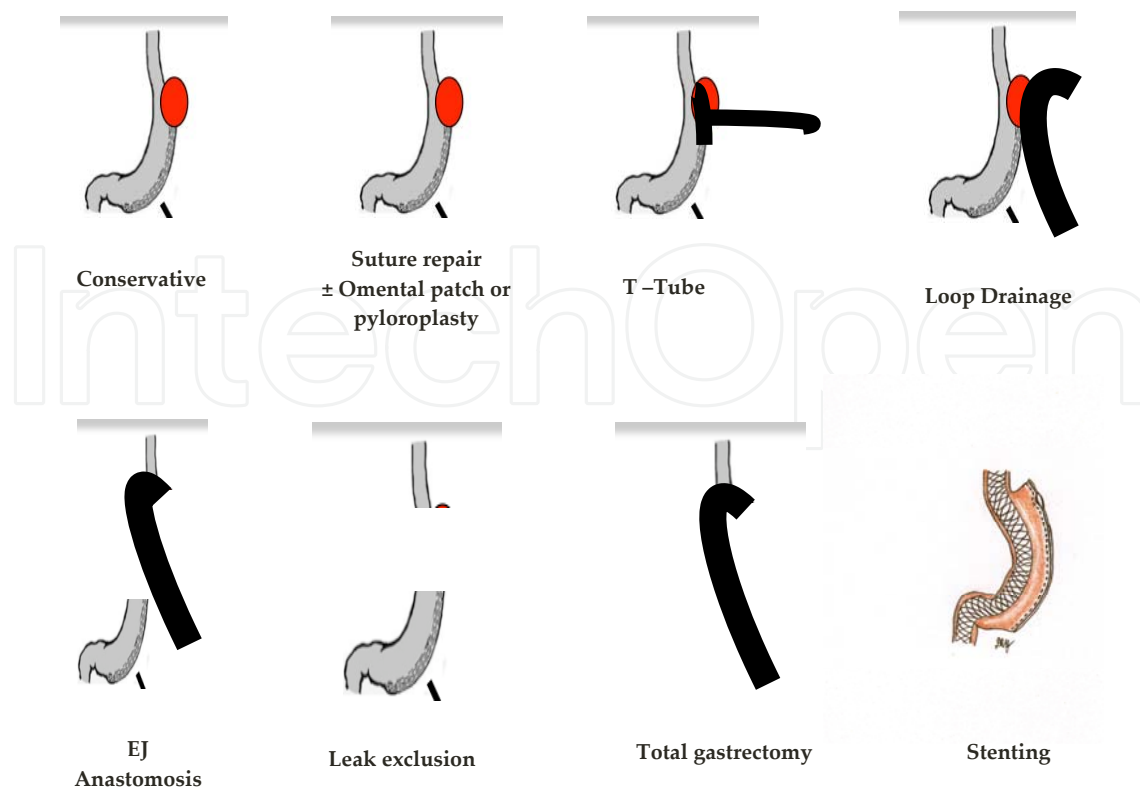
Figure 11. Approaches to sleeve leak

4.   Loop drainage: using a free loop of jejunum anastomosed to the leak site

5.   Transection of gastroesophageal junction and proximal esophago-jejunostomy leaving gastric tube in place

6.   Total gastrectomy with esophago-jejunostomy

7.   However currently the most favored approach for acute leak is stenting. Baltazar first reported the use of coated self-expanding stents (CSES) in patients with gastric leaks post sleeve gastrectomy; successful resolution of the leak was reported in 4 out of the 5 patients who underwent CSES. None out of 5 patients required a re-operation and all patients recovered within 6 to 8 weeks. In our opinion early stenting help because stenting

    a.   Obliterates the defect thus preventing on going leak and thus helps control sepsis

    b.   Neutralises pressure in the stomach as it traverses gastroesophageal junction to across pylorus

    c.   It corrects any abnormal axis along the sleeved tube especially acute bends at incisura

    d.   Promotes healing by allowing tissue apposition and omental adherence

    e.   Reduces the risk of gastro-atmospheric fistula formation

    f.   Prevents on going air leak into abdominal cavity in patients who need BIPAP support.

