Intraluminal Surgery: A New Arena for Minimally Invasive Surgery

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Although surgery within the lumen of the gut has been performed for many years, this has traditionally involved a laparotomy and enterotomy. With the advances in flexible endoscopy, surgeons and gastroenterologists have been able to perform therapeutic procedures with instruments introduced through the working channel of flexible endoscopes. These procedures, however, have been mainly limited to technically minor ones, such as injection and cautery of bleeding ulcers and resection of polyps and small mucosal lesion. More recently, laparoscopic surgeons have been able to isolate the lumen of hollow organs as a separate working space and develop instrumentation and technique specifically for "intraluminal surgery." This paper provides an overview of our approach, which includes development of a new device for intraluminal access and operations within the lumen of the stomach. Future application of this approach will also be discussed.

EVOLUTION OF INTRALUMINAL SURGERY

Dr. J. B. Petelin was the first to perform pancreatic cystgastrostomy using the laparoscopic approach. Using a standard laparoscopic setup, he opened the anterior wall of the stomach, incised the cyst, and then closed the anterior gastrotomy. The patient recovered without incident.[1] A large gastrostomy, however, may potentially negate the advantages of minimally invasive surgery. The next advance was to perform intragastric surgery while maintaining the integrity of the gut (i.e., avoiding a large enterotomy). Kitano et al. and Ferzli et al. reported successful results by intragastric surgery in the treatment of Dieulafoy's vascular malformation of the stomach, claiming cost effectiveness, early discharge, less pain and patient satisfaction as the benefits of this procedure over a conventional open laparotomy and oversewing of ulcer.[2-3] We have reported pancreatic cystgastrostomy in 9 patients using the intraluminal surgical technique, making use of new radially expanding devices.[4]

A working space within the lumen of the hollow organ is created either by inserting trocar and cannula devices through the wall or by mechanically retracting the wall. The former is simi-

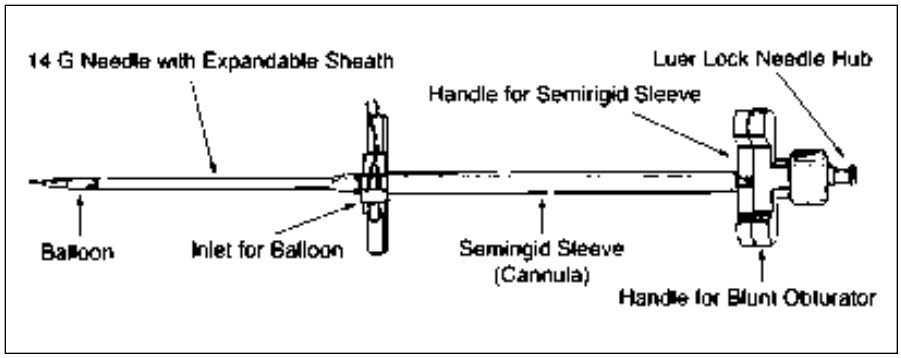

Figure 1a. Scheme of R.E.D.

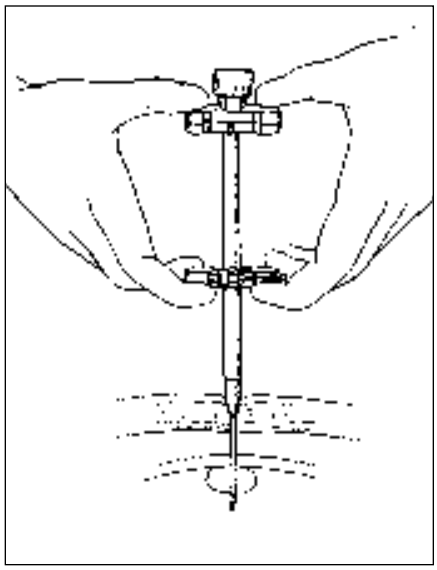

Figure 1b. After inserting the needle in the stomach, the balloon at the tip of the sheath is inflated, the needle is withdrawn, and an obturator with a semirigid sleeve is passed down the elastic sheath, expanding it.

