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REVIEW

Current applications of endoscopic suturing

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Abstract

Endoscopic suturing had previously been considered an experimental procedure only performed in a few centers and often by surgeons. Now, however, endoscopic suturing has evolved sufficiently to be easily implemented during procedures and is more commonly used by gastroenterologists. We have employed the Apollo OverStitch suturing device in a variety of ways including closure of perforations, closure of full thickness defects in the gastrointestinal wall created during endoscopic full thickness resection, closure of mucosotomies during peroral endoscopic myotomy, stent fixation, fistula closure, post endoscopic submucosal dissection, endoscopic mucosal resection and Natural Orifice Transluminal Endoscopic Surgery defect closures, post-bariatric surgery gastrojejunal anastomosis revision and primary sleeve gastroplasty.

Key words: Endoscopic suturing; Peroral endoscopic myotomy; Endoscopic full thickness resection; Natural Orifice Transluminal Endoscopic surgery; Endoscopic bariatric surgery; Endoscopic sleeve; Transoral outlet reduction

Core tip: The recent development of an endoscopic suturing platform, the only such device that is currently available in the United States, has led to a rapid expansion of endoscopic suturing applications ranging from simple procedures such as stent fixation to more complex ones such as closure of large full thickness defects and primary and revisional bariatric endoscopic surgery.

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INTRODUCTION

Endoscopic suturing devices have been used in a limited fashion for about a decade. Some of the known devices

Table 1 Advantages and disadvantages of different suturing patterns

Suturing Pattern	Pros	Cons
Interrupted/simple	Less tissue drag during tightening of the suture compared to a running suture No risk of suture crossing and entanglement as described for running suture Any failure during suturing would only involve the most recently placed interrupted suture rather than the entire suturing work up to that point as is the case with running sutures Suture failure after termination of the procedure would only involve a small segment of the closure without the risk of dehiscence of the entire closure that exists with running sutures	Approximation of the defect edges occurs as soon as the first interrupted suture is tightened and may limit good visualization and grasping of the edges of the nearly closed defect thus making placement of the subsequent interrupted sutures difficult or inaccurate Substantial increase in cost proportionate to the number of sutures used as discussed under running sutures
Figure of 8	Specialized suture used to close small circular defect in a circular fashion with equal circumferential anisotropic compression towards the center of the defect. Thus, it may be the optimal suturing pattern for fistula closure or oversewing an ulcer containing large vessel(s) at risk for bleeding	Technically more challenging than interrupted sutures Risk of suture entanglement Any suture failure (*e.g.*, erosion through tissue, breakage) would result in slack along the entire suture and result in dehiscence of the entire closure
Running	Allows clear visibilty of the defect edges until the suturing is completed Less expensive as it uses only one suture and cinch (in the United States, for the OverStitch platform, each additional suture+cinch adds approximately $100)	Tissue drag caused by the suture going through multiple bites of tissue requires gentle slow careful technique during tightening of the suture prior to cinching Avoiding entanglement of the long suture leading to the start of the suture line during placement of the transverse sutures across the defect requires careful technique and experience Any error such as accidental drop of the needle, fraying and breakage of the suture or device failure results in loss of the entire work up to that point with the need to start the closure from the beginning Similarly, any suture failure after termination of the procedure (*e.g.*, suture eroding through tissue prematurely or breaking) would result in failure of the entire closure

include the Bard Endocinch (MA-US), T-bars (Wilson Cook-NC-US), NDO Plicator (MA-US-no longer available) and GERDX TM (G Surg Seeon, Germany)[1-3]. There are reports on limited preliminary data from experimental or limited-release devices[4-7]. The OverStitch endoscopic suturing system (Apollo Endosurgery, Austin, Texas) evolved from the previously developed Eagle Claw device[8] and is currently the only widely available suturing device, and only Food and Drug Administration approved commercially available device in the United States[9]. Since the other devices briefly mentioned are not available either because they have been withdrawn or because they are at early experimental stages of development, this review will focus on the rapidly emerging widespread applications of suturing enabled by the Overstitch platform. Figure 1 illustrates the use of the endoscopic suturing device. It is a disposable, single-use device that is mounted onto a double-channel gastroscope and it can enable interrupted or continuous suture application[10]. Table 1 and Figure 2 demonstrates the advantages and disadvantages of different suturing patterns. Full thickness suturing is possible for tissue approximation or plication in the gastrointestinal tract *via* use of a tissue anchor, curved suturing arm and a cinch. The current version was approved in 2011 and early use included oversewing a recurrent marginal ulceration, a fundic ulcer, stoma reduction after gastric bypass surgery, and closure of a post-operative rectovaginal fistula[11,12].

PERFORATION CLOSURE

Closure of iatrogenic inadvertent endoscopic perforations not associated with endoscopic submucosal dissection (ESD)/endoscopic mucosal resection (EMR) is largely confined to the animal model. Recently, three patients with iatrogenic esophageal perforation had apparent successful repair with the OverStitch device[13]. The OverStitch device was used to successfully close a full thickness gastric defect in the pig in a two week survival study[14]. An interesting study in humans assessed the depth of endoscopic suture placement in the colon. Test sutures were placed intraoperatively in patients undergoing partial colectomy in the portion of the colon to be resected. Examination of the resected colon demonstrated successful placement of full thickness transmural sutures[15]. Figure 3 demonstrates a case in which we performed successful closure of a very large perforation that occurred during a colonoscopy performed to evaluate Crohn's disease in a 35-year-old patient. The patient had a second perforation at the cecum that was not appreciated by the referring endoscopist and was discovered during surgical exploration performed due to persistent abdominal pain, fever and leukocytosis 24 h after the index colonoscopy. The surgeon discovered a second perforation in the cecum, which he successfully repaired surgically and confirmed successful endoscopic closure of the splenic perforation not requiring surgical intervention. He noted that the endoscopic sutures placed using the OverStitch

