Laparoscopic Bariatric Surgery

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INTRODUCTION

Obesity has become a major health problem in the last few decades. Obesity is the most prevalent chronic disease of the 21st century. The World Health Organization (WHO) has identified obesity as one of the five leading health risks in developed countries. WHO has reported that over a billion people are overweight and that 300 million are clinically obese with a projection of 3 million deaths annually worldwide. In the United States, 65% of adult Americans are overweight and 31% are clinically obese. Fourteen percent of American children and adolescents are obese. Bariatric surgery is now considered the only valid therapeutic option for morbidly obese patients but can be associated with significant risk, especially in patients affected by life-threatening comorbidities. Morbid obesity [defined as a body mass index (BMI) > 40 kg/m^2] affects 4.7% of Americans and these numbers are rapidly rising. For these patients, surgery represents the most effective treatment. However, failure is frequent issue and selection of correct surgery is of paramount importance for success.

Among various bariatric procedures, laparoscopic sleeve gastrectomy (LSG) has rapidly gained popularity to become most frequently performed worldwide. The sleeve gastrectomy is a restrictive form of weight loss surgery in which approximately 85% of the stomach is removed leaving a cylindrical or sleeve-shaped stomach with a capacity ranging from about 60 to 150 cc. Stomach is reduced to about 15% of its original size, by surgical removal of a large portion of the stomach along greater curvature **(Fig. 1)**. The open edges are then attached together with the help of stapler to form a sleeve or tube with a banana shape **(Figs. 2A and B)**. The procedure permanently reduces the size of the stomach. The procedure is performed either open or laparoscopically and is not reversible.

Laparoscopic sleeve gastrectomy is a relatively new option originally published by Marceau et al. Unlike many other forms of bariatric surgery, the outlet valve and the nerves to the stomach remain intact and, while the stomach is drastically reduced in size, although its function is preserved. Again, unlike other forms of surgery such as the Roux-en-Y gastric bypass (RYGB), the sleeve gastrectomy is not reversible.

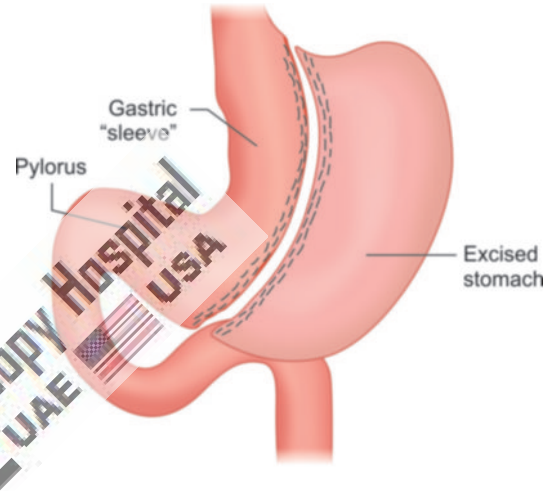


Fig. 1: Sleeve gastrectomy.

Because the new stomach continues to function normally there are far fewer restrictions on the foods which patients can consume after surgery, although the quantity of food that can be eaten will be considerably reduced. This is seen by many patients as being one of the great advantages of the sleeve gastrectomy, as is the fact that the removal of the majority of the stomach also results in the virtual elimination of hormone (ghrelin) produced within the stomach which stimulate hunger.

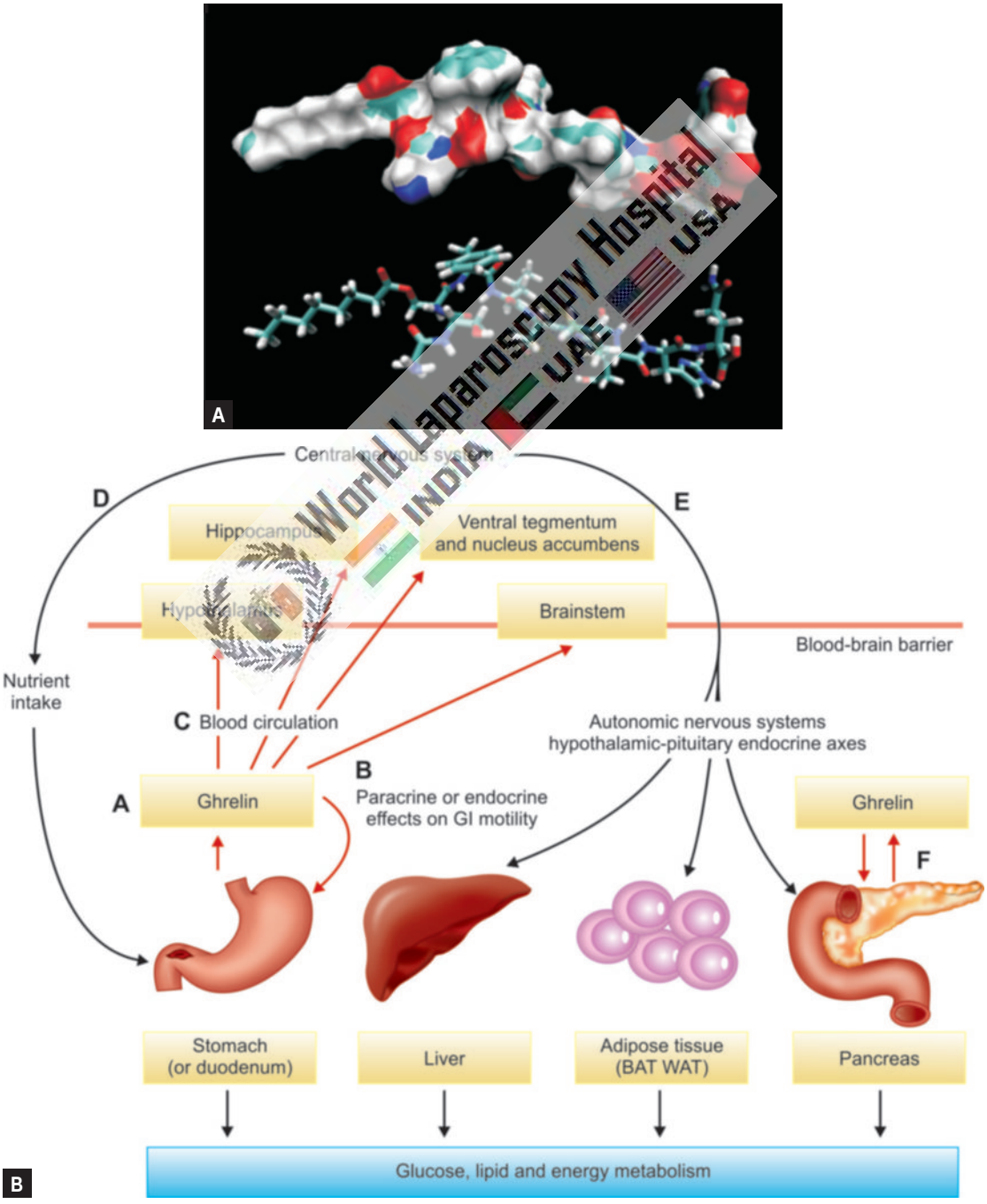
GHRELIN HORMONE

Ghrelin got its name from the word "ghre" from the Proto-Indo-European language, meaning to grow. Scientists did not go purposefully looking for a substance that stimulated appetite. Indeed the discovery of ghrelin occurred when scientists were investigating drugs that stimulated the release of growth hormone from the anterior pituitary gland. They came across some drugs that, rather than acting on the growth hormone releasing hormone receptor, were acting on an unknown receptor located in the hypothalamus and pituitary, these drugs were called growth hormone secretagogues. It was concluded that the body had a second pathway for the induction of growth hormone secretion.

Ghrelin was identified as being the natural legend for these receptors causing secretion of growth hormone in

1999 by the Japanese scientist Masayasu Kojima. During Kojima's investigations, they found that although ghrelin's receptors were in the brain, ghrelin was surprisingly identified in the human stomach and circulating in the blood leading to the conclusion that it was released from the stomach, from where it then traveled in the blood and acted on the brain.

Ghrelin is a hormone produced mainly by P/D1 cells lining the fundus of the human stomach and epsilon cells of the pancreas that stimulates hunger **(Figs. 2A and B)**. Ghrelin levels increase before meals and decrease after meals. It is considered as the counterpart of the hormone leptin, *produced by adipose tissue, which induces satiation when present at higher levels*. In some bariatric procedures, the level of ghrelin is reduced in patients, thus causing satiation before it would normally occur. Ghrelin is also produced in the hypothalamic arcuate nucleus, where it stimulates the secretion of growth hormone from the anterior pituitary gland. Receptors for ghrelin are expressed by neurons in the arcuate nucleus and the ventromedial hypothalamus. Once the high amount of ghrelin is secreted the patient feels intense hunger **(Fig. 3)**. Apart from hunger,



Figs. 2A and B: (A) Ghrelin hormone; and (B) Role of ghrelin in glucose and lipid metabolism. (BAT: brown adipose tissue; GI: gastrointestinal; WAT: white adipose tissue)

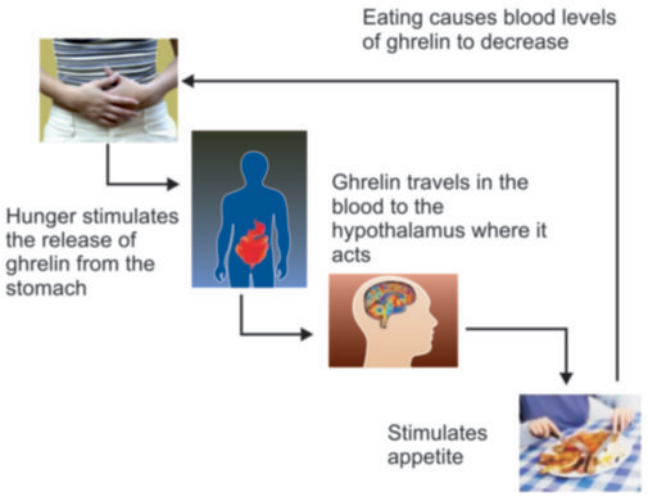


Fig. 3: Mode of action of ghrelin.

ghrelin plays a significant role in neurotrophy, particularly in the hippocampus, and is essential for cognitive adaptation to changing environments and the process of learning.

Ghrelin has emerged as the first circulating hunger hormone. Ghrelin and synthetic ghrelin mimetic increase food intake and increase fat mass by an action exerted at the level of the hypothalamus. They activate cells in the arcuate nucleus that include the orexigenic neuropeptide Y (NPY) neurons. Ghrelin-responsiveness of these neurons is both leptin- and insulin-sensitive. Ghrelin also activates the mesolimbic cholinergic-dopaminergic reward link, a circuit that communicates the hedonic and reinforcing aspects of natural rewards, such as food, as well as of addictive drugs, such as ethanol **(Fig. 3)**.