8. For chronic leak with small cavities, endoscopic septoplasty of the bridging stomach wall can be considered

9. Use of tissue glue for closure of chronic fistula

10. Use of endoscopic vacuum therapy (Endosponge) is now a novel approach to upper gastrointestinal tracts and well as the over the scope clips [33].

3.2.2. Strictures / Gastric volvulus

The formation of strictures and gastric pouch stenosis is an uncommon but important complication of LSG. The mean stricture rate in a meta-analysis of 4888 patients who have undergone LSG was 0.5% [30]. Regurgitation is the most common presenting complaint for patients with significant stenosis with the most common site of stenosis at the angular incisura. A smaller bougie size used to size the sleeve is associated with a greater risk for developing of strictures post operatively. In patients whom strictures are suspected, assessment can be via contrast swallow studies or endoscopy. The latter also allows for dilatation to be performed in the same setting. After gastroscopy in patients with short segment stenosis dilatation with or with out stenting is an option, should they respond to this treatment repeat dilatation is advisable. In cases of failed dilatation therapy or long segment stenosis, revisional surgery in the form of conversion to other procedures like gastric bypass or stricturoplasty may be considered. Eubanks reported that in patients who underwent stenting for strictures, 84% achieved immediate symptomatic control and subsequent resolution of the stricture. 16% (1 out of 6 patients) had unsuccessful stent treatment [34, 35]. Burgos also reported success in the use of endoscopic balloon dilatation (preferably a Rigilflex balloon) and endoscopic bougie dilatation in the treatment of stricture post sleeve gastrectomy [34]. In patients with excessive length of stricture where endoscopic dilatation was not possible, Dapri reported that laparoscopic seromyotomy enabled patients to tolerate regular diet with improvement in mean dysphagia score. The aim of the procedure was to achieve a myotomy 1 cm beyond the stenosis proximally and distally [36]. Conversion to a roux-en-Y bypass is the last resort for patients with strictures post sleeve gastrectomy. Other options include stricturoplasty, gastro-gastrostomy and gastrectomy [37].

Gastric volvulus post sleeve gastrectomy is a rare complication. After sleeve gastrectomy the stomach has no fixation along its greater curve, this together with the increased laxity of tissue after weight loss increases the risk of a gastric volvulus. Classically patients present with the Borchardt clinical triad of epigastric pain, retching and inability to pass a nasogastric tube. Laparoscopic fixation of the gastric tube as one would do for congenital malrotation of the stomach will fix the problem.

3.2.3. Gastroesophageal reflux disease (GERD)

In patients with symptoms of pre-existing reflux prior to surgery, Roux-en-Y bypass should be the treatment of choice instead of sleeve gastrectomy. A recent review of the Bariatric Outcomes Longitudinal Database with 4832 patients concluded that LSG did not reliably relieve or improve GERD symptoms and that preoperative GERD was associated with worse

outcomes and decreased weight loss with LSG and thus may be a relative contraindication [12]. Institutional practices may vary; some like ours do routine preoperative gastroscopy to establish any reflux esophagitis and exclude the presence of hiatus hernia and if a hiatal hernia is found we would in asymptomatic patients suture repair the hiatal hernia, the surgeon should actively look out for a hiatal hernia intraoperatively and repair the hernia if it is identified. [10] Soricelli et al compared their obese patients with GERD undergoing sleeve with or without hiatal hernia repair and reported 80.4% versus 57.9% remission of GERD and persistent GERD in 7.5% versus 42.2% respectively [38].

The notion that sleeve gastrectomy is a refluxogenic operation remains controversial, as Chiu S et al reviewed 15 published reports of which 4 found sleeve to increase reflux and 7 showed reduction in prevalence of GERD [39]. The anatomic and physiological factors influencing GERD after sleeve gastrectomy are listed as such

a. Worsen GERD

Decrease in gastric emptying

Lower LES pressure

Blunting angle of HIS

Decrease in gastric compliance and volume

Increase gastric pressure

Dilated proximal sleeve (technical) and fundus regeneration,

Angulation, volvulus of sleeve

Gastric atony

b. GERD Improvement

accelerated gastric emptying

weight loss

reduced acid production

removal of fundus (Source of relaxation waves to LES)

Reduced wall tension (Laplace's Law)

In patients who develop reflux symptoms after sleeve gastrectomy, the first line treatment should be with proton pump inhibitors [10]. Early reports have shown that in patients with GERD but refuse gastric bypass, laparoscopic Nissen fundoplication with gastric plication may be an acceptable weight loss option but long-term weight loss data is still required [40].