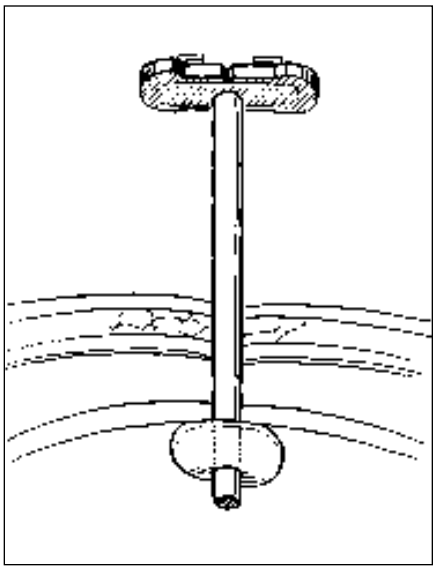

Figure 1c. The obturator is removed, leaving the sleeve as a 5-mm port, snugly gripped by the gastric wall.

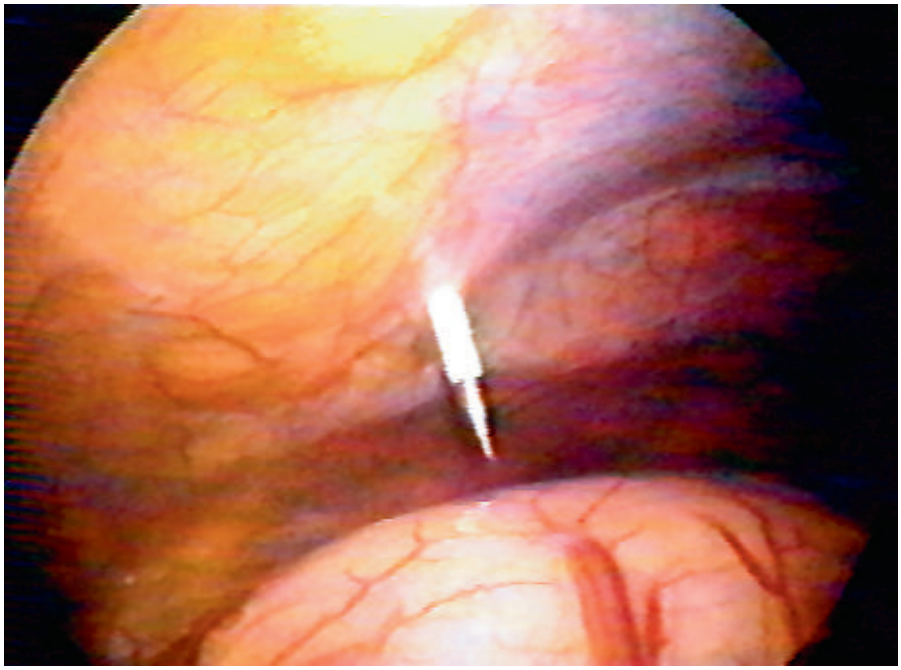

Figure 2. A R.E.D. is percutaneously inserted under direct vision through the anterior wall of the stomach that has been inflated with CO_2.

lar to conventional laparoscopic surgery as it requires pneumatic distention of the working space before inserting the trocars and the latter similar to laparoscopic surgery with mechanical abdominal wall lifting devices.

Our approach has been to develop a unique device specifically for percutaneous access to the lumen of the gut, which can keep the stomach well inflated with CO_2 instilled via a nasogastric tube. We chose cystgastrostomy as the first intraluminal laparoscopic operation because we estimated that technical success or failure would be easy to determine almost immediately, and any problem could be dealt with by opening the abdomen. We have so far operated on 14 patients with pancreatic pseudocyst.