Ghrelin levels in the plasma of obese individuals are lower than those in leaner individuals. Recently, Scripps research scientists have developed an anti-obesity vaccine, which is directed against the hormone ghrelin. The vaccine uses the immune system, specifically antibodies, to bind to selected targets, directing the body's own immune response against them. This prevents ghrelin from reaching the central nervous system, thus producing a desired reduction in weight gain.

Obesity is the result of multifactorial changes involving both genetic and environmental factors. The physiopathology of obesity from the point of view of intake regulation has led to numerous experimental studies aimed at identifying new forms of regulation. These new forms of regulation are not only found in the secretion of ghrelin from gastrointestinal system but also in the adipose tissue (via the metabolism of leptin and insulin) and the central nervous system to finally produce the relevant orexigenic or anorexigenic effect.

GLUCAGON-LIKE PEPTIDE

Glucagon-like peptide 1 (GLP-1) is a 30-amino-acid peptide mainly secreted by the small intestine L cells after contact of food. This hormone increases insulin secretion on one end and slows gastric emptying and intestinal motility on the other. GLP-1 is increased after LSG, and it is postulated that increased levels of GLP-1 contribute to weight loss by improving glucose metabolism, reducing hunger, and increasing satiety. Although GLP-1 has been shown to slow gastric emptying, the gastric emptying time accelerated after LSG (47.6 ± 23.2 vs. 94.3 ± 15.4 minutes) in one study. It is likely that more than one mechanism is in play when determining the gastric transit time after LSG. LSG has also been shown to alter the levels of glucose-dependent insulinotropic peptide (GIP), bile acids, and leptin, the clinical significance of which is still under investigation.

INDICATIONS OF SLEEVE GASTRECTOMY

Similar to other bariatric operations, LSG is indicated in all patients meeting the 1991 National Institutes of Health (NIH) consensus conference criteria. These criteria include:

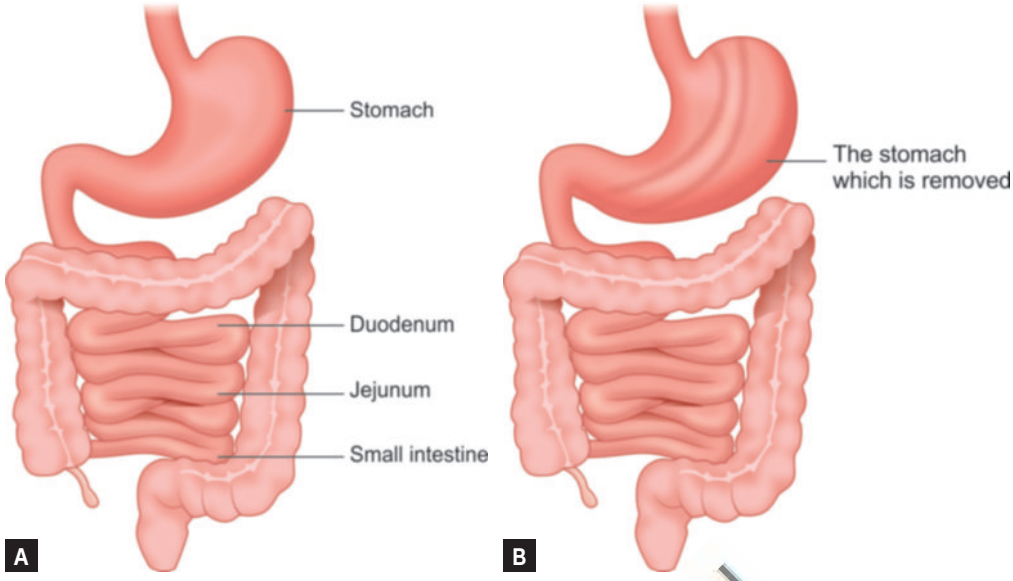
- Body mass index ≥40 kg/m^2 with or without any associated comorbidities.
- Body mass index between 35 and 40 kg/m^2 with at least one serious weight-related comorbidity, including but not limited to diabetes, obstructive sleep apnea, hypertension, and coronary artery disease.
- Body mass index between 30 and 35 kg/m^2 with uncontrollable type 2 diabetes or metabolic syndrome.

Besides being a primary bariatric operation, LSG has also been used as a bridging procedure in super morbid obese patients (BMI of 50 kg/m^2 and above) before biliopancreatic diversion with duodenal switch (BPDDS). Additionally, LSG is also a good revisional procedure for patients who fail laparoscopic adjustable gastric banding (AGB).

Laparoscopic sleeve gastrectomy is safe for patients with diabetes, metabolic syndrome, and inflammatory bowel disease. LSG is also an effective treatment for type 2 diabetes. Finally, LSG has been safely performed in both adolescents and older adult patients. LSG can also be offered to high-risk patients such as those with child's A or B liver cirrhosis, and those awaiting kidney, liver, or heart transplant, with the goals of improving eligibility for transplant through weight loss and improving future graft function. As an example, between 2006 and 2016, the number of patients with end-stage kidney disease undergoing bariatric surgery increased ninefold, and the use of LSG increased.

ADVANTAGES OF SLEEVE GASTRECTOMY

Some authors described LSG as a stand-alone procedure with good results with respect to excessive weight loss (EWL) and lower plasma ghrelin levels **(Figs. 4A and B)**. Also, there are numerous reports of morbidly obese patients who underwent LSG as a first step before an intended malabsorptive procedure and lost their excessive weight after LSG, so that further surgery was not necessary. This is important because the disadvantages of the malabsorptive



Figs. 4A and B: Before and after sleeve gastrectomy

procedure are avoided. Perhaps the greatest advantage of the gastric sleeve lies in the fact that it does not involve any bypass of the intestinal tract and patients do not, therefore, suffer the complications of intestinal bypass such as intestinal obstruction, anemia, osteoporosis, and vitamin and protein deficiency. It also makes it a suitable form of surgery for patients who are already suffering from anemia, Crohn's disease and a variety of other conditions that would place them at high risk for surgery involving intestinal bypass. Sleeve gastrectomy can be performed laparoscopically without much problem in patients who are extremely overweight and this accounts for the rising popularity of the LSG.

DISADVANTAGES OF SLEEVE GASTRECTOMY

Perhaps the main disadvantage of this form of surgery is that it does not always produce the reduction in weight which people would wish for and, in the longer term, can result in weight regain. This is indeed true of any form of purely restrictive surgery, but is perhaps especially true in the case of the sleeve gastrectomy. Because the procedure requires stapling of the stomach, patients do run the risk of leakage and of other complications directly related to stapling. In addition, as with any surgery, patients run the risk of additional complications such as postoperative bleeding, small bowel obstruction, pneumonia and even death. The risk of encountering any of these complications is, however, extremely small and varies from about 0.5 and 1%. Having said this, the risk of death from this form of surgery at about 0.25% is extremely small.

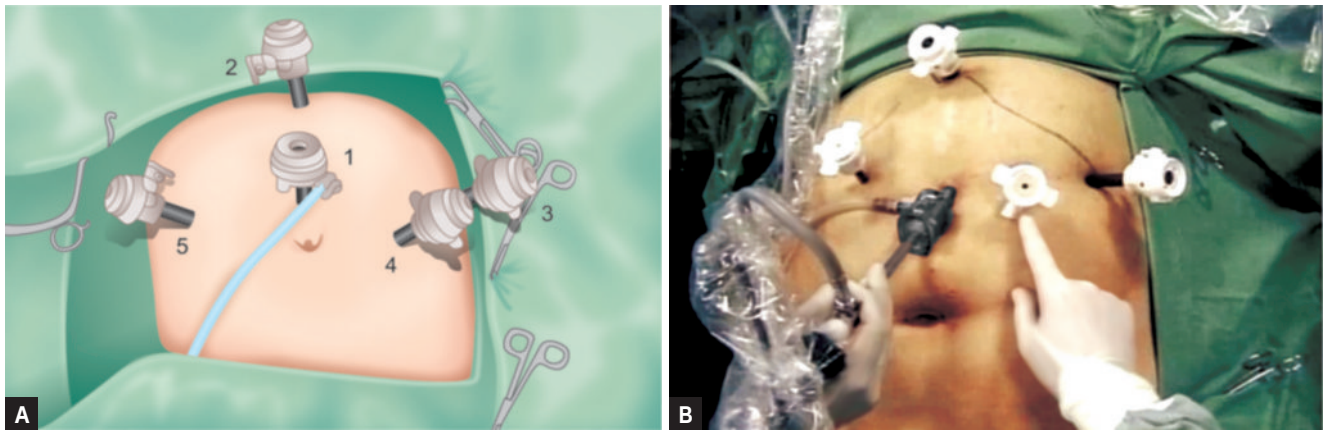
CONTRAINDICATIONS OF SLEEVE GASTRECTOMY

Absolute contraindications to LSG include prohibitive anesthesia risks, severe uncontrolled psychiatric illnesses (including certain eating disorders such as malignant hyperphagia), and coagulopathy. Barrett's esophagus and uncontrolled severe gastroesophageal reflux disease (GERD) are relative contraindications to LSG. Some surgeons do not perform LSG in the presence of Barrett's esophagus, for fear that a sleeve gastrectomy would preclude a future gastric pull-up procedure, which may be required if Barrett's esophagus progresses to esophageal cancer. Others do not consider Barrett's esophagus a contraindication to LSG. Hiatal hernia without esophagitis is not a contraindication to LSG. Performing LSG in patients with known GERD is controversial. RYGB is a better surgical option of weight loss than LSG in patients with severe GERD.

SURGICAL TECHNIQUE

The patient is positioned in a modified reverse Trendelenburg position with the right arm away from the body. The abdomen is prepared and draped in the customary fashion. Ports are placed in the given order (1–5) according to base ball diamond concept as shown in **Figures 5A and B**.

After exploration of the abdomen and the anterior wall of the stomach, the liver is retracted via fifth port **(Fig. 6)**. The first step is to identify the pylorus by visualizing the prepyloric vein of Mayo and palpating with laparoscopic instruments. The pylorus is a crucial landmark because gastric transection typically begins 6 cm from the pylorus. Dissection should be started with dissection of the short gastric vessels to the point of the angle of His, using either the harmonic scalpel (Ethicon Endo-Surgery) or LigaSure. The greater omentum is then separated from the greater curvature under protection of the gastroepiploic arcade **(Fig. 7)**. A complete mobilization of the greater curvature ensures that a sizable portion of the posterior fundus is not left behind during gastric transection.



Figs. 5A and B: Port position for laparoscopic sleeve gastrectomy.

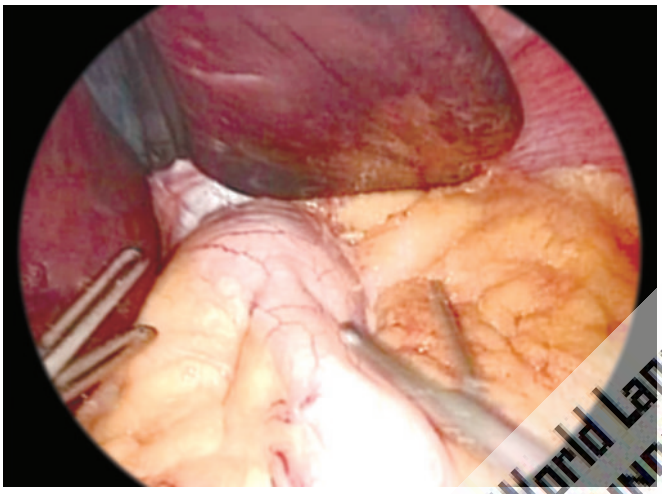


Fig. 6: Exposure of stomach up to angle of HIS.