3.2.4. Nutritional complications

As LSG is a relatively young operation, there is a lack of reliable data arising from long-term follow up of patients who have undergone the procedure. Being a restrictive procedure, it is

postulated that no long-term nutritional deficiencies should result from laparoscopic sleeve gastrectomy unless there is inadequate intake of nutrients. If a large sleeve has been resected, Vitamin B12 and resultant megaloblastic anaemia may result due to the lack of Intrinsic factor produced by the remnant stomach. In a cross sectional study reported during a mean follow up period of 4 years post gastric bypass or LSG, patients were identified with several micro-nutrient deficiencies, including vitamin D, folate, and vitamin B12. LSG had a more favorable effect on the metabolism of vitamin B12 compared with gastric bypass [41]. Thus, postoperative prophylactic iron and B_{12} supplementation, in addition to general multivitamin and mineral supplementation, is recommended based on the comparable deficiency risk.

4. Outcomes

4.1. Weight loss

A meta-analysis in 2012 comprising of 12,129 patients showed that mean percentage of excess weight loss (EWL) at 12 months follow up was 59.0% [42], and this further increased to 64.5% and 66.0% at 24 and 36 months follow up respectively [42]. At 48 months follow up, %EWL declined to 60.9% but this decline was not statistically significant. The same paper also elucidated that patients who underwent Laparoscopic Roux-en-Y bypass had significantly higher %EWL at 12 months follow up but this difference was negligible at 24 months. In a recent review of European data, mean excess weight loss was 68.4%, and 67.4% after 1 and 2 years respectively. Excess weight loss peaked at 70.5% at the 4-year mark before decreasing to 58.3% at the 5-year mark. The authors concluded that the long-term results regarding weight loss were satisfactory [43]. Among super obese patients, the reported mean EWL is be 52%, 43%, 46% at 72, 84 and 96 months follow up respectively [44].

Durability of LSG has been debated and available data does suggest that it is durable. A review of 492 patients with follow-up of at least 5 years after laparoscopic sleeve gastrectomy (373 at 5 years, 72 at 6 years, 13 at 7 years, and 34 at 8 or more years) was performed by Daimantis T at al [45]. Mean preoperative body mass index in all 16 studies was 49.2 kg/m². The mean percentage excess weight loss (%EWL) was 62.3%, 53.8%, 43%, and 54.8% at 5, 6, 7, and 8 or more years after LSG, respectively [45]. The overall mean %EWL (defined as the average %EWL at 5 or more years after LSG) was 59.3% (12 studies, n=377 patients). The overall attrition rate was 31.2% (13 studies). They concluded that the existing data supports the role of LSG in the treatment of morbid obesity. It seems to maintain its well-documented weight loss outcome at 5 or more years postoperatively, with the overall mean %EWL at 5 or more years after LSG still remaining in excess of 50%.

4.2. Eating behavior

Several studies had elicited a change of eating behavior following bariatric surgery. Schweiger et al [46] studied the effect of different bariatric operations on food tolerance and quality of eating. On a score of 1 to 27 with 27 points standing for excellent quality of eating, there was no significant difference between patients who underwent RYGB, LAGB, SG and BPD at 3-6

months follow-up. At 6-12 months and long-term follow-up, patients who underwent sleeve gastrectomy achieved a score of 22.27+/-4.66 and 20.25+/-4.9 respectively. Adjusting for other variables, the total score in the 3 follow up periods was 20.1 for RGYB, 14.3 for LAGB, 19.7 for SG and 21.6 for BPD/DS patients. Food tolerance at 2-4 years post surgery was also shown to be best after LSG, followed closely by RYGBP [47].

4.3. Quality of life

In a study of 78 consecutive patients who underwent LSG subjected to the Medical outcomes Study Short Form Questionnaire (SF-36) coupled with the Impact of Weight on Quality of Life-Lite Questionnaire pre-operatively and 12 months post-operatively, scores show a significant overall improvement of the scores 12 months post operatively [48]. Subset analysis showed that lesser patients reported improvement in self-esteem if they suffered complications as a result of the surgery or had negative or moderate loss of weight compared to those who had excellent or satisfactory loss of weight [48]. Studies have also shown that the perceived quality of life after LSG is better compared to LAGB [47, 49]. However, LSG is the only truly irreversible procedure.