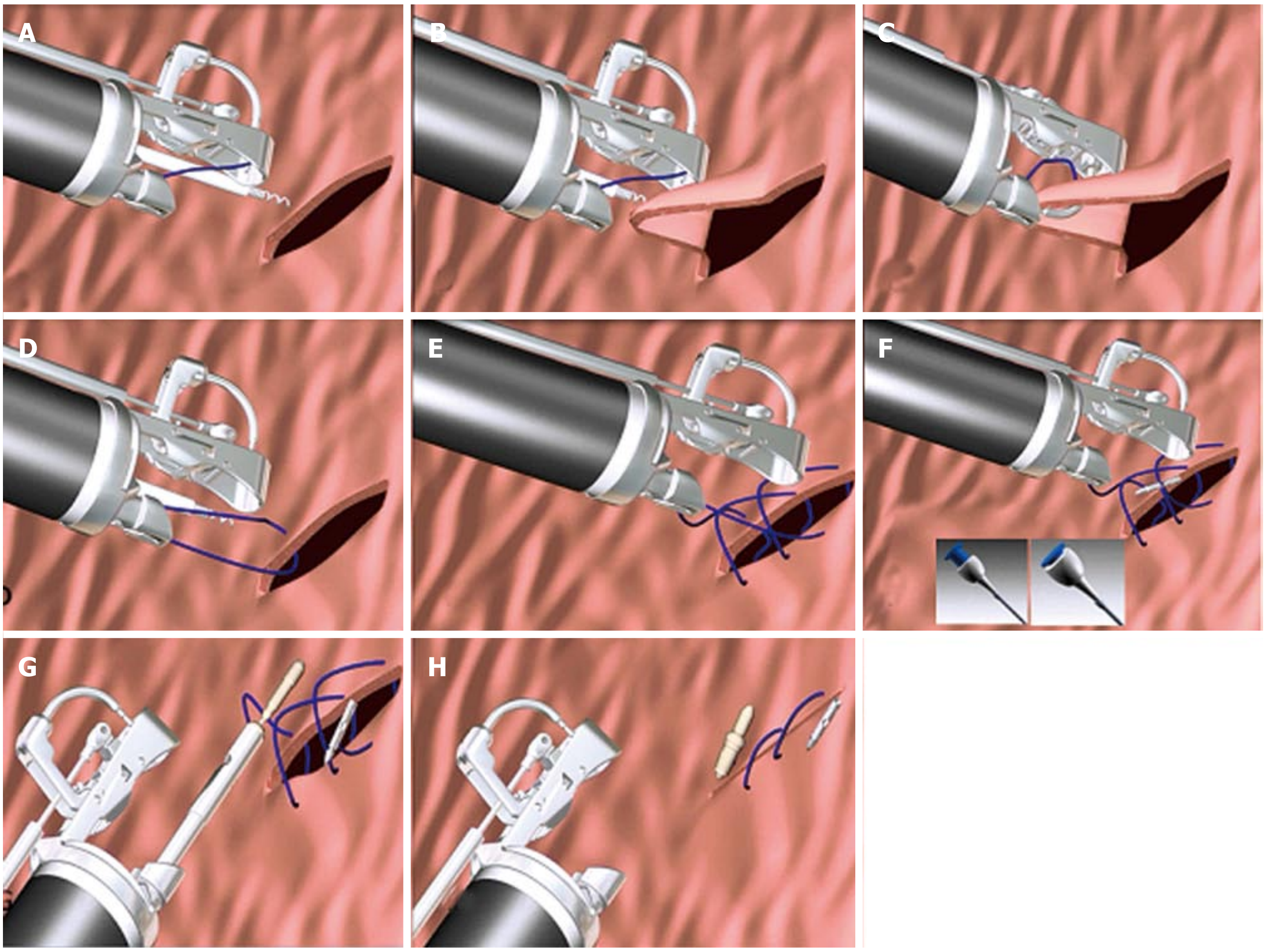

Figure 1 Steps involved in placing endoscopic sutures (Courtesy Apollo endosurgery Austin Texas). A: Grasp the tissue using the tissue helix; B: Retract the tissue into the needle path; C: Drive the needle through the tissue; D: Open the arm and release the tissue; E: Repeat stitched as desired; F: Press the blue button to release the needle (T-fastener); G: Tighten and cinch; H: Repeat as desired.

device had traversed the entire colonic wall, which is in accordance with the results of the colectomy study described above.

STENT FIXATION

Covered self-expanding metal stents have been employed in the treatment of perforations, strictures and fistulae/leaks. The covered feature allows subsequent removal but also predisposes to stent migration. Previously, endoscopic clips have been deployed to prevent stent migration with doubtful efficacy, but there is now an increasing experience with endoscopic suturing for this purpose. A porcine model study comparing clip *vs* suture fixation of esophageal stents favored suturing in terms of migration tendency and force needed to disrupt the stent fixation[16]. A study of esophageal fully covered self-expanding metal stents (FCSEMs) for leaks and strictures compared stenting with and without suturing, and the sutured stents migrated much less.(55% *vs* 35%)[17]. A case series featuring a variety of upper gastrointestinal issues (perforation, leaks, fistulae) necessitating stents had a similar migration of sutured stents (7 of 21 sutured SEM's)[18]. FCSEMs may have a role in treating post-bariatric leak/fistulae and our center and others have employed suturing for stent fixation and occasionally for primary defect closure[19].

FISTULA/LEAK CLOSURE

There is accruing experience with endoscopic suturing use in the treatment of gastrointestinal fistula/leak closure. These can be acute or chronic in nature and often result as complications from surgical anastomoses and stapled tissue divisions such as those of bariatric surgery (especially sleeve gastroplasty). As mentioned, suturing is often used in conjunction with other therapies including stents and glue[20]. The StomaphyX suturing system was used to treat gastric leaks in two bariatric patients[17]. The OverStitch device achieved closure in 3 of 7 patients with gastrogastric fistulae after gastric bypass[8]. This device has been used for a variety of fistulae[21,22]. One study demonstrated the superiority of the full-thickness OverStitch device compared to a superficial suction-based suturing system in the closure of gastrogastric fistulae[23]. The OverStitch device was used to close a persistent esophagopleural fistula[24].

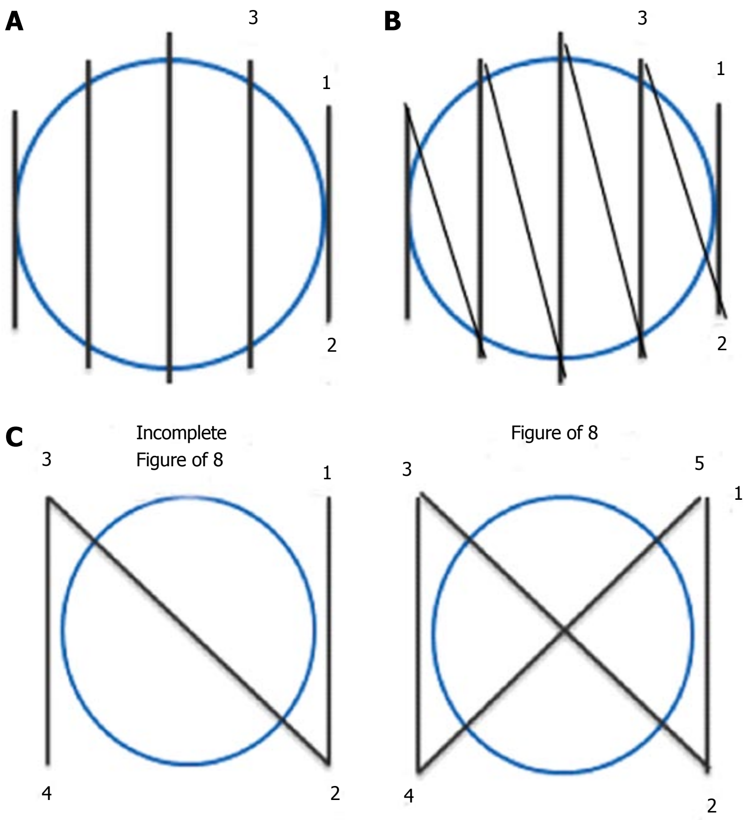

Figure 2 Types of suture pattern. A: Interrupted suture; B: Running suture; C: Figure of 8 suture.

Patients who are fortunate enough to have removal of their feeding tube after gastrostomy usually have wound closure, but occasionally there is a persistent gastrocutaneous fistula. There are a variety of closure techniques and endoscopic suturing may be employed as the sole intervention or in combination with other therapies (glue, clips, percutaneous suturing, *etc.*) Successful closure with the OverStitch device has been described[25,26].

ESD-EMR CLOSURE

There has been a veritable explosion of publications regarding endosurgical resection; predominantly ESD and related offshoots such as submucosal tunnel endoscopic resection (STER) and endoscopic full-thickness resection (EFTR). Endoscopic suturing has ensconced itself as an important if not indispensable component of advanced endoscopic resection. A porcine model study suggested quicker and more complete closure of ESD defects with sutures *vs* clips[27]. However, the efficacy of closure was somewhat subjective (visualization) and this comparison will need to be made in humans. The same group noted in another porcine study that effective suture closure after ESD can be done in a variety of ways and combined with clips[28]. In one study of 12 patients having ESD (4 gastric 8 colon), closure was made successfully with the OverStitch device and the patients were discharged home on the day of the procedure[29].