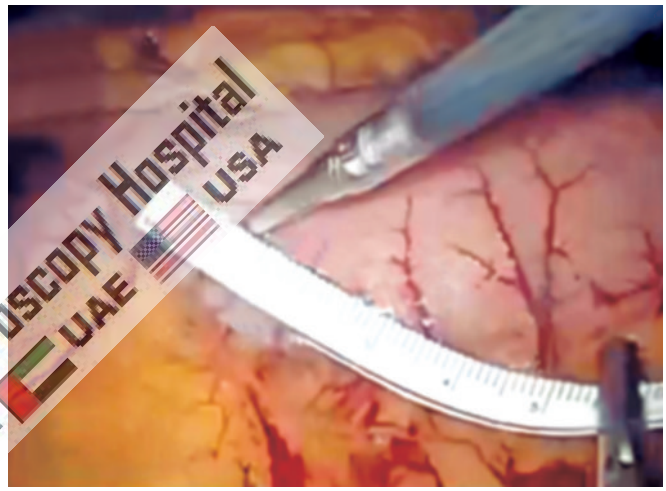


Fig. 7: 6 cm of stomach toward the pylorus is left.

At this point, surgeon should assess the hiatus for hernias. Any large hiatal hernia should be repaired using standard laparoscopic techniques. The blood supply to the lesser curvature (i.e., left gastric artery) must be preserved since it will become the sole blood supply to the sleeve after gastric transection.

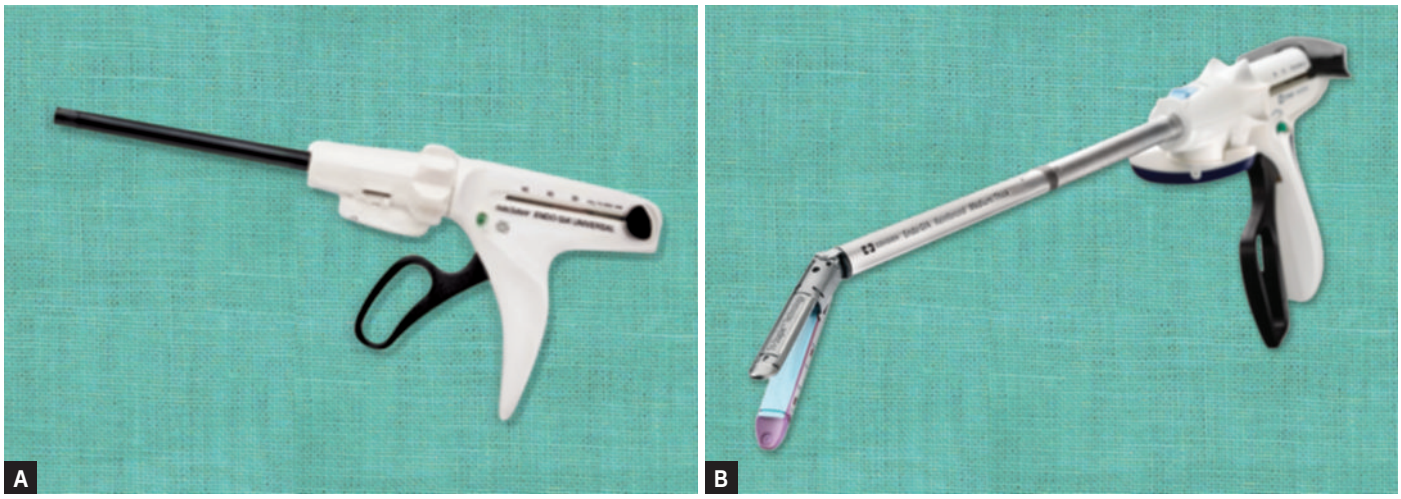
A 36-Fr tube is then positioned along the lesser curvature of stomach as the leading structure for the stapling line to follow. Although experts agree on the need for calibrating the sleeved stomach with a bougie, the optimal size of such a bougie is still debated. According to a survey of 863 surgeons with a cumulative experience of 520,230 procedures, the majority of experts used a bougie size of 36 French.

After freeing the omentum, staple should be applied along the greater curvature strictly along the stomach tube using a 60-mm Endo-GIA, Ethicon Endo-Surgery or Auto Suture **(Figs. 8A and B)**. The starting point is 7–8 cm prepyloric to the point of the angle of His. Typically, 4–5 staple lines are needed **(Figs. 9A to C)**. Different types of staplers are available in the market. As the gastric transection proceeds, the height of the staples may need to be adjusted according to the thickness of the tissue. In general, most experts would not use staples with closed height <2.0 mm to transect the antrum (the thicker part of the stomach) or staples with closed height <1.5 mm to transect the rest of the stomach (thinner parts).

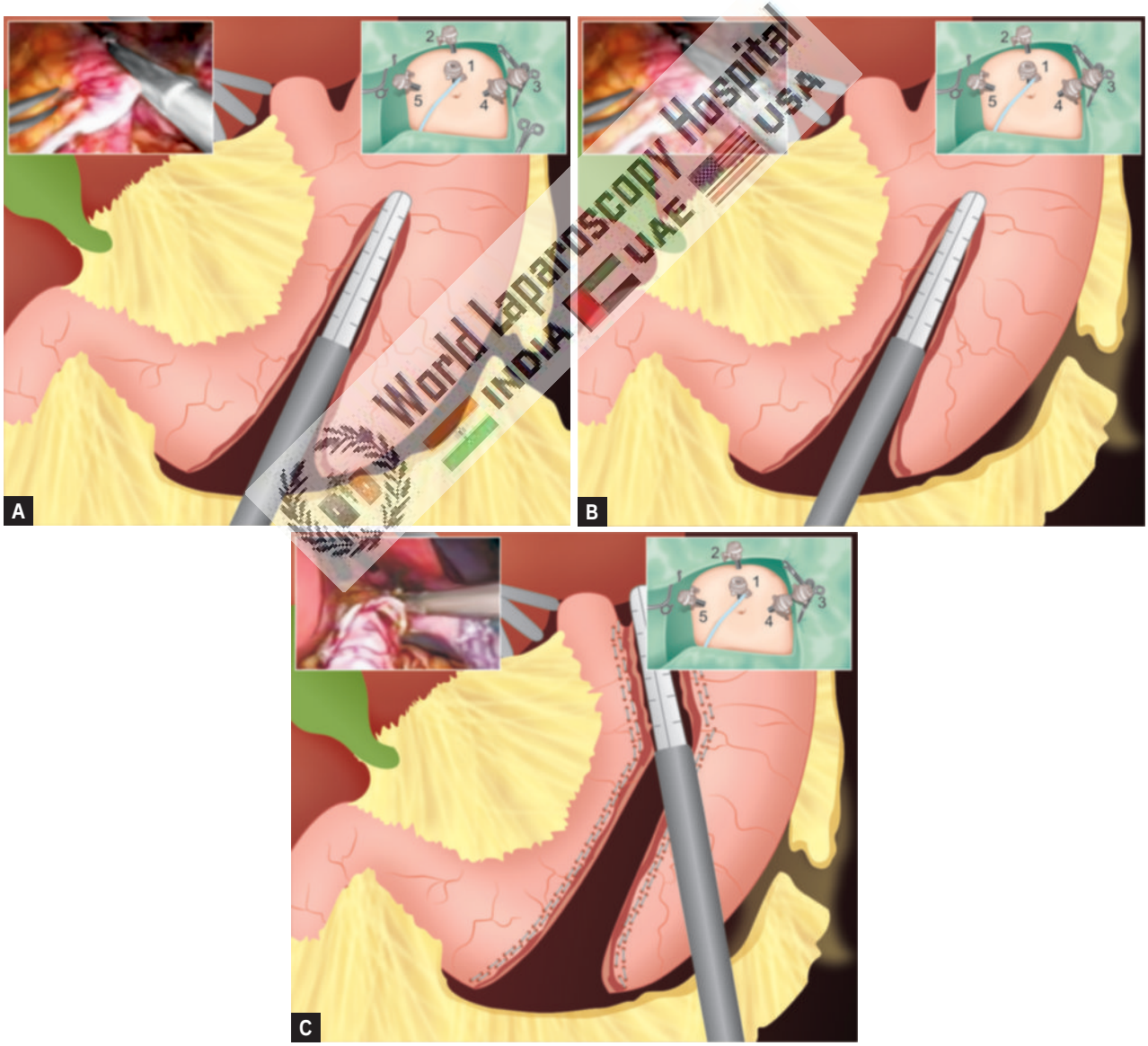
While transecting the stomach, the surgeon must avoid twisting the staple line along the longitudinal axis and avoid narrowing the sleeve, particularly at the level of the incisura angularis. A twisted or narrowed sleeve can cause distal obstruction, which is responsible for the majority of the occurrences and persistence of staple line leaks in the proximal sleeve.

The dissected part of the stomach is withdrawn from the abdomen at port number 3 and the staple line is overstitched by absorbable intracorporeal suturing. This is done not to prevent insufficiency in the staple line but rather to prevent staple line bleeding. It is possible to overstitch only areas of bleeding between the staples, and not the whole staple line. When performing the last stapler firing, it is important to avoid stapling too close to the gastroesophageal junction, which may result in ischemia and postoperative leak.

Like most of the bariatric surgery operations, currently there are multiple variations in the technique for the LSG.



Figs. 8A and B: Laparoscopic Endo-GIA stapler.