5. Sleeve as a metabolic procedure

a.   Proposed mechanisms of T2 DM remission

Multiple studies have recently demonstrated that patients with raised BMI and diabetes experience remission of T2DM after laparoscopic sleeve gastrectomy. In a meta-analysis of 27 studies including 673 patients by Gill et al [50], it was shown that DM resolved in 66.2% of patients and improved in another 26.9% with a mean decrease of 1.7 in HbA1c after sleeve gastrectomy at mean follow up of 13 months. Perathoner et al reported a resolution rate of 85% and 50% for Type 2 diabetes mellitus and dyslipidemia respectively in his patients [51]. LSG has been shown to be superior to intensive medical therapy in the resolution of comorbidities and improved quality of life [52].

The mechanism behind T2DM 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 T2DM remission. It has been found that in patients who underwent sleeve gastrectomy, their postprandial levels of glucagon like peptide (GLP-1) and total peptide YY (PYY) levels increased significantly at 6 weeks post operation and remained elevated for at least 1 year [53]. By reducing the volume of the stomach, chyme could theoretically be exposed to the L cells earlier in the small bowel earlier, resulting in earlier production of hind gut hormones. Melissas J et al in their gastric emptying study demonstrated faster gastric emptying after sleeve gastrectomy [54]. It has also been postulated that there is restoration of the first phase of insulin secretion after sleeve gastrectomy. N Basso et al reported his "Gastric hypothesis" that a loss in HCL in the stomach stimulated release of GRP which in turn stimulates the release of GLP-1 [55]. GLP-1 initiates what is known as the incretin effect,

which increases insulin secretion while inhibiting glucagon release, thereby leading to better glucose hemostasis.

Ghrelin, an appetite stimulant, produces the orexigenic (appetite stimulating) effects via stimulation of neuropeptide Y from the hypothalamus. Ghrelin is mainly produced by the oxyntic cells of the stomach, and has been implicated in obesity and metabolic syndrome. Diet induced weight loss raises circulating ghrelin levels. In sleeve gastrectomy patients, ghrelin levels was markedly reduced and remained low for several months after the operation. The reduction in serum ghrelin levels persisted at five year follow-up post sleeve gastrectomy [56].

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 hemostasis in post SG patients [57]. Most authors would agree that the effect of T2 DM resolution 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. PYY a hormone co-secreted with GLP 1 from the distal intestine after meals. It increases insulin sensitivity and also inhibits the hypothalamic production of neuropeptide Y. PYY levels are increased after either sleeve gastrectomy or gastric bypass [58].

b.   Metabolic outcomes

Increasingly, more trials have demonstrated the effectiveness of SG for excess weight loss. Himpens et al reported the percentage excess weight loss (EWL) after sleeve gastrectomy as 77.5% and 57.3% at 3 and 6 years respectively [59].

Direct comparison of medical versus bariatric surgical management of obesity and diabetes was performed in the STAMPEDE prospective randomized controlled trial at the Cleveland Clinic [60]. Gastric bypass (Roux-en-Y) or sleeve gastrectomy provided a mean percentage reduction in weight from baseline of 24.5±9.1% and 21.1±8.9% respectively, versus 4.2±8.3% in the intensive medical group. Regarding diabetes, the success rate for reduction in HbA1c to 6.0% at 36 months was met by 5% of the patients in the medical-therapy group, as compared with 38% of those in the gastric-bypass group (P<0.001) and 24% of those in the sleeve-gastrectomy group (P=0.01) respectively). As a result, lesser medications for diabetes, hypertension and hyperlipidaemia were needed with composite improvement in all parameters of metabolic syndrome. Long-term follow up of sleeve gastrectomy patients at 6-8 years showed a 77% improvement or remission of diabetes [44].

Apart from T2 DM remission, LSG patients also have improved overall cardiovascular risk profiles with improved in dyslipidemia as well as improved blood pressure control.