ESD has evolved such that large submucosal lesions and those with significant extraluminal extension can be resected with the technique known as EFTR. EFTR requires closure of potentially large defects (essentially intentional perforations) and endoscopic suturing is invaluable for this purpose. A porcine two-week survival study demonstrated the feasibility of suturing to close a full-thickness gastric defect (average size of gastric specimen 11 mm) without site ulceration[30]. Three patients with endoscopic perforation avoided surgery *via* OverStitch closure of the defect (all > 2 cm) in conjunction with catheter decompression of pneumoperitoneum, NGT insertion and IV antibiotics[31]. We employ the device after EFTR for gastric stromal tumors[32]. Without availability of the robust closure achievable with endoscopic suturing, closure of EFTR defects with endoscopic clips often requires specialized adjunctive techniques to achieve secure closure of these large perforations. We have demonstrated use of an omental patch to achieve secure closure with endoscopic clips of a large gastric EFTR one of our early cases prior to OverStitch availability[33]. In Asia, where OverStitch is not yet available, EFTR operators have largely converted to closures of EFTR defects with the endoloop and clips technique further emphasizing the inadequacy of clips for secure closure of these relatively large perforations[33-36]. Figure 4 demonstrates a few cases of EFTR defect closure with OverStitch. Kantsevoy

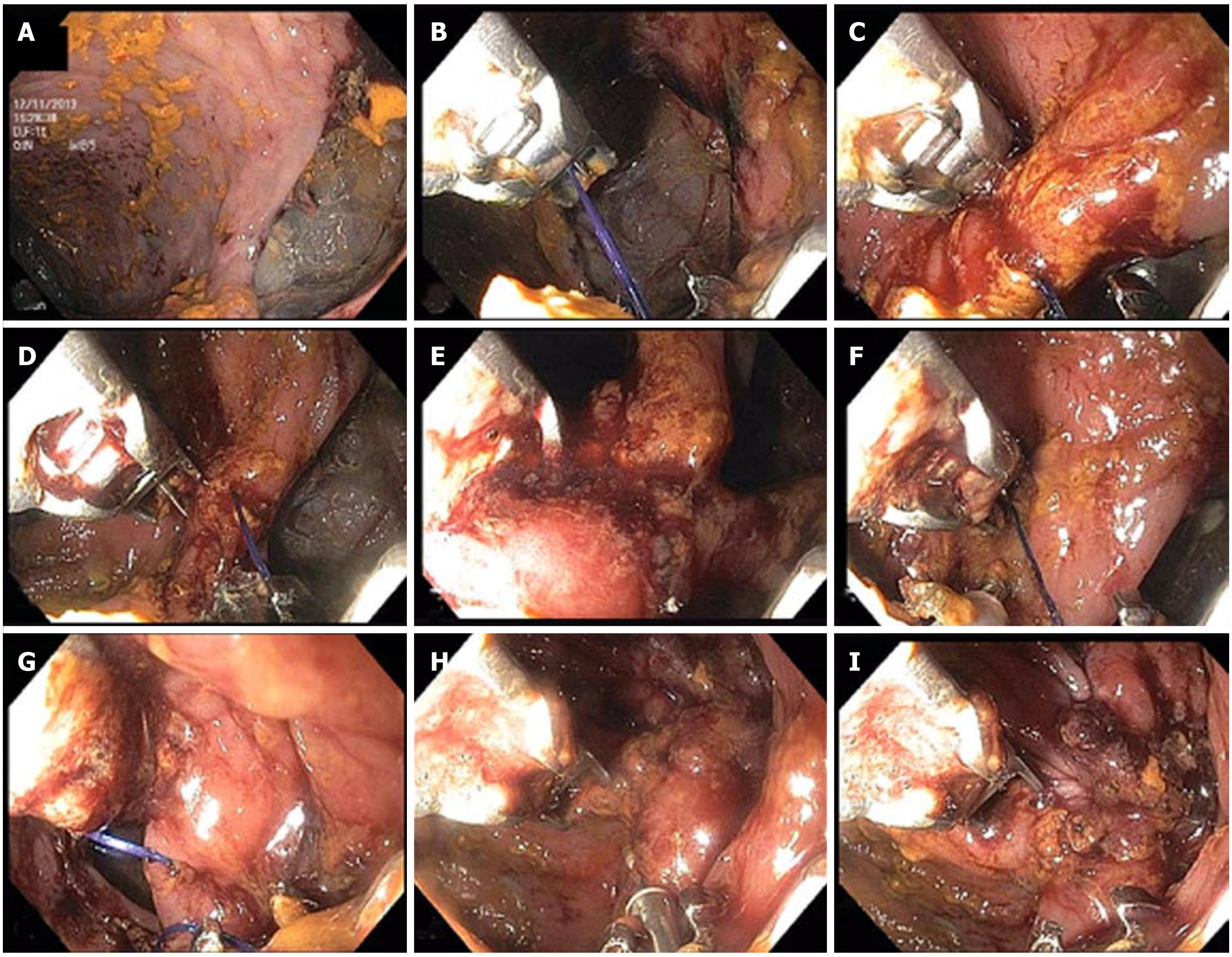

Figure 3 Closure of colonic perforation with endoscopic suturing device. A: Initial tissue bites forming a running suture (B-E) starting at the inferior edge of the perforation and progressing towards the center; F: Tissue helix retractor is used to ensure deep tissue bite along the distal, superior edge of the perforation; G: Suturing has reached the superior edge of the perforation the edges of which are now being pulled together by the sutures; H: After tightening of the sutures closure of the perforation has been achieved and the cinch device is seen being deployed at the 6 o' clock position of the image; I: Immediately after cinch deployment, the complete closure of the perforation is seen. Gastrograffin was injected through the scope that confirmed absence of leak (not shown).

had successful OverStitch closure of two patients with one cm colon perforations after more extensive experience with closing two centimeter colon defects in pigs[36].

ESD is challenging for lesions in difficult locations where the endoscope cannot achieve a path tangential to the lesion such as the gastric lesser curvature. For such lesions, ESD can be facilitated by countertraction accomplished *via* use of the OverStitch device to create a "suture-pulley"[37].

A natural extension of EFTR is Natural Orifice Transluminal endoscopic surgery (NOTES) where the endoscopic intervention is done within the peritoneum and the trans-gastric entry site reliably closed. A suturing device was demonstrated to attain durable closure of gastric defects ranging to 18 mm in an animal model[38]. Closure success is similar for both continuous and interrupted suture application[39]. The OverStitch device was used in conjunction with a robotic device to remove a five cm diameter area of the gastric wall in two pigs, solely *via* endoscopic means[40].