INTRALUMINAL TROCAR

The trocar we used is called a Radially Expanding Dilator (R.E.D., InnerDyne Medical, Mountain View, Calif.). It consists of a 14 G needle enclosed in an elastic sheath with a balloon on the tip of the sheath (Fig. 1a). The device is passed through the abdominal wall and into the lumen of the stomach, which has been distended with CO_2. The balloon is inflated, the needle is withdrawn, and an obturator with a semirigid sleeve is passed down the elastic sheath, expanding it (Fig 1b). The obturator is removed, leaving the sleeve as a 5-mm port, snugly gripped by the gastric wall (Fig 1c).

The features that allow this instrument to perform well as an intraluminal trocar are as follows. The gastric wall is traversed by a puncture instead of an incision, and the trocar is inserted by radial dilatation of the tract, so the gastric wall hugs the cylinder firmly enough to produce a gas-tight fit when the stomach is inflated. The balloon on the tip of the device prevents the gastric wall from slipping off the cylinder, if the pneumogastrium is temporarily lost (as a result of using suction within the lumen of the stomach). Later, when the trocars are removed, the holes in the gastric wall are so small that they each require only one or two sutures for closure.

TECHNIQUE OF CYSTGASTROSTOMY

The first step of the operation consists of establishing a CO_2 pneumoperi-

toneum, and placing a standard trocar and laparoscope into the peritoneal cavity. The stomach is insufflated through a nasogastric tube with CO_2. Intra-abdominal gas pressure is reduced to avoid the competition for space between intraperitoneal and intragastric gases, maintaining the laparoscopic view of the anterior surface of the stomach (e.g., down to 8 cm H_2O). One of the intraluminal trocars is percutaneously inserted under direct vision through the anterior wall of the stomach (Fig 2). The balloon is then inflated and the trocar deployed. A 5-mm laparoscope is passed down through this trocar to inspect the lumen, verifying that positioning is good. Then with the camera returned to the peritoneal laparoscope, a second intraluminal trocar is inserted into the stomach under direct vision, several centimeters away from the first one (Fig 3). A third gastric trocar can be inserted, if needed.

At this point, the gas in the peritoneal cavity is completely evacuated, so the stomach can be inflated to its maximum size with 15 cm H_2O pressure. One of the intragastric trocars is used for the laparoscope and the other for the hand instruments. After establishing this basic setup, the intragastric anatomy is inspected. The scope can be passed about halfway down the second portion of the duodenum (Fig 4). Before starting the cystgastrostomy, it is important to ascertain the location of the cyst in relation to the posterior wall of the stomach. In some cases, the pseudocyst is obvious, because it produces a prominent convexity on the back wall of the stomach. This phenomenon is exaggerated compared with open surgery, probably because the stomach is distended. The location of the cyst is verified by inserting a long 18 G needle through the intraluminal trocar and aspirating cystic fluid from the area where the cyst is thought to lie (Fig 5). In only one patient has this been unsuccessful; in this case the cyst contained predominantly solid material, which plugged the needle. A preoperative CT scan is also vital in gauging the position of the cyst.

A hole is then made through the back wall of the stomach and into the cyst using the hook electrocautery device. We proceeded slowly, with the coagulation current set high to reduce the likelihood of bleeding from the stomach wall (Fig 6). After entering the cyst, its fluid contents are aspirated, giving a better view of the interior of the cyst and showing more clearly where the original incision was in relation to the center of the cyst. The incision was then extended to the desired length (i.e., more than half the diameter of the cyst) and direction. Occasionally a small artery large enough to produce pulsatile bleeding was divided, but most vessels can be successfully controlled with electrocautery. We placed two sutures of 2-0 silk in the cystgastrostomy margin in one patient. It proved relatively difficult to tie the knots because the space to work within was so small. Otherwise, the cystgastrostomy was not sutured. In no patient did the operative blood loss exceed 50 mL, and no patient bled postoperatively.