A systematic analysis of 33 studies comprising 3997 patients demonstrated reduction in hypertension in 75% of cases, with resolution in 58%, at an average follow up of 16.9±9.8 months [61]. Cardiac remodeling following sleeve gastrectomy has been shown on echocardiography. Reduced left ventricular mass, septum and posterior wall thickness, was demonstrated in the study by Cavarretta et al, resulting in improvement in cardiac function [62]. Lipid profile improvement, specifically HDL and triglyceride levels, total cholesterol/HDL and

triglyceride/HDL ratios at one year follow-up have been reported without lowering of total cholesterol and LDL levels after sleeve gastrectomy [63].

The Asian population in general is known to develop metabolic syndrome at lower BMIs in comparison to their Caucasian counterparts and hence, studies have reported outcomes from Asia in this cohort. In Asian populations with T2DM and non-morbid obesity (BMI 25-35kg/m^2), sleeve gastrectomy has demonstrated up to 50% resolution in diabetes at 1 year [64]. The principal mechanism is thought to be related to calorie restriction and weight loss, and C-peptide levels returning to >3ng/ml appears to be the most reliable marker of resolution.

5.1. Sleeve gastrectomy as a revisional procedure

Revising a restrictive procedure to yet another revisional procedure and even more to the same procedure does not sound promising to many. However for patients where technical failure has led to failure to lose weight or weight regain, re-sleeve is an option. Rebibo L et all reported 15 patients undergoing repeat sleeve and compared to 30 matched primary sleeve patients. The weight loss for the re-sleeve group was 66% versus 77% for the primary sleeve group at 12 months, which was deemed similar [65]. Cheung et al reviewed the literature on procedures after failed sleeve and concluded that re-sleeve was associated with good weight loss and its technically less challenging nature may make its clinical use more acceptable [66].

Also, sleeve for failed gastric band and vertical banded gastroplasty is a good and effective revisional procedure with 60% EWL at 26 months follow up [67]. Where sleeve took off as a first stage procedure of duodenal switch, it is also finding its way as a first stage procedure for conversion of failed gastric bypass to duodenal switch and has been shown to be safe and effective, leaving patients in better condition to have a duodenal switch [68].

5.2. Sleeve gastrectomy in combination with other bariatric procedures

Gastric bypass has a long history and long-term results support its efficacy in treating obese patients with metabolic disorders. It is an established fact that there are mechanisms beyond weight loss that are responsible for the excellent metabolic outcomes of gastric bypass and that these are related to bypassing the foregut. In order to maximize the scope of sleeve gastrectomy as a metabolic procedure, innovative procedures possessing benefits of both sleeve gastrectomy and gastric bypass are being employed. The sleeve duodeno-jejunal bypass surgery (LSG/DJB), single-anastomosis duodeno-jejunal bypass with sleeve gastrectomy (SADJB-SG), sleeve gastrectomy with loop bipartition, and loop duodeno-jejunal bypass with sleeve gastrectomy, are all largely based on manipulation of foregut. The short-term outcomes have been promising . However, they are still considered experimental as both intermediate and long term data are awaited. Loop duodenal bypass in combination with sleeve gastrectomy for type II diabetes in individuals with BMI 21-38kg/m^2, has shown promising early results, with 91% of achieving HbA1c of 7.0g/dl at 6 months from surgery [69].

Laparoscopic Roux-En-Y gastric bypass prohibits visualization of the excluded stomach. For populations with a high risk of gastric cancer, including Japan, the ability to perform endoscopic visualization after bariatric surgery is paramount. In obese individuals with risk factors

such as Helicobacter pylori infection, atrophic gastric mucosa including intestinal metaplasia, or a family history of gastric cancer, Kasama et al. published a series of laparoscopic sleeve gastrectomy with duodeno-jejunal bypass [70]. The procedure was found to be feasible, and safe, with similar EWL to Roux-En-Y gastric bypass. Additional EWL compared to sleeve gastrectomy was attributed to the added malabsorptive effects of the duodenojejunal bypass.

Sleeve with ileal interposition is an example of sleeve with hindgut manipulation. Patients undergoing this procedure have demonstrated restoration of insulin sensitivity, with in-creased insulin output, and doubling of β-cell glucose sensitivity [71]. The mechanism is postulated to be intestinal over-stimulation, with increased GLP-1 and incretin secretion.

Acknowledgements

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