PERORAL ENDOSCOPIC MYOTOMY MUCOSOTOMY CLOSURE

Per-oral endoscopic myotomy is a successful clinical application of NOTES. Endoscopic suturing has been utilized for closure of inadvertent mucosotomies and perforations during peroral endoscopic myotomy (POEM)[38-40]. Endoscopic suturing has also been shown to be useful in closing the mucosal entry point after the myotomy is performed (Figure 5)[41-43]. This is now our customary practice in POEM. During the first three years of our POEM experience (2009-2012), prior to the availability of endoscopic suturing, we performed closure of the tunnel entry site with clips. However, when endoscopic suturing with the OverStitch device became available, we converted to closure using suturing hoping for a more predictable and secure closure. We performed a retrospective comparison of clip closure *vs* OverStitch closure in our series of POEM procedures. We compared our initial 62 POEMs closed with a variety of endoscopic clips commonly available

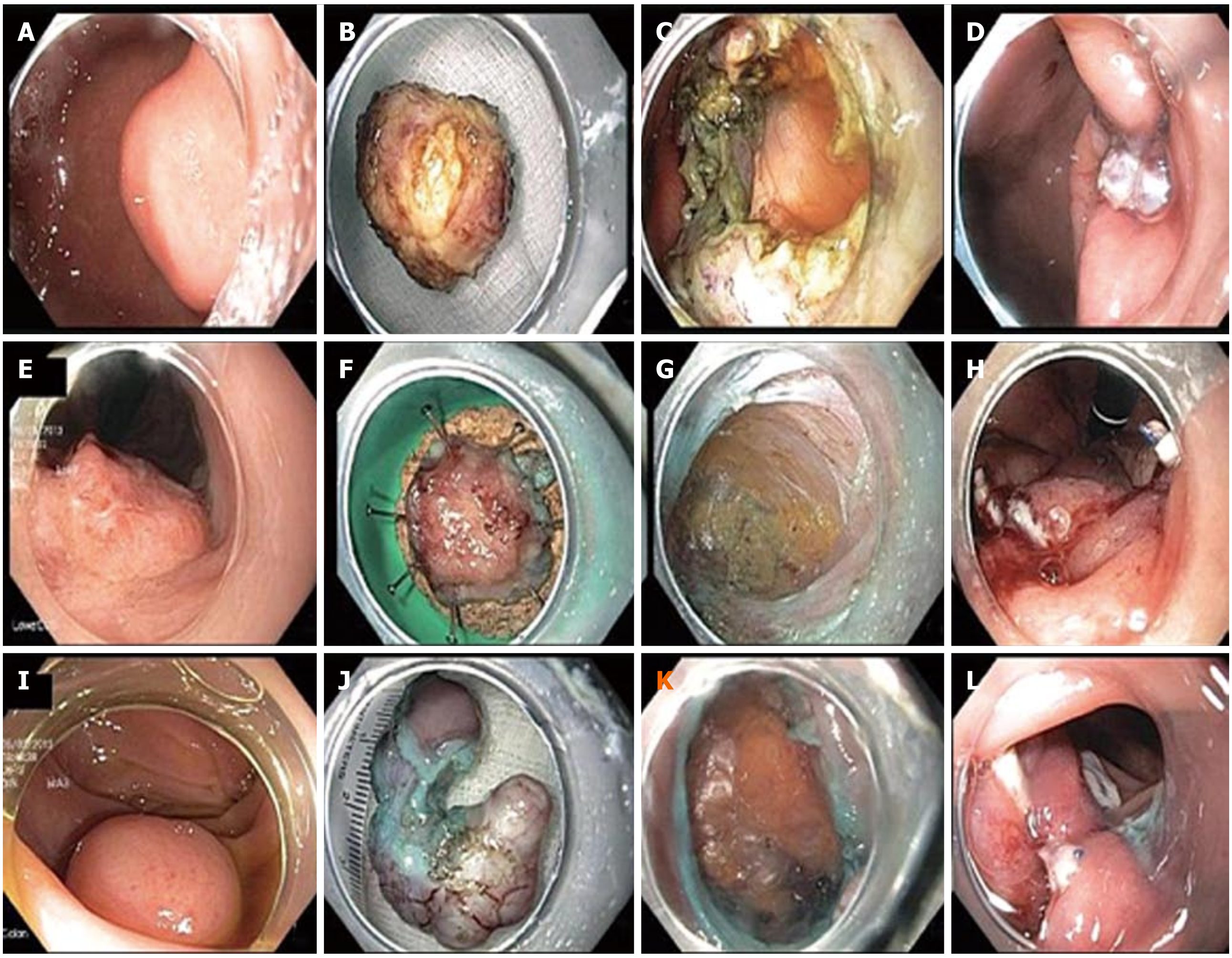

Figure 4 Closure of intentional full thickness perforations after subepithelial tumor removals with endoscopic suturing device. A: Endoscopic image of gastric muscularis propria based subepithelial tumor; B: 2.5 cm schwannoma; C: Resection crater revealing transmural fat; D: Endoscopic sutured closure of defect; E: Endoscopic image of rectal carcinoma superficially extending to muscularis propria; F: 1.3 cm rectal low-grade adenocarcinoma; G: Resection crater demonstrating perirectal fat, circular muscle layer and longitudinal muscle layers; H: Endoscopic sutured closure of defect; I: Endoscopic image of sigmoid muscularis propria based subepithelial tumor; J: 3cm leiomyosarcoma; K: Resection crater demonstrating peritoneal fat; L: Endoscopic sutured closure of defect.

in the United States with the subsequent 61 POEMS closed with endoscopic suturing (Table 2). We did not detect a significant difference in length of stay (1.9 *vs* 1.7 d) or complications (no significant complications in either group). There was one conversion to clips in the suturing group due to a superficial hypopharyngeal mucosal tear caused while attempting to insert the endoscopic suturing device in a patient with very narrow hypopharynx. Closure time and cost per closure was assessed for the most recent 25 cases where clips were used and the most recent 25 cases where suturing was used (after a plateau in the learning curve had been achieved by both techniques) and were found to be similar: mean closure time 8.8 (6-15) *vs* 10.1 (5-16) min and mean cost per closure $916 ($454-$2160) and $818 respectively, (cost based on the cost of these devices to our institution). We should note here, however, that endoscopic suturing device cost varies geographically with relatively small differences within the United States but significantly higher prices in Europe due to distribution costs there.

POST-BARIATRIC SURGERY ENDOSCOPIC STOMA REDUCTION

It is commonplace for patients with Roux-en-Y gastric biopsy to have dilation of both the gastric pouch and the gastrojejunal stoma. Endoscopic suturing lends itself well in reducing the gastric pouch and the stomal diameter, though most work to date centers on the latter. Endoscopic treatment of this condition avoids the need for revisional surgery which is technically challenging and carries significant morbidity. Twenty-five patients with dilated GJ anastomosis (mean 26 mm) had 100% technical success using the OverStitch device with marked reduction of the stoma diameter (mean 6 mm) and mean weight loss of 11 kg[44]. These results are concordant with the results of a multicenter randomized trial[45]. Weight loss was shown to be