Solid contents of the cyst should be debrided thoroughly. This is the most difficult part of the operation, for debridement is best performed during open surgery manually. Having to rely entirely on instruments (e.g., forceps) risks trauma to the cyst wall, which can cause bleeding. On the other hand, unless the necrotic material is removed, it may plug culs-de-sac of the cavity and prevent them from draining. Therefore, we spent an average of 30 min on this stage of the procedure. One question arose as to what to do with the debris being pulled out of the cyst and into the stomach. In three early cases, we removed it through the trocars, which proved time consuming. In later cases, the material was pushed down the duodenum, which appeared to cause no clinical difficulties postoperatively (Fig 7).

After the cyst has been drained, the gastric trocars are withdrawn and the stomach deflated. With the laparoscope returned to the subumbilical port and two other trocars appropriately placed in the abdominal cavity, the holes in the anterior wall of the stomach are each closed (in one layer) with one, or occasionally two, interrupted Lembert sutures of 2-0 silk, using the Szabó-Berci suturing instrument (Karl Storz, Culver City, Calif.) (Fig 8). All trocars were removed and the procedure concluded.

RESULTS

In all patients, the intraluminal laparoscopy setup was successful. A cystgastrostomy was performed in 13 of 14 patients. In one patient, whose last CT scan was four weeks preoperatively, a pseudocyst could not be found, even though a preoperative ultrasound scan reported that it was present. In one patient, early on in the author's experience, the cyst recurred, as the incision though the stomach was not made large enough. This patient required an open operation several days later for fever and CT evidence of gas bubbles in the

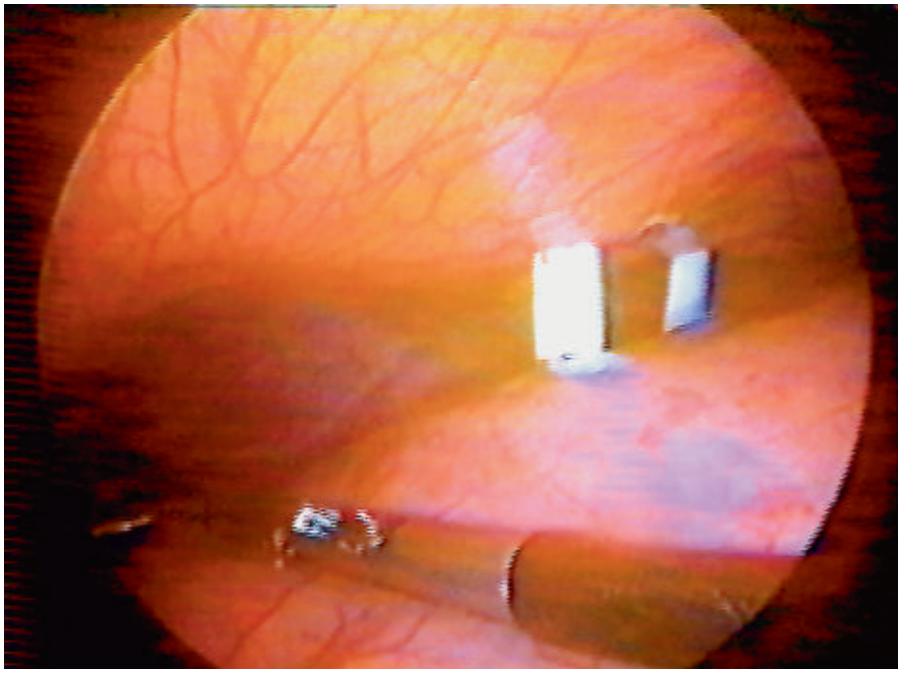

Figure 3. A second intraluminal trocar is inserted into the stomach under direct vision, several cm away from the first one.

cyst. In another patient, the cyst was found not to be adherent to the back wall of the stomach. In this operation, aspiration through the back wall of the stomach yielded typical cystic fluid. An incision through the back wall of the stomach into the cyst was made. A small (3 in) laparotomy was then made, followed by a small gastrotomy. The cyst and posterior gastric walls were pulled up to the level of the abdominal wall. The edge of the incision in the back wall was then anastomosed to the cyst, and the gastrotomy was closed in two layers. The small abdominal incision was closed. Except for the small abdominal incision