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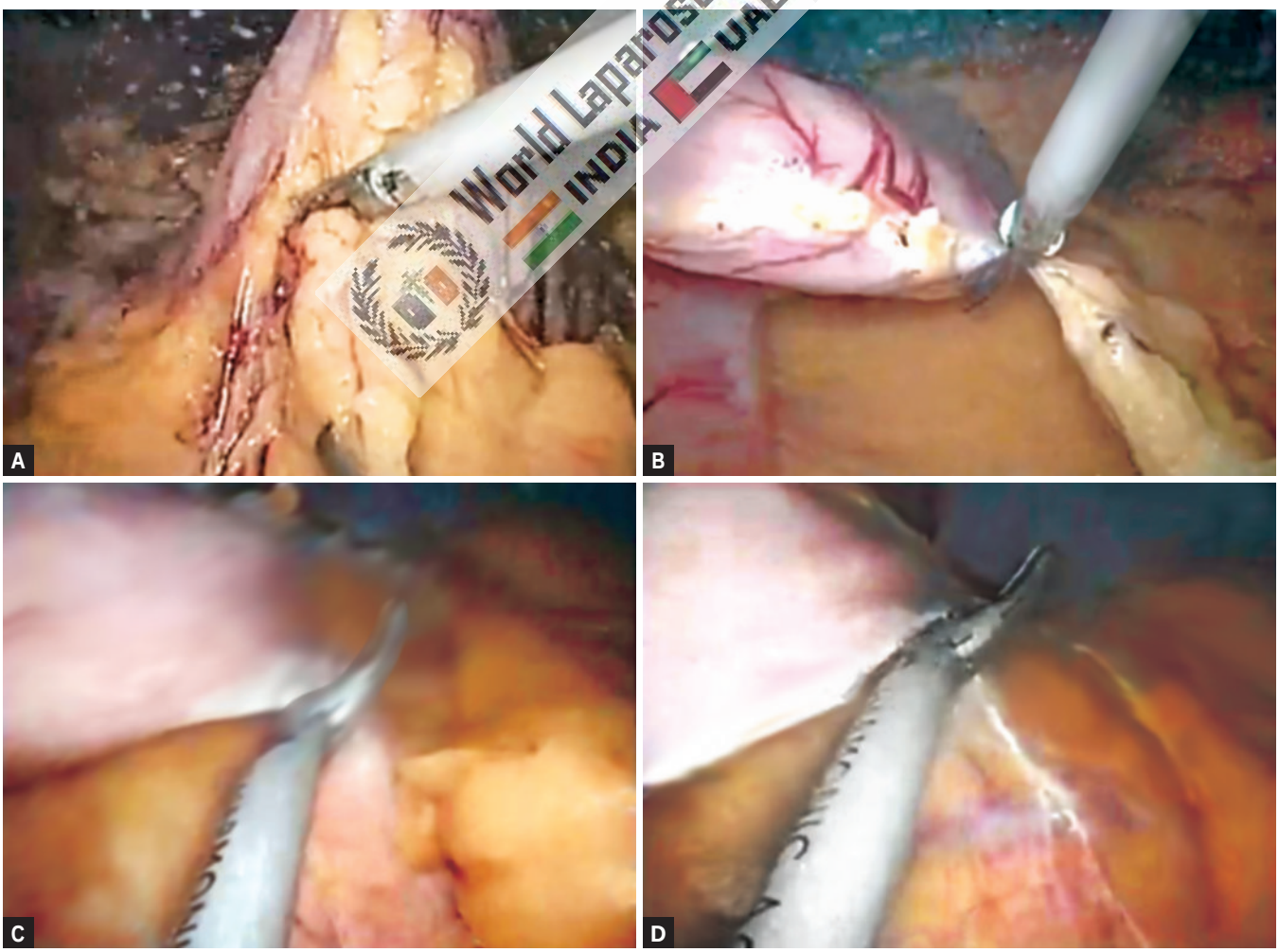
Figs. 9A to C: (A) After dissecting the greater omentum from the greater curvature, a 34-Fr stomach tube is placed along the lesser curvature. The first staple line is then set strictly along the stomach. The starting point of the dissection of the greater curvature is about 7–8 cm prepyloric; (B) The second staple line is set strictly and continued along the stomach tube; and (C) Finishing of the gastric sleeve with the third staple line. The greater curvature is resected to the point of the angle of His.

Some of these variations are: the size of bougie (determines the size of the pouch) beside which the Endo-GIA staplers are placed to divide the stomach, the level at which the surgeons start the division in the central area. Many surgeons leave most of the antrum for its pumping, emptying action and also to avoid the possibility of leak from this thick-walled tough area, and whether to reinforce or not reinforce this long staple line.

Five or six ports are used for LSG and the surgeon standing between the patient's legs. An open technique could be used for the first port, establishing a pneumoperitoneum of 15 mm Hg. Then, two right ports, one left port, and a midline ports are usually sufficient **(Figs. 5A and B)**. The right subcostal trocar is used to insert the fan retractor for the liver. The camera should be placed high between the umbilicus and xiphoid. Initial decompression of the stomach with nasogastric tube (NGT) is preferable. Some surgeons commence the LSG with an opening through the gastrocolic ligament to lesser sac, and the posterior stomach wall is visualized and fine adhesions to the pancreas are divided and the lesser sac totally freed using harmonic scalpel, LigaSure□ , or coagulation hook. The left side of the gastroesophageal junction should be cleared off fat to avoid later compromise of the stapling during creation of the sleeve **(Figs. 10A to D)**. Left crus should be exposed completely.

Majority of surgeons start the dissection 6 cm proximal to the pylorus, but some European surgeons start the dissection closer to the pylorus. If the dissection starts too close to the pylorus, the antrum will not empty properly and its pumping mechanism will be defective, thus postoperative nausea may occur. The linear Endo-GIA stapler is generally introduced through a right trocar toward the left shoulder and leaves about 1 cm of fat pad along the lesser curvature (3 cm width). This assures adequate blood supply on the lesser curvature for the sleeve. Transaction of the stomach should be started 6 cm proximal to the pylorus and then the anesthesiologist inserts a 36–40-Fr bougie down to pylorus if the LSG is intended as the sole operation, but if only as a preliminary step before duodenal switch, then instead a 60-Fr bougie is used. Kueper et al. considered using a 34-Fr bougie in their study, which results in a pouch of 100 mL. The sleeve is started at the lower end of the crow's foot. The procedure requires 5–6 firings of the linear cutting stapler (60 mm long, 4.8 mm staple-height, and green cartridge) to divide the entire stomach **(Figs. 11A to H)**. It is important to remove



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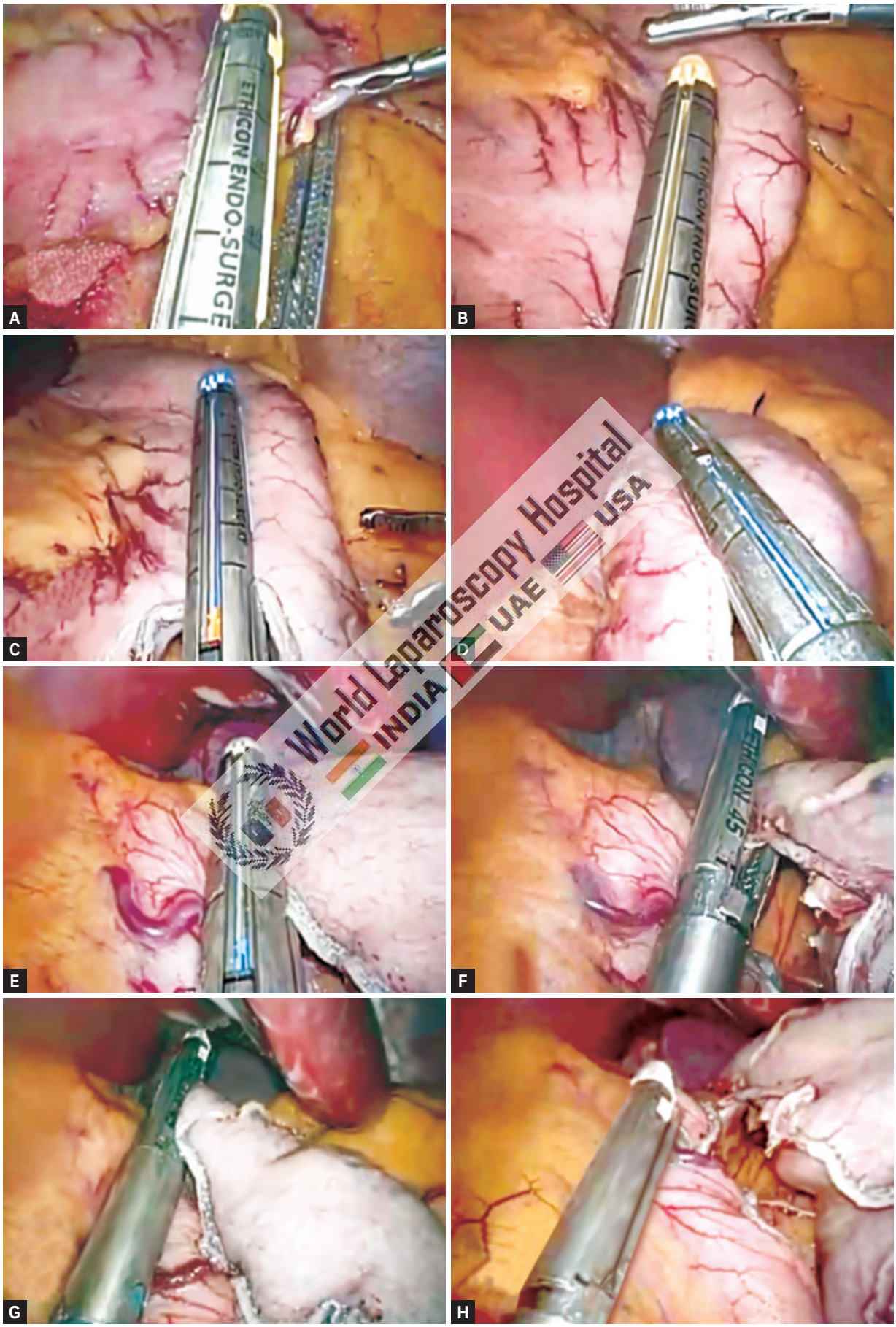
Figs. 10A to D: Dissection and mobilization of stomach along the greater curvature outside the epiploic arcade.



Figs. 11A to H: Gastrectomy with the help of Endo-GI stapler.

all of the fundus to avoid regain of weight. The vagus nerves anteriorly and posteriorly are preserved for normal gastric emptying.

Many surgeons recommend reinforcing the staple line to reduce the risk of bleeding and leak. This can be accomplished by using a buttressing material at the time of stapler firing or by oversewing the staple line. A combination of buttressing and oversewing, however, increased staple line leak rate compared with either method alone in one study was done and there was no significant difference. Oversewing should be done with the bougie still in place to avoid excessive imbrication and narrowing of the sleeve lumen.

The resected greater curvature could be extracted in a bag via epigastric or right paramedian port-site after being dilated to two-finger diameter. The typical specimen has the shape of a comma or banana with the fundus at the top. After dividing the stomach, most surgeons use over sewing of the staple-line by continuous or interrupted absorbable sutures to prevent bleeding and leak.

Intraoperative testing through an 18-Fr Argyle tube with diluted methylene blue or air under saline using a gastroscope, with concurrent compression of prepyloric area is a complementary step. A Gastrografin® swallow is ordered by many surgeons on the second postoperative day, or others perform this study only if there is a problem. A liquid diet may be commenced on the first postoperative day.

POSTOPERATIVE CARE

Most patients are admitted for overnight observation after LSG, especially if they have a history of obstructive sleep apnea. Postoperative nausea is the most common complaint and should be treated with scheduled doses of intravenous antiemetics such as ondansetron, with other antiemetics, such as prochlorperazine and scopolamine patch, provided as needed for breakthrough symptoms. Minimizing narcotic use by liberal use of local anesthetic infiltration, transverse abdominis plane (TAP) blocks, and intravenous acetaminophen also contributes to the reduction of postoperative nausea and early discharge.