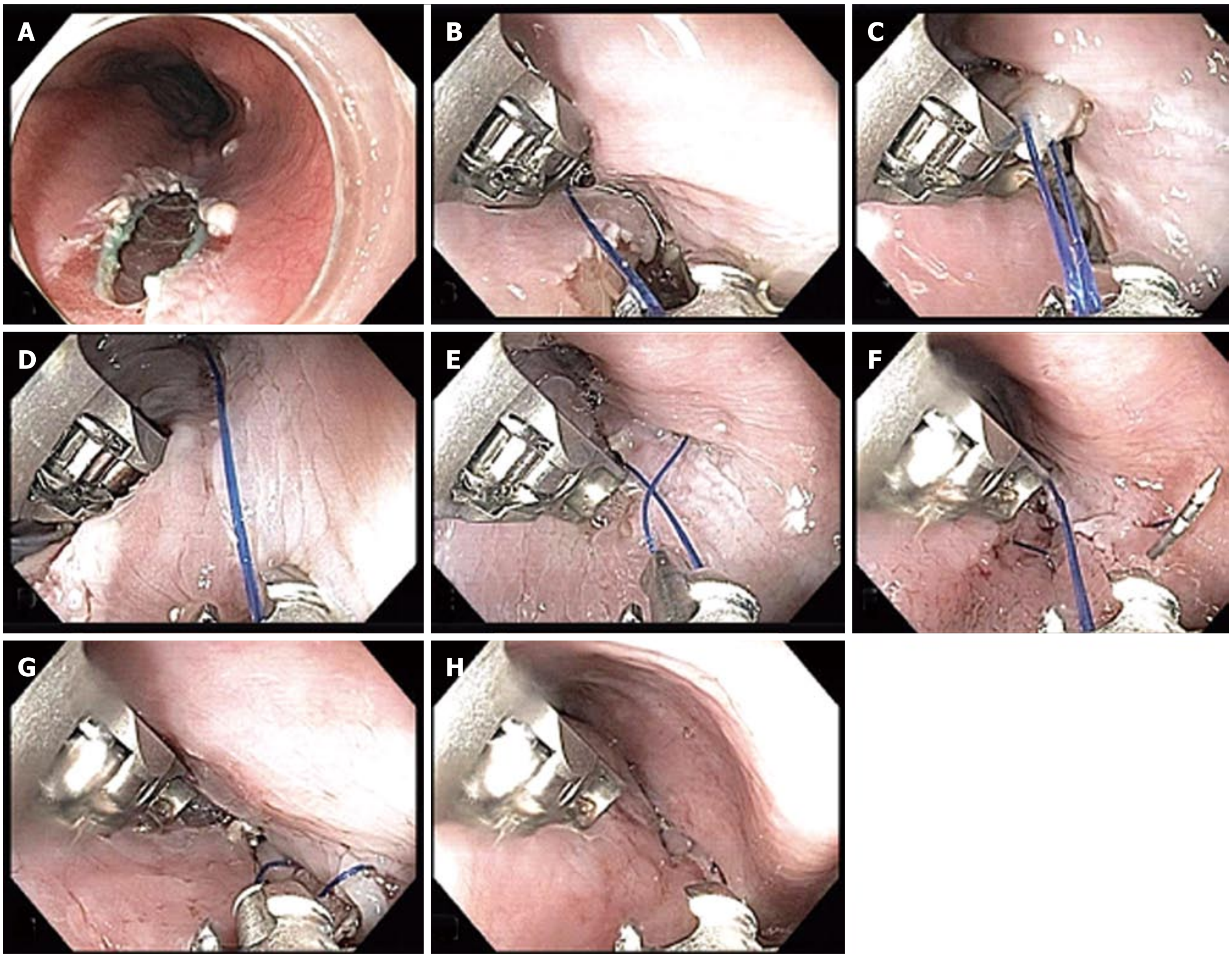

Figure 5 Closure of per oral endoscopic myotomy tunnel orifice with endoscopic suturing device. A: Closure of peroral endoscopic myotomy (POEM) tunnel orifice in a posterior POEM with the tunnel opening at the 5 o' clock position; B, C: We use a single running suture for closure starting at the distal, left margin of the defect as shown here. We attempt to penetrate mucosa and submucosa but not muscularis propria to avoid ischemia and pain or even possible injury to mediastinal structures; D: We proceed with suture placement through the right margin of the defect which is accomplished by torquing the endoscope as shown here; E: It is important to avoid having the running suture (here held by the needle onto the needle transfer catheter prior to loading it onto the needle driver) cross over the long suture leading to the start of the suture line which would then result in inability to properly deploy the cinch to the start or the suture line; F: The single running suture has been completed and has approximated the edges of the defect and the needle has been dropped in order to serve as a T-tag securing the suture at the proximal end of the defect; G, H: The cinch catheter is inserted over the long suture leading to the start of the running suture in the distal end of the defect, the suture is tightened and the cinch is deployed securing the suture at the start of the suture line in the distal end of the defect.

Table 2 Peroral endoscopic myotomy mucosal tunnel closure comparing endoclips and overstitch

	Endoclip	Overstitch
Total number of patients	62 patients	61 patients
Comparison of 25 consecutive closures		
Closure technique (mean number)	8 clips (5-14)	1 suture, 1 cinch, 1 device
Closure duration (mean minutes, $P = 0.1$)	8.8 min (6-15)	10.1 min (5-16)
Cost analysis (mean dollars, $P = 0.2$)	$915.84 ($453.81-$2160)	$818
Hospital Stay (mean days, $P = 0.1$)	1.9 d	1.7 d
Complications	No leaks Increased length of stay (4 d) in one patient with thick mucosal edges approximated with clips and endoloop	No leaks One aborted overstitch closure due to a mucosal tear in the hypopharynx during Overstitch insertion. Had mild sore throat for 4 d

inversely proportionate to stoma diameter[46]. Transoral outlet reduction (TORe) is most effective with a full thickness suturing device as compared to a superficial suturing device, even with similar stoma apertures[47].