A clear liquid diet is usually started in the morning after the procedure. If the patient tolerates that, they can be advanced to a full liquid diet within 24 hours. Once the patient tolerates a liquid diet and their pain is controlled with oral pain medications, they can be discharged home with instructions to only take crushed or liquid medications and a full liquid diet for 2 weeks

A postoperative contrast study is performed after LSG to detect leak by some surgeons but not others. Because most leaks from LSG occur late after patient discharge, routine contrast studies on postoperative day 1 have a very low yield of detecting leaks.

RISKS AND COMPLICATIONS OF THE SLEEVE GASTRECTOMY

As with all forms of weight loss surgery, the vertical gastrectomy does carry risk and these will clearly vary from one patient to the other. In modern series, the overall mortality rate of LSG is approximately 0–1.2%; the overall morbidity rates range from 0 to 17.5%.

Complications include:

- Bleeding to 15%
- Gastric leakage and fistula 1.0%
- Strictures 0.26–4%
- Deep vein thrombosis 0.5%
- Nonfatal pulmonary embolus 0.5%
- Postoperative bleeding 0.5%
- Splenectomy 0.5%
- Acute respiratory distress 0.25%
- Pneumonia 0.2%
- Death 0.25%

BLEEDING AFTER SLEEVE GASTRECTOMY

Postoperative bleeding after LSG has been described in up to 15% of cases. It can occur within the lumen of the stomach, intra-abdominally, or at the trocar/incision sites. In a retrospective study of over 175,000 LSGs performed from 2015 to 2016, 0.6% were complicated by postoperative bleed. Bleeding after LSG was associated with higher rates of complications, readmission, reoperation, and mortality at 30 days. With bleeding, the mortality rate increased over 10-fold from 0.07 to 0.99%. In multivariate analysis, bleeding was associated with patient factors such as older age, prior cardiac procedure, hypertension, renal insufficiency, therapeutic anticoagulation, diabetes, obstructive sleep apnea, as well as technical factors such as larger bougie size and longer operative length. Staple-line reinforcement or oversewing and higher BMI were protective against bleeding

LEAK AFTER SLEEVE GASTRECTOMY

Although LSG does not involve an anastomosis, it is more susceptible to a leak than RYGB (2.4 vs. 0.7%) because of a long staple line and high intraluminal pressure. As explained above, the high luminal pressure is generated by a narrow-sleeved stomach sealed between an intact pylorus and lower esophageal sphincter. Leaks that occur after LSG are also less likely to close spontaneously because of the high luminal pressure. Other etiologies, besides a high intraluminal pressure, that also contribute to staple line leaks include ischemia, hematoma formation, and staple misfiring. Besides (rare) manufacturing issues, staple misfiring can be due to improper use of the stapler or improper selection of the staple height. When choosing staple cartridges, surgeons must be aware of the progressive decrease in the thickness of the gastric wall from the antrum to the fundus and adjust the

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staple height accordingly. In unstable patient with a contained or uncontained symptomatic leak requires immediate reoperation. In stable patients with leak, endoluminal stenting is a valid treatment option for an acute proximal leak that has failed conservative therapy. Stenting has limited efficacy for chronic leaks. After 30 days, the likelihood of a leak to seal by means of exclusion via stent is very low. In stable patients with a proximal leak, the surgeon should wait at least 12 weeks before reoperating to allow the body to heal and avoid thick adhesions. Surgical options include revising the sleeve and converting to RYGB. When revising the sleeve, the surgeon should oversew the leak with a bougie in place to avoid a stricture. Converting to RYGB is a valid treatment option that is usually reserved as the last resort for patients with chronic proximal leaks. It converts a high-pressure system (LSG with distal obstruction) to a lower-pressure system (RYGB), which promotes healing of the leak/fistula.

Although sleeve strictures have been reported in 0.26–4% of LSG operations, <1% result in symptoms that require endoscopic or surgical intervention. A stricture can manifest acutely, early after surgery, or more chronically. Although strictures can occur anywhere along the long staple line, they are most often located at the level of the incisura angularis for anatomic reasons. Patients with an acute stricture who do not respond to conservative management require early surgical reintervention. Laparoscopy could demonstrate kinking of the gastric tube, a tight suture, or a compressing hematoma. Patients with chronic strictures often present with mild symptoms that mimic acid reflux. Such patients can be initially managed with proton pump inhibitors. Those who fail medical management or develop severe symptoms are candidates for further endoscopic or surgical interventions. Endoscopy is a good initial treatment for short-segment strictures, most of which can be dilated with balloons. Multiple treatments in 4- to 6-week intervals are sometimes needed to treat the stricture and improve patient symptoms.

WEIGHT LOSS

"Durable" weight loss is the one most important gain of bariatric surgery operations, and it is the parameter by which success or failure of weight-reducing techniques is measured. Success of treatment has been defined as weight loss >50% of excess weight, maintaining or even losing further after surgery **(Table 1)**.

TABLE 1: Outcome of published series on sleeve gastrectomy.

S. No.	Author	No. of patients	Average preoperative BMI	Bougie (Fr)	FU (Months)	Weight loss (%)
1.	Weiner et al. (2007)	A = 25	61.6	NR	60	62% at 12 ms
		B = 32	60.8	44	60	C > B > A
		C = 63	60.3	32	60	Significantly
2.	Skrekas (2008)	93	46.86 ± 6.48	36	12.51 ± 4.15	58.32± 16.54%
3.	Dapri et al. (2007)	A = 20	42.5	34	12	48.3%
		B = 20	47	34	12	49.5%
4.	Lee et al. (2007)	216	49 ± 11	32		
5.	Melissas et al. (2007)	23	47.2 ± 4.8	34	12	33.1%
6.	Hamoui et al. (2006)	118	55		24	47.3%
7.	Langer et al. (2006) (Sleeve dilatation)	23	48.5 ± 6.9	48	12	56%
8.	Quesada (2008)	15	54	38	6	44%
9.	Baltasar (2006) (Re-sleeve)	2	46, 42			
10.	Cottam et al. (2006) (Initial, high-risk)	126	65.3 ± 0.8	48	12	46%
11.	Vidal et al. (2007) (Effect of LSG on DM)	35		48		NR
12.	Silecchia, et al. (2006)	41; superobese ≥ 2 major comorbidities	57.3 ± 6.5	48	22.2± 7.1	NR
13.	DePaula et al. (2008) (Effect of LSG as initial to two different procedures on DM with BMI ≤ 35	39	23.4–34.9	NR	7	22%
14.	Madhala et al. (2007) (Technique)	25	44 ± 2	50	4	22.7%
15.	Till et al. (2008) (LSG in morbid obese children)	4 (≤14.5 years)	48.4	40	12	23%
	Total	**707**	**MEAN = 57.76**	**MEAN = 43.7Fr.**	**Mean = 14.5 months**	**Mean= 40%**

(BMI: body mass index; DM: diabetes mellitus; LSG: laparoscopic sleeve gastrectomy)

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The percentage weight loss after LSG in 707 morbidly obese patients included in the reviewed series is 40% (a mean) after a mean follow-up of 14 months **(Table 1)**.

Effect on Associated Comorbidities

Laparoscopic sleeve gastrectomy had been carried out for super obese patients with multiple severe comorbidities and in at least 50% of the patients; there was marked improvement of the comorbidities especially diabetes mellitus which got marked benefit in 50–57%.

Complications Review

In one of the reviewed series (n = 707), there are 17 major complications with an incidence of 2.4%. One should consider the heterogeneity of the patient's population where those with high risk and multiple severe comorbidities are included. One death due to gastric leakage reported with 11 gastric leakage, four renal failures, and one stenosis. GERD occurs in too many cases but most of the patients improve gradually on conservative management. Bleeding from the suture line was reported rarely and could be managed conservatively in most of the cases.

Laparoscopic Sleeve Gastrectomy as Initial Step for Super Obese and High-risk Patients

In two studies, LSG was used as a planned initial step and entertained over other major final technique due to super obesity with poor general condition in an attempt to minimize the risk in this subgroup of patients. During the post-LSG follow-up, the authors found the second stage operation is only needed in 5% in one study and 39% in the others **(Table 2)**.

TABLE 2: Main complications of LSG in the reviewed published series.

S. No.	*Author*	*No. of patients*	*Main complications*	*Recommendations*
1.	Weiner (2007)	120	Reflux symptoms, severe esophagitis	
2.	Skrekas (2008)	93	Four cases of gastric leak, three managed conservatively	More suitable for intermediate morbidly obese patients with BMI between 40 and 50 kg/m^2
3.	Dapri et al. (2007)	20 + 20	One early leak. One late leak, one stenosis	Better mobilize the stomach than resect it
4.	Lee et al. (2007)	23	Two leaks	Recommended for BMI < 50 kg/m^2
5.	Melissas et al. (2007)	23	Eight GERD; only one persisted	The term restrictive may not be applicable to the LSG
6.	Hamoui et al. (2006)	118	One death due to gastric leakage	Out of 118 super obese patients, only six requested second stage duodenal switch
7.	Langer et al. (2006)	23	One severe GERD, one renal failure	Sleeve dilatation does not necessarily lead to weight gain
8.	Quesada (2008)	15	-	LSG is best option in the presence of adhesions
9.	Baltasar (2006)	2	-	Re-LSG is achievable with minimal complication
10.	Cottam et al. (2006) (Initial, high-risk)	126 (+9.3 comorbidities in each; mean)	-	Only 36 patients (39%) were in need of the second stage. LSG is a good initial option in those severely comorbid patients
11.	Vidal et al (2007) (Effect of LSG on DM)	35	-	DM resolved in 51.3%, 4 months after LSG
12.	Silecchia et al. (2006)	41 super obese ≥ 2 major comorbidities	One leakage, one bleeding, one transient renal failure	After 12 months, 57.8% of the patients were comorbidity-free
13.	DePaula et al. (2008)	39	Two leakage, two renal failure	50% resolution of DM after 7 months
14.	Madhala et al. (2007)	25	-	-
15.	Till et al. (2008) (LSG in morbid obese children)	4 (≤14.5 years)	-	Comorbidities improved significantly
	Total	**707**	**11 gastric leaks, 1 DEATH, 4 RF, 1 stenosis = 17; 2.4%**	

(BMI: body mass index; DM: diabetes mellitus; GERD: gastroesophageal reflux disease; LSG: laparoscopic sleeve gastrectomy; RF: renal failure)

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Laparoscopic Sleeve Gastrectomy in Morbidly Obese Children

Till et al. carried-out LSG in four morbidly obese pediatric patients with multiple comorbidities. Marked improvements in their comorbidities and 23% weight loss had been achieved after 12 months follow-up.

GASTRIC PLICATION

The field of bariatric surgery is evolving continuously. Surgical procedures have now been used to induce weight loss, and many different operations have been tested and dumped owing to the unsatisfactory long-term weight loss or metabolic or mechanical complications.