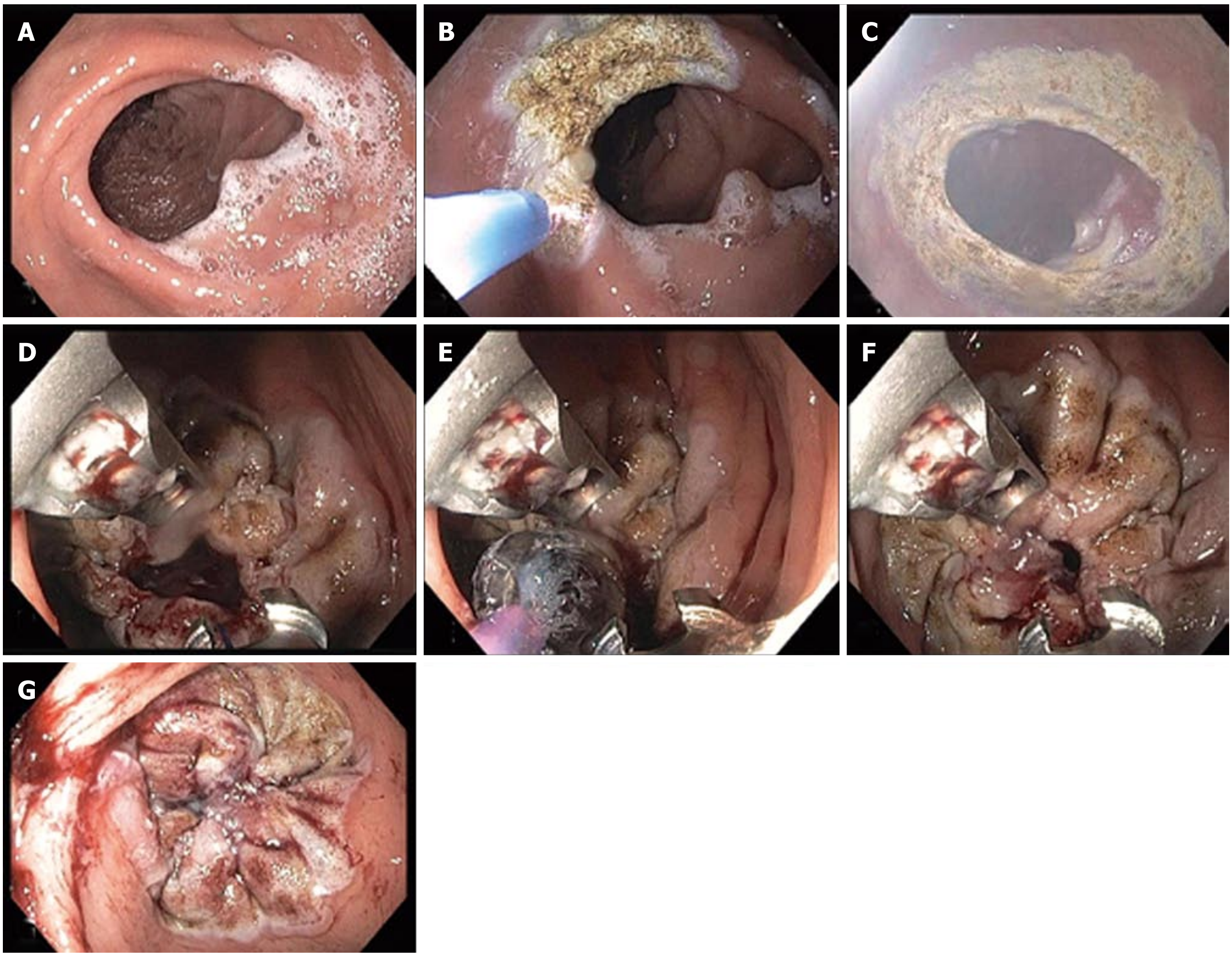

Figure 6 Endoscopic revision of gastrojejunal anastomosis in gastric bypass patient. A: An enlarged gastrojejunal anastomosis is noted; B and C: Argon plasma coagulation was used around the stoma to ablate the mucosa and facilitate tissue fusion during the healing process; D: Two sutures were used obtaining circumferential tissue bites to achieve a purse-like closure of the stoma; E: A 10 mm controlled radial expansion balloon was dilated and placed through the stoma opening via the second channel of the double-channel therapeutic endoscope and then the sutures were tightened so that the final stoma diameter was approximately 10 mm in size; F and G: The balloon was then deflated and removed. A markedly diminished stoma orifice is seen at the end of the procedure.

Preliminary TORe experience at our center in 10 patients is also favorable with mean weight loss of 19 lbs at mean follow-up of 34 wk. Figure 6 demonstrates TORe *via* endoscopic suturing in a 39-year-old woman who had roux en y gastric bypass 14 years ago. Longer term data concerning TORe is being accumulated.

PRIMARY ENDOSCOPIC OBESITY SURGERY

It appears that the restrictive anatomy after surgical sleeve gastroplasty can be duplicated by endoscopic plication of the gastric wall *via* endoscopic suturing. Two groups utilizing an older endoscopic suturing platform (Endocinch) performed gastric restriction in humans with excellent technical success rates and encouraging short term efficacy. Fogel utilized an early generation device of the Endocinch platform to reduce the gastric volume in 64 obese subjects from South America with no reported complications and an impressive 58% excess weight loss at 12 mo that has not been replicated however by other groups[48]. More recently another group used a second generation of the same device used by Fogel to reduce the gastric volume in 18 obese patients from the United States with no complications and a 27% (SD 22%) excess weight loss at 12 mo[49]. Preliminary encouraging data are emerging on endoscopic sleeve gastroplasty performed with the OverStitch device[50]. Under the current protocol followed at the Mayo Clinic, Brigham and Women's, our center and other centers investigating this technique in the United States, sutures are placed approximating the anterior wall, greater curvature and posterior wall of the stomach extending from the antrum to the fundus to achieve restriction similar to that of a surgical sleeve gastroplasty (Figures 7 and 8). The impressive restriction can be seen on the endoscopic images from a patient that underwent the procedure at our institution (Figure 9). Preliminary data indicate no significant morbidity with short-term weight loss similar

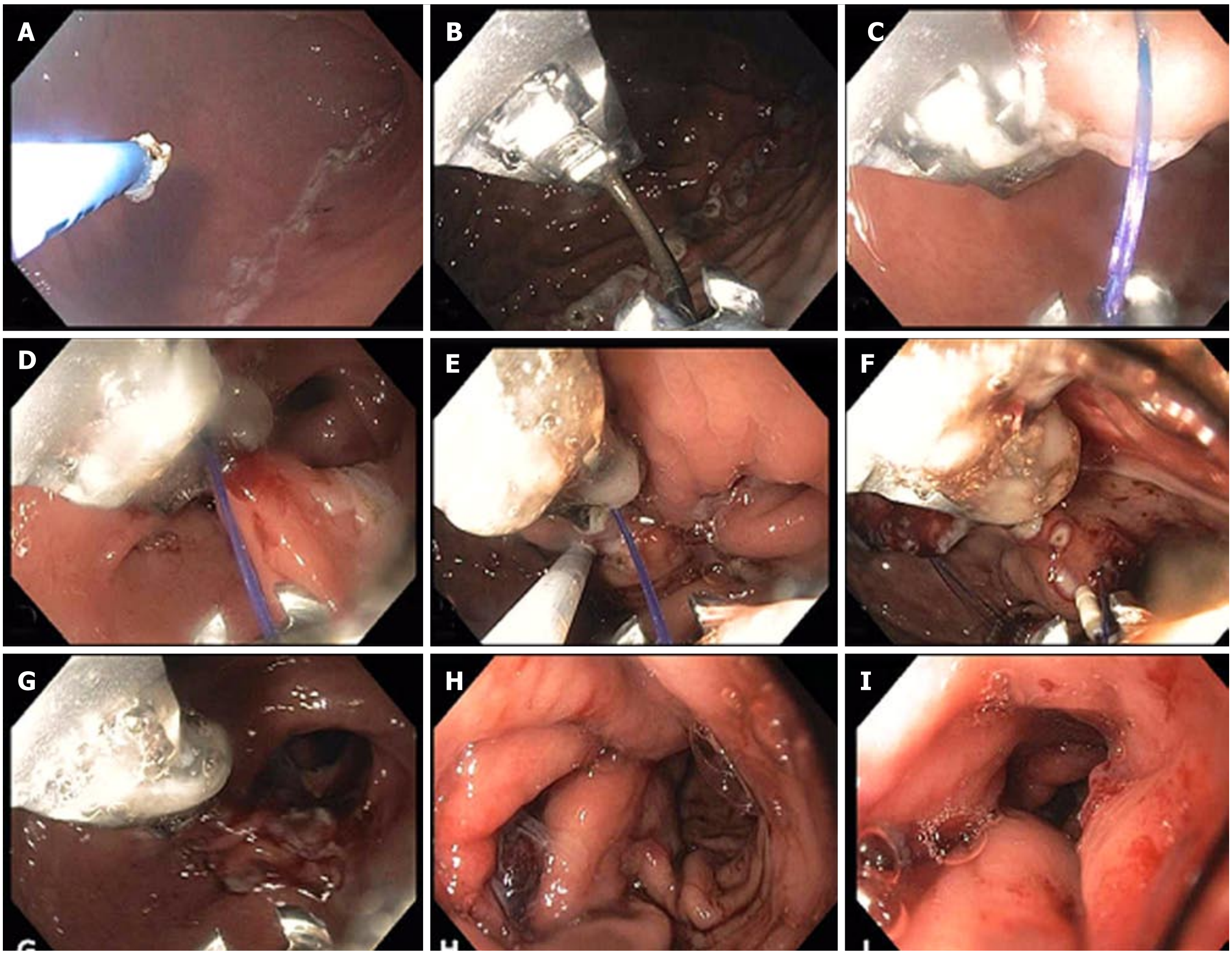

Figure 7 Endoscopic sleeve gastroplasty. A: Initially argon plasma coagulation is used at a setting of 0.8 L 30 W, forced coagulation to mark the anterior and posterior extents of a corridor that will contain the outer sutures to be placed (as shown in the attached schematic (bites along the anterior wall, greater curvature and posterior wall); B: The suturing device is inserted and placement of the first running outer suture is begun as shown in figures C and D reducing the lumen along the greater curvature of the antrum; E: The helical tissue retractor is used through the second channel of the endoscope as seen in figure E to achieve deep, transmural if possible placement of the sutures and to facilitate suture placement in difficult locations; F: Insertion of the cinch device shown at the 6 o'clock position. The running suture can be seen at 7 o' clock prior to tightening; G: After tightening and cinching of the suture the lumen reduction forming the beginning of the endoscopic sleeve can be seen; H: Completion of the outer sutures showing marked lumen reduction; I: Completion of the inner row of sutures with final appearance of the endoscopic sleeve gastroplasty at the end of the procedure. A tight 3-4 cm tunnel is seen which extends from just distal to the fundus to approximately 3 cm proximal to the pylorus.

to that reported for laparoscopic band (Christopher Gostout personal communication). Thus this procedure may find a niche along with other minimally invasive interventions, such as intragastric balloons, in the treatment of patients with moderate obesity (BMI 30-35) for whom traditional bariatric surgery may represent overtreatment. We have entered an era of endoscopic management of obesity, and the huge economic burden associated with this entity will drive further studies and technological development.

WINTHROP ENDOSCOPIC SUTURING EXPERIENCE

At our institution, we employed the Overstitch endoscopic suturing device extensively and in a variety of ways[51] (Table 3). One hundred and seventy-seven procedures incorporated endoscopic suturing. Since this represents one of the 2 or 3 largest volume series worldwide and includes novel applications such as a large number of POEM tunnel closures, we briefly review these data that illustrate the broad range of applications of endoscopic suturing. We typically do not require an overtube for device insertion. The closure success was remarkable with all patients having suturing for POEM, STER, EFTR, ESD, accidental perforations and leak closures having complete closure. Of these 149 closure procedures, there were no episodes of leakage or wound dehiscence; only 2 minor adverse events including one patient with dysphagia due to stricture at site of tunnel closure requiring a single balloon dilation with total resolution of dysphagia and one superficial mucosal tear in the hypopharynx during OverStitch insertion, which was clinically insignificant except for transient sore throat. Table 2 presents comparative data on POEM closure with clips *vs* suturing. We used clips in the

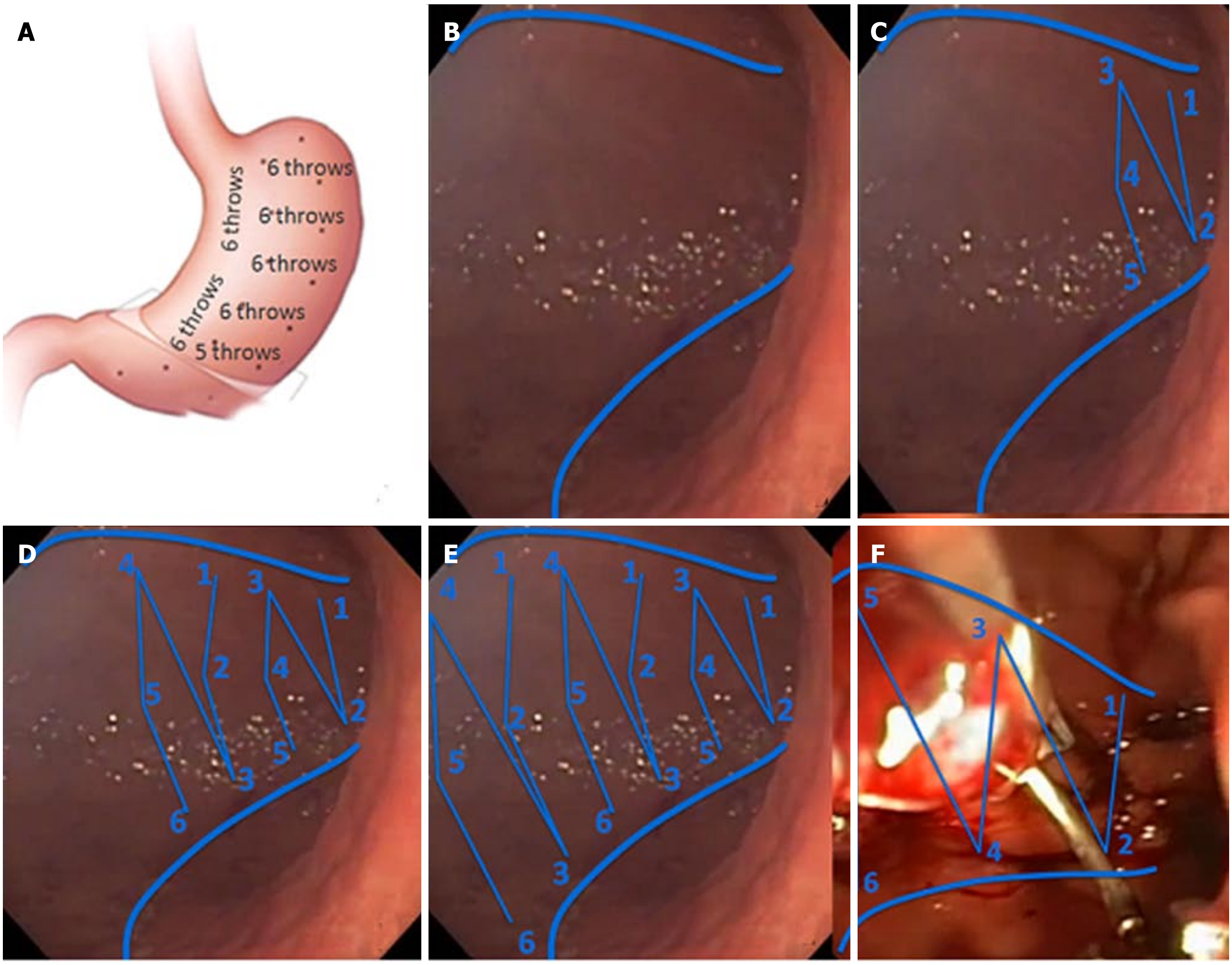

Figure 8 Suture placement needed to achieve endoscopic sleeve gastroplasty. A: Schematic of the configuration of sutures used to achieve endoscopic sleeve gastroplasty. Initially 5 to 8 plication sutures are placed along the greater curvature in a distal to proximal direction, followed by placement of an inner row of 2 to 3 short anterior/posterior "retention sutures" that take some of the tension off the plication sutures; B: Using APC ablation two lines are made along the anterior and posterior wall that mark the outer borders of the plication sutures; C: The first plication suture is placed within 3 cm of the pylorus where due to the narrowing of the lumen results in a modified 5-point suture with the first bites placed on the anterior and posterior wall of the antrum while the 3rd, 4th and 5th bites are placed on the anterior wall, greater curvature and posterior wall; D, E: Subsequent plication sutures all have the same 6 point configuration (anterior wall, greater curvature, posterior wall, anterior wall, greater curvature, posterior wall); F: The inner row of retention sutures consists of sutures of sutures between the anterior and posterior wall a shown (Courtesy Apollo Endosurgery Austin Texas).