In sleeve gastrectomy a long staple line is created which can lead to complications, such as bleeding and leaks, and that the operation is irreversible has been a discouragement for few surgeons and patients. So a new operation came into design called laparoscopic gastric plication which is similar in some aspects to sleeve gastrectomy but with reduced risk. It started with the concept of plicating the greater curvature to itself to reduce the lumen of the stomach. Then the procedure was modified by division of the short gastric vessels and inverting and placating the greater curvature without any need for stapling or resection.

Surgical Technique

Two different techniques can be used to achieve laparoscopic gastric volume reduction **(Figs. 12A and B)**.

- In the first group [anterior plication (AP)], the anterior gastric wall was folded inward from the fundus to the antrum using two rows of 2-0 polypropylene running suture. The greater and lesser curvatures were approximated on the anterior surface of the stomach to create an intraluminal fold.
- In the second group [(greater curvature plication (GCP)], the short gastric vessels were divided starting 4 cm from the pylorus and continuing up to the left crus of the diaphragm, similar to the dissection performed for sleeve gastrectomy. After the fundus and body were completely mobilized, the greater curvature was folded inward with two suture lines of 2-0 polypropylene suture to create a large intraluminal gastric fold **(Figs. 13A to D)**. The fold was started just below the angle of His and continued distally to within 4 cm of the pylorus. In both procedure groups, full-thickness suture bites were used to secure the plications **(Fig. 14)**. This was confirmed by intraoperative endoscopy.

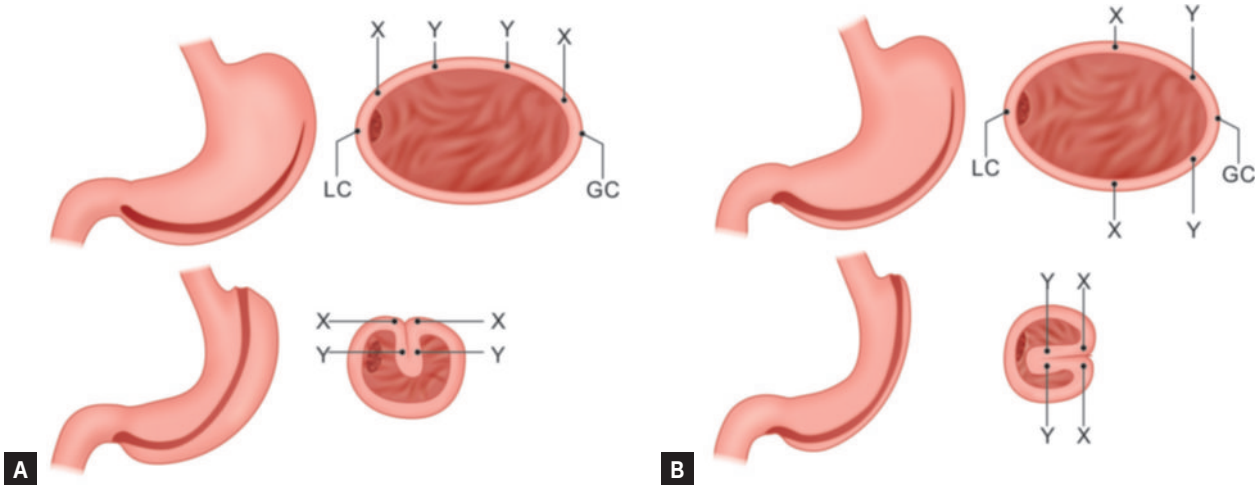
Complications

- Gastric obstruction due to fold prolapse or edema
- Adhesions or accumulation of fluid within the gastric fold
- Leak
- Fistula
- Nausea, vomiting, and sialorrhea
- Dysphagia or obstruction

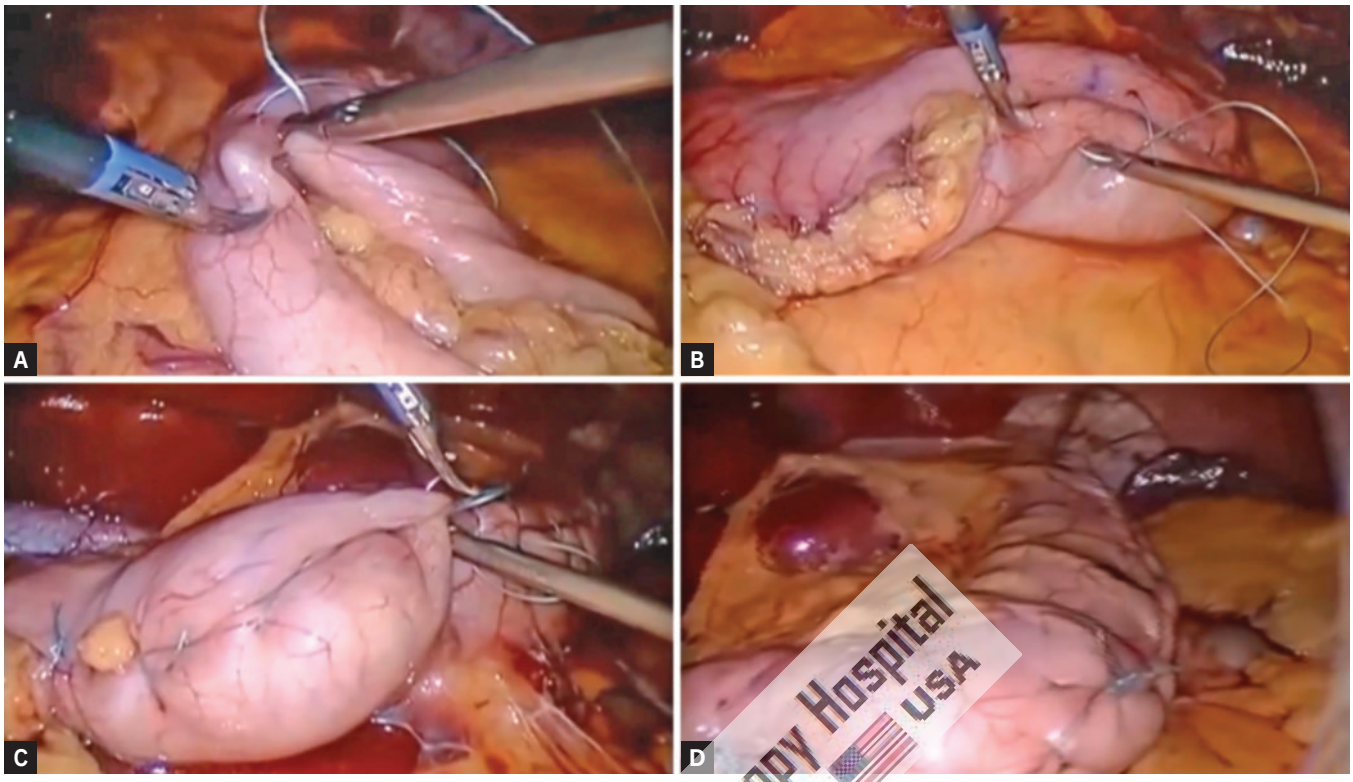
Compared with LSG, laparoscopic gastric plication appears to have worse long-term outcomes (e.g., weight loss and diabetes resolution), more complications, and similar operating time and length of hospital stay. Thus, it is doubtful at this point that the laparoscopic gastric plication will become a meaningful operation for obesity and metabolic control.

MINI GASTRIC BYPASS

The mini gastric bypass (MGB) is a short, simple, successful, reversible laparoscopic gastric bypass weight loss surgery. It has been recently renamed as one anastomosis gastric bypass **(Fig. 15)**. The operation usually takes shorter time with lesser or similar hospital stay as regular bypass. Mini gastric bypass is a feasible and safe bariatric surgical procedure.



Figs. 12A and B: Different techniques to achieve laparoscopic gastric volume reduction.



Figs. 13A to D: Steps of gastric plication.

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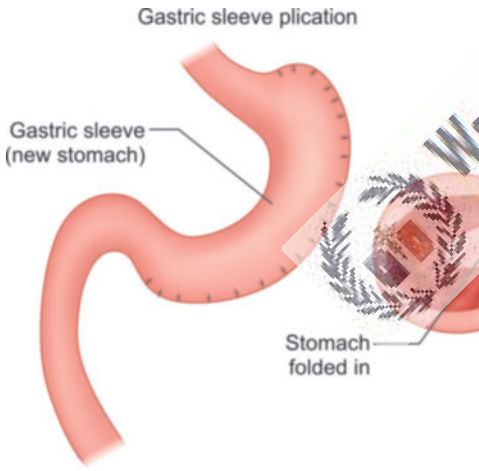


Fig. 14: Folded stomach in gastric plication.

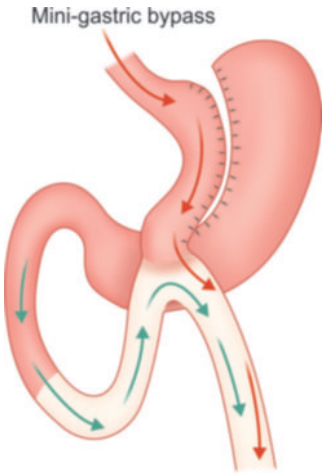


Fig. 15: Mini-gastric bypass.

Indications

It is indicated for people with a BMI of 40 kg/m^2 or more, and also in those whose BMI is 35–39 kg/m^2 that are suffering from obesity associated health conditions such as:

- Type 2 diabetes
- Heart disease
- High blood pressure
- High cholesterol
- Sleep apnea
- Nonalcoholic fatty liver disease
- Cancer