Table 3 Winthrop University Hospital endoscopic suturing registry

Indication	Number of Cases	Comment
POEM submucosal tunnel entry closures	100	100% successful closure
EFTR of subepithelial tumor intentional defect closures	24	Mean closure time: POEM/STER -10 min for a mean 2 cm defect
STER submucosal tunnel entry closures	6	EFTR/ESD -13 min for mean 3 cm defect
ESD	22	Perforations/leaks-18 min for mean 1.8 cm defect
Accidental perforation	16	Complications: No episodes of leakage or wound dehiscence 2 minor adverse events
Transoral outlet reduction	7	At mean 34 wk follow-up, mean 19.1 lb weight loss (2-34 lbs)
Primary sleeve gastroplasty	1	At 32 wk follow-up pt lost 40 lbs
Ulcer oversew	1	Required surgical intervention 2 wk post procedure due to lack of response
Leak/fistulae closure	14	2 leaks and 12 fistulas (9 gastric sleeves, 2 roux en y gastric bypass, 1 post- PEG tube removal. 2/2 (100%) leaks and 10/12 (83%) fistulas were successfully closed
Stent anchoring	10	Mean time was 8 min. No episodes of stent migration at mean 8 wk

POEM: Per oral endoscopic myotomy; EFTR: Endoscopic full thickness resection; STER: Submucosal tunnel endoscopic resection; ESD: Endoscopic submucosal dissection.

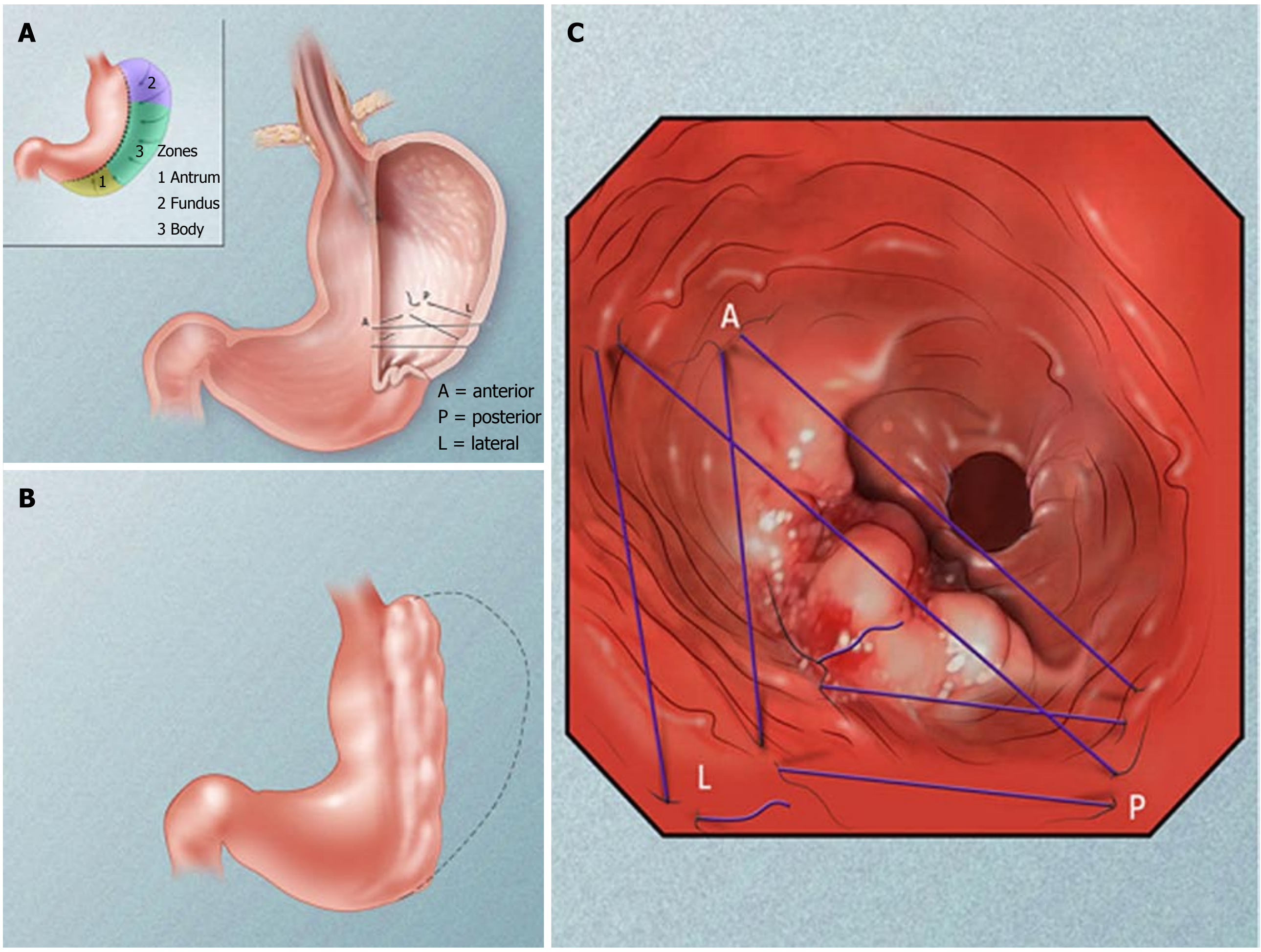

Figure 9 Illustration of the overall sleeve gastroplasty configuration achieved by placement of sutures as to achieve plication of the greater curvature of the stomach. A: Endoscopic gastroplication pattern; B: Plicated stomach; C: Schematic of suture pattern (Courtesy Apollo Endosurgery Austin Texas).

first half of our experience but switched to endoscopic suturing over the past two years. We selected the most recent 25 consecutive cases in each group (to eliminate any learning curve effects) to compare cost, closure time, length of stay and complications. There was no statistically significant difference between clips and suturing for POEM closure (however, regarding cost, it should be noted that this reflects costs of clips and the suturing device in the United States). All 10 sutured stents were in the same place at 8 wk. There was significant weight loss with both gastric outlet stomal reduction and the one primary sleeve gastroplasty. There were two fistula patients that required surgery and the single ulcer oversew patient required surgery for no evident healing at 2 wk.

FUTURE CONSIDERATIONS

The current version of the OverStitch, the dominant endoscopic suturing device requires a double channel gastroscope which limits flexibility and length of insertion thus making suturing in difficult locations such the gastric fundus or duodenum or in deep locations such as the right colon and small bowel difficult or impossible. Newer versions of the device are expected to address these issues. Looking further into the future, it is unclear what the impact of the development of flexible endoscopic staplers might have on endoscopic suturing. One would expect that selection of stapler *vs* suturing device would be guided by similar considerations as guide selection of hand-sewn *vs* stapled closures or anastomoses in surgery. However, unfortunately, this dilemma may not be a consideration for the near future given the expense and technical hurdles involved in developing flexible endoscopic staplers which likely resulted in two prior stapler devices having failed to become commercially viable[52,53]. Another device is in early trials but in its current version is restricted to a single indication, endoscopic fundoplication to treat GERD.

CONCLUSION

There has been a true revolution in gastrointestinal endoscopy with the evolution of endoscopic suturing to now be practically incorporated into clinical practice. As noted, there is a wide gamut of potential applications. There are issues including training and best implementation, but these should be clarified with time. The current instruments may be replaced or refined with technological developments and experience. Endoscopic suturing is here to stay!

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