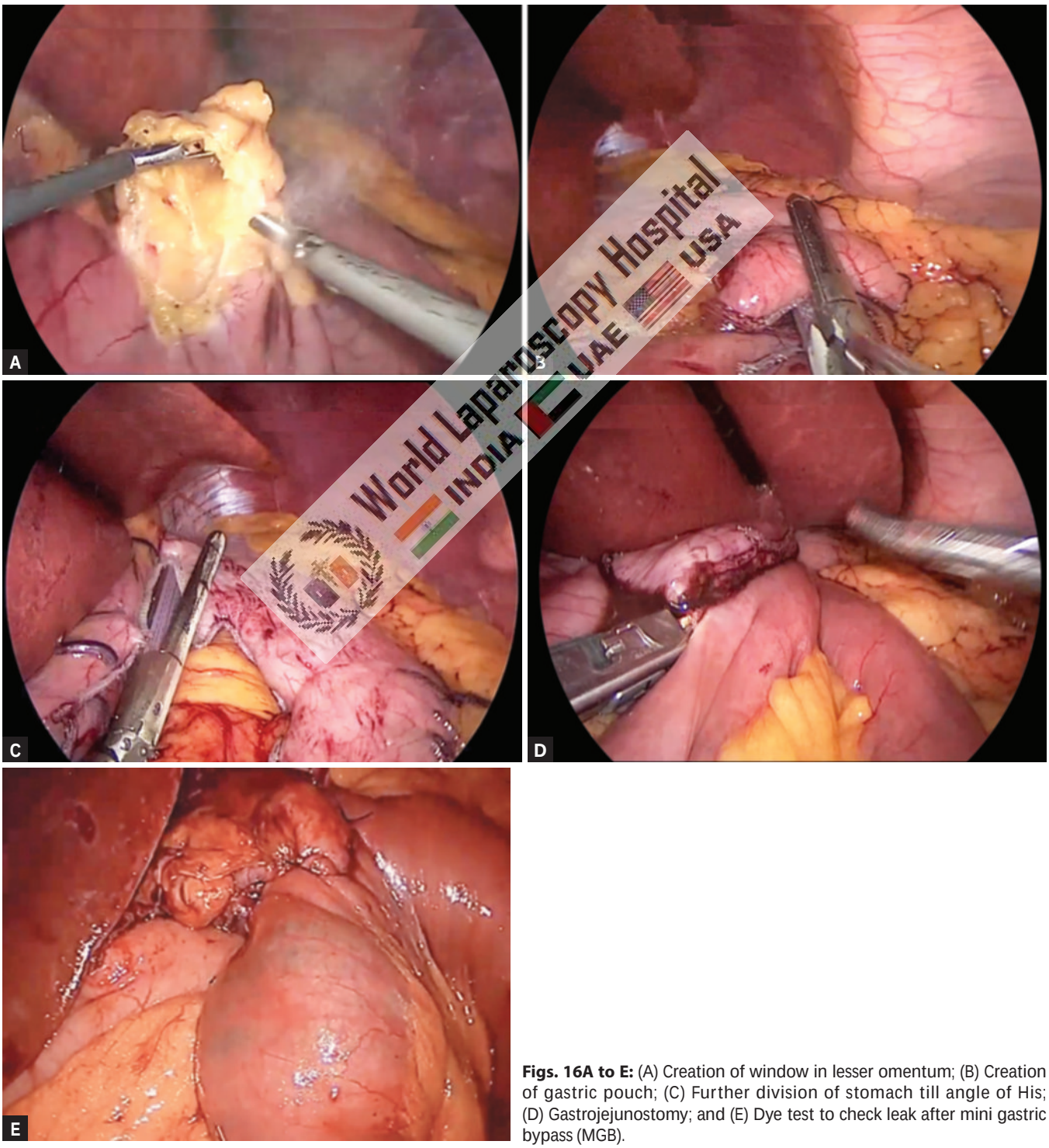
Position of Patient and the Surgical Team

The operation is performed with the patient in the supine position with legs open and with steeply inclined reverse Trendelenburg position. The surgeon stands between the legs with the first assistant, who handles the camera on the right. Antibiotic prophylaxis is routinely administered. The prevention of thrombotic events is made with use of graduated compression stockings and intermittent pneumatic cuffs. A NGT (32-Fr) should be placed. The pneumoperitoneum is performed by means of a direct puncture with a Veress needle in the left upper quadrant, near the costal margin at the level of

the midclavicular line (Palmer's point) or some surgeon prefer supraumbilical port. The initial pressure is set at 20 mm Hg, 10 mm permanent trocars for introduction of 30° camera placed at the level of mesogastrium between 12–15 cm below the xiphoid process and 3 cm to the left of the midline. The next trocar of 5 mm is placed near the xiphoid process for the use of liver retractor which is a probe held by the assistant. The next trocar of 12 mm, to be used by the surgeon's left hand, is placed on the right side of the patient in an intermediate position between the previous two, 3–5 cm lateral to the midline. The next trocar of 5 mm is placed along the left costal margin in the anterior axillary line near to the assistant. The last trocar of 12 mm is placed adjacent to the left costal margin in the midclavicular line for surgeon's right hand manipulation.

Surgical Technique (Figs. 16A to E)

The operation begins with the dissection of the angle of His and the opening of the left gastrophrenic ligament with a



Figs. 16A to E: (A) Creation of window in lesser omentum; (B) Creation of gastric pouch; (C) Further division of stomach till angle of His; (D) Gastrojejunostomy; and (E) Dye test to check leak after mini gastric bypass (MGB).

harmonic scalpel, so as to expose the lateral aspect of the left diaphragmatic crus. Then, the resection of the fat pad of the esophagogastric junction, also known as Belsey's fat, is performed. The surgeon then proceeds to the ligation of the distal lesser sac, next to the insertion of the Latarjet nerve, until the exposure of the posterior gastric wall. The gastric pouch must be lengthy and narrow, measuring around 15–18 cm with a 50–150 mL reservoir capacity. The pouch is created using 45-mm blue cartridges to perform the horizontal section and 2–3 units to perform the vertical section. The stapling lines of the pouch and excluded stomach are then reinforced with a 3-0 polydioxanone continuous suture. The Treitz ligament is then identified and the small bowel is counted until 150–200 cm from the Treitz angle, so that part of the stomach, duodenum, and proximal jejunum gets excluded from the food pathway. This segment is then attached to the pouch and a vertical or slightly oblique omega-loop, isoperistaltic, antecolic, and side-to-side 25-mm gastrojejunostomy is performed using a 45-mm white cartridge; the orifice for the cartridge insertion is then closed by a continuous suture with 3-0 polydioxanone reinforced with separate stitches of 3-0 polyester. The Petersen's defect is closed by means of a continuous suture with 3-0 silk.

Complications

- Breakage
- Dumping syndrome
- Gallstones (risk increases with rapid or substantial weight loss)
- Hernia
- Internal bleeding or profuse bleeding of the surgical wound
- Leakage
- Perforation of stomach or intestines
- Pouch/anastomotic obstruction or bowel obstruction
- Protein or calorie malnutrition
- Pulmonary and/or cardiac problems
- Skin separation
- Spleen or other organ injury
- Stomach or intestine ulceration
- Stricture
- Vitamin or iron deficiency

Mini gastric bypass led to both early morbidity and mortality less than those observed after RYGB. Furthermore, due to its simplified design and the necessity to perform a single anastomosis, it is simpler and potentially more cost-effective since less stapler cartridges are necessary.

LAPAROSCOPIC ROUX-EN-Y GASTRIC BYPASS

Laparoscopic Roux-en-Y gastric bypass (LRYGB) remains the gold standard against which other bariatric procedures are measured **(Fig. 17)**. LRYGB induces more weight loss than AGB and more durable weight loss than sleeve gastrectomy. LRYGB, as a bariatric procedure, was first described by Alan Wittgrove in 1994. Over the ensuing decades, the technique of LRYGB as well as perioperative care of patients have been gradually improved and refined. Consequently, the mortality rate associated with the RYGB has decreased from 2.6% at the turn of the century to 0.12%.

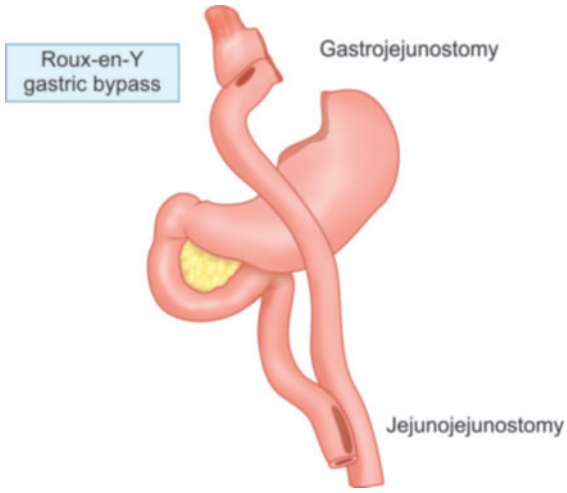


Fig. 17: Roux-en-Y gastric bypass.

Indications

The indications for LRYGB are the same as for all accepted bariatric procedures.

- Body mass index of >40 kg/m^2
- Body mass index of >35 kg/m^2 with one or more obesity-related comorbidities.
- Body mass index of >30 kg/m^2 with uncontrolled type 2 diabetes mellitus or metabolic syndrome.

Because LRYGB treats insulin resistance better than most other bariatric procedures, it may be preferred in patients with uncontrolled type 2 diabetes, nonalcoholic fatty liver disease, metabolic syndrome, or polycystic ovarian syndrome. These conditions are attributable to insulin resistance. Additionally, while sleeve gastrectomy and RYGB are equally effective in improving diabetes in the short term, LRYGB is associated with better long-term control of diabetes and lower rates of relapse.

Surgical Technique of Roux-en-Y Gastric Bypass (Figs. 18A to H)

The patient is placed in a moderate to steep reverse Trendelenburg position. The LRYGB operation is initiated by placing a total of six trocars, of which four are 10 mm and two are 5 mm **(Fig. 19)**. A part of the gastrophrenic ligaments is dissected down at the angle of His. A small gastric pouch is demarcated by creating a window in the lesser sac. After entering the retrogastric space, the surgeon should fully

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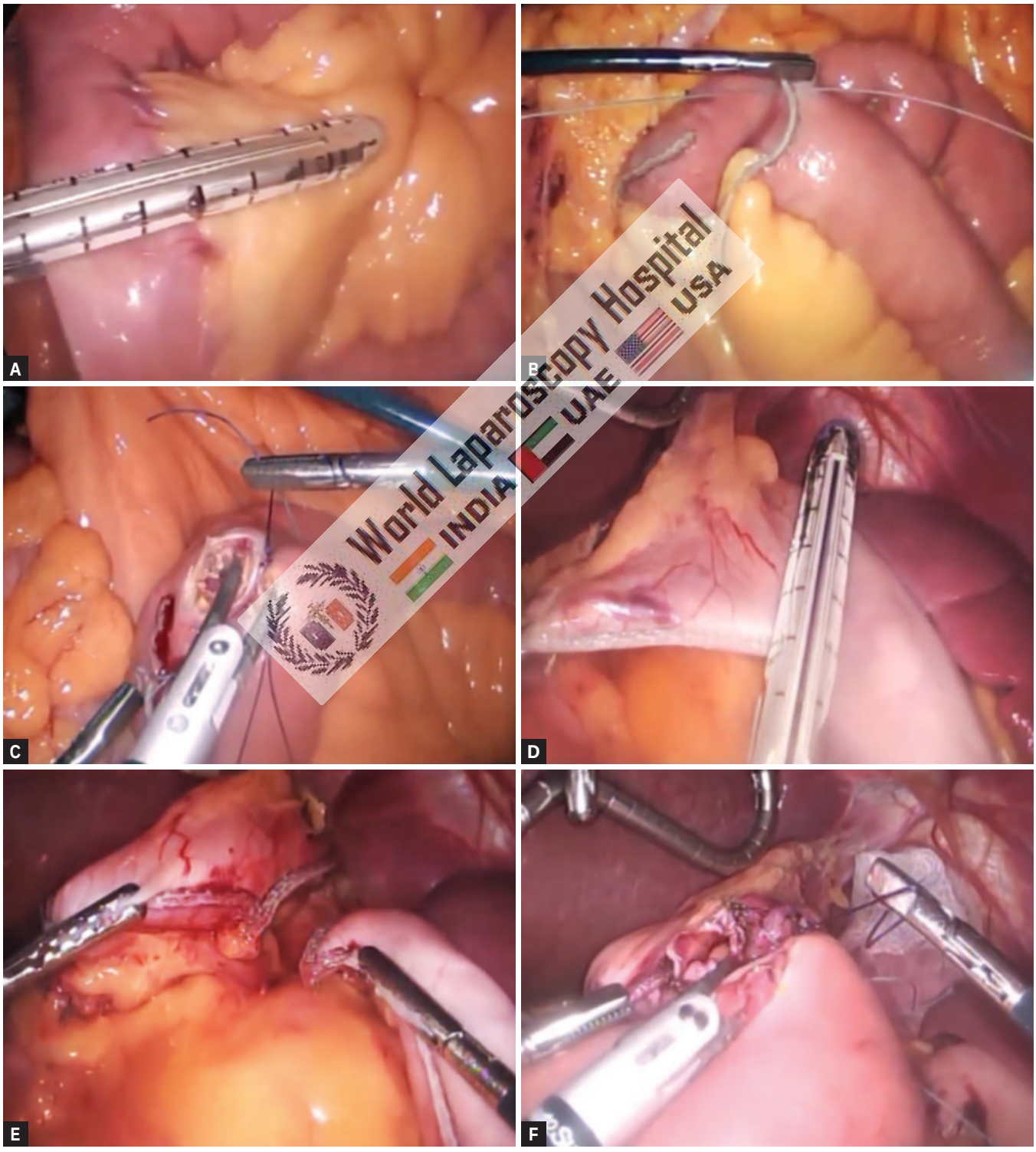
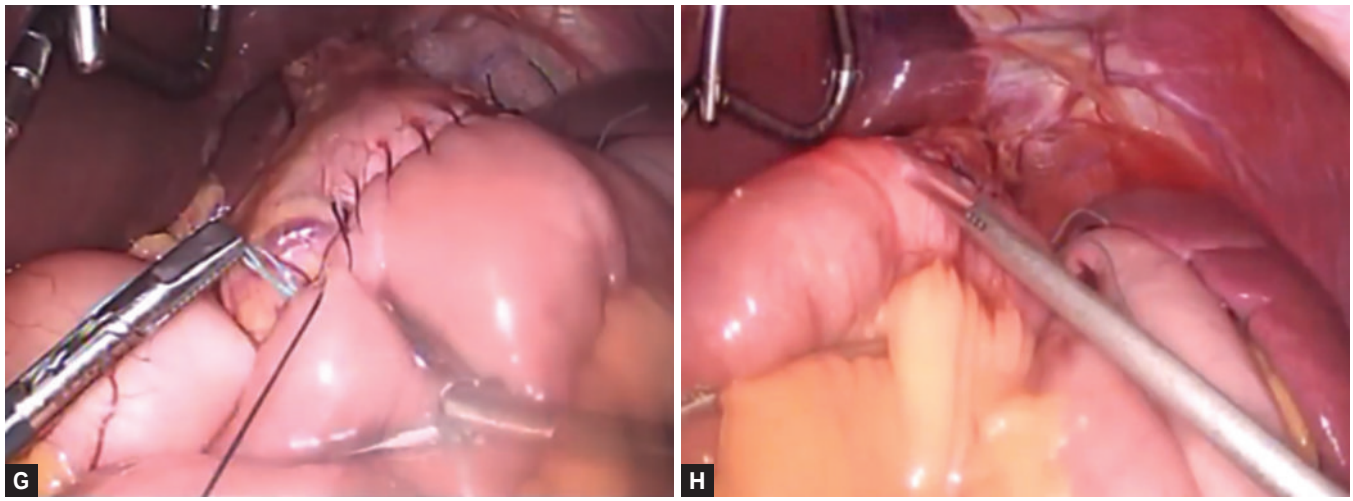
mobilize the angle of His by dividing the cardia's attachments to the overlying diaphragm. Complete mobilization of the fundus, especially a large one, will ensure that the gastric pouch is not created too large. The gastric vascular pedicle is also visualized, and blood supply to the gastric pouch should be preserved. A stapler is used to transect and staple the stomach first horizontally and then vertically to the angle of His. An endoscopic Maloney dilator is used to guide in creating the pouch. A 30-mL pouch has a dimension of approximately 3 × 3 × 3 cm. This can be measured using laparoscopic instruments, rulers placed in the abdomen, or a 30-mL balloon deployed in the proximal stomach as a guide.

When creating the pouch, some surgeons spare the perigastric neurovascular bundle containing vagal fibers, while others divide it routinely. In theory, sparing the vagal nerve fibers may allow better peristalsis and normal emptying



Figs. 18A to F: (A) Division of jejunum at 150 cm; (B) Transected jejunum; (C) Jejunojejunostomy; (D) Stomach pouch; (E) Complete pouch created; (F) Gastrojejunostomy started.



Figs. 18G and H: (G) Gastrojejunostomy near completion; and (H) Dye leak test.

of both the gastric remnant and the gallbladder. Normal gallbladder emptying may help prevent gallstone formation.

After entering the retrogastric space, the surgeon should fully mobilize the angle of His by dividing the cardia's attachments to the overlying diaphragm. The omentum and the transverse colon are retracted cranially, and the ligament of Treitz is thereby exposed. The small bowel is measured 50 cm distal to the ligament of Treitz and is stapled and transected along with mesentery creating a Roux limb. A jejunojejunal anastomosis is performed around 150 cm distally. The common enterotomy of the jejunojejunal anastomosis can be stapled or sewn by hand in a double-layered fashion. The mesenteric defect is then closed to prevent internal hernias.

The Roux limb is brought out in an antecolic and antegastric manner. A gastrojejunal anastomosis between the pouch and the Roux limb is performed in a double-layered fashion as well. A gastrotomy and an enterotomy are created anastomosed using a stapler. The gastrojejunal anastomosis is tested for air leak by submerging the anastomosis with irrigation fluid and inflating the orogastric tube with air. The anastomosis (gastrojejunal or jejunojejunal) can be either stapled or hand sewn. The basic tenets of LRYGB is to create a 30-mL gastric pouch from the proximal stomach, anastomose it to a Roux limb that is 75–150 cm in length, and connect the Roux limb to the biliopancreatic limb to create a common channel. It is generally accepted that the common channel (from the jejunojejunal anastomosis to the cecum) must be >200 cm to permit sufficient absorption of nutrients to prevent malnutrition.

Banded Gastric Bypass

Some laparoscopic surgeons have advocated placing a band (silastic ring) around the gastric pouch during the initial RYGB procedure. Although there have been no randomized trials comparing banded RYGB with standard RYGB, several prospective comparative studies have associated banded RYGB with less weight recidivism and more weight loss,

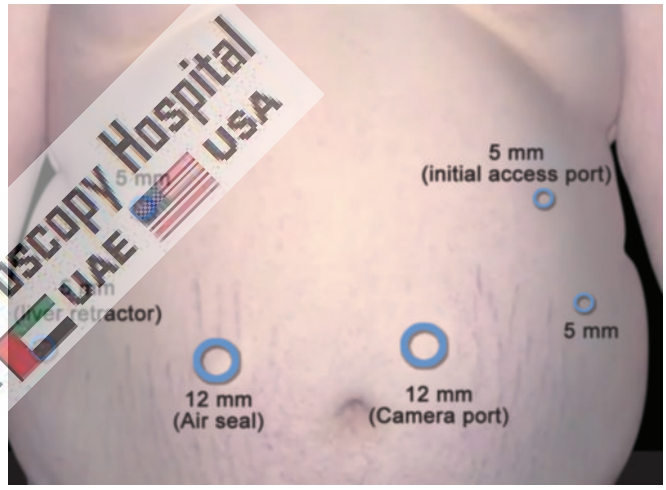


Fig. 19: Port position for Roux-en-Y gastric bypass (RYGB).

especially after the first year following bariatric surgery. Banded RYGB, however, was also associated with more mild complications such as dysphagia as well as vomiting and severe complications such as band eroding through the stomach wall. Thus, banded RYGB has not gained universal acceptance among bariatric surgeons.

Once bypass is successfully performed the pneumoperitoneum is evacuated actively. Trocar incisions that are >10 mm are closed at the fascia level. Because of the large amount of subcutaneous tissue in obese patients, a transfascial suturing device can be used. At this point and under laparoscopic guidance, long-acting local anesthesia is given to assist with postoperative pain control. A drain is only placed in revision operations and when there is concern about the integrity of the gastrojejunostomy anastomosis. The drain can potentially identify a leak and/or potentially help control a small leak.

Prophylaxis against venous thromboembolic events (VTEs) should continue after surgery. Specifically, patients should ambulate on the night of surgery, sequential compression devices (SCDs) should be worn, and chemoprophylaxis should be continued starting from the night after surgery. If a post-RYGB leak test is routine, it is

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typically performed on the first postoperative day before oral intake is started. If the test is negative for a leak or stenosis, oral intake is started with <30 mL of water every hour. If water is tolerated, the patient can be advanced to a clear liquid diet at breakfast on postoperative day 2 with the rate increased to 30 mL every 15 minutes. If the clear liquid diet is tolerated, the patient is advanced to a full liquid diet for lunch on postoperative day 2. A full liquid diet contains necessary protein supplements that will enable the patient to take in 60 g of protein daily.

Complications

Laparoscopic Roux-en-Y gastric bypass is a major elective surgical procedure. Risks include the following:

- Mortality may occur due to pulmonary embolism or gastrointestinal leak
- Wound infections
- Gastrojejunal stomal stricture
- Marginal ulcers (possibly more common with an antecolic approach than with a retrocolic approach)
- Internal hernia
- Roux limb ischemia
- Blowout of the stomach remnant
- Long-term deficiencies of micronutrients (e.g., vitamin B_{12}, folate, and iron)
- Bleeding from the staple line can become a serious problem. It gets controlled by means of clipping or monopolar cauterization.

CONCLUSION

As the prevalence of morbid obesity continues to escalate, the incidence of progressively complicated patients will rise. Clearly, a valid and effective strategy, beyond the current comprehensive evaluation measures, is needed for the optimal management of these patients.

Bariatric surgery is the most effective treatment for severe obesity, producing durable weight loss, improvement of comorbid conditions, and longer life. Patient selection algorithms should favor individual risk benefit considerations over traditional anthropometric and demographic limits. Bariatric care should be delivered within credentialed multidisciplinary systems. RYGB, AGB, and BPDDS are validated procedures that may be performed laparoscopically. Laparoscopic sleeve gastrectomy is also a promising procedure. Comparative data find that procedures with more dramatic clinical benefits carry greater risks, and those offering greater safety and flexibility are associated with less reliable efficacy.

Sleeve gastrectomy has been introduced and well accepted recently into the armamentarium of bariatric procedures. It was initially intended as a first step for poor-risk patients deemed too ill to undergo BPDDS or RYGB. Some of the patients lost significant weight and declined the proposed second stage, making the first stage with sleeve gastrectomy as a sole procedure. Sleeve gastrectomy has gained popularity with both bariatric surgeons and patients, mainly because of its relative operative simplicity and lower risk profile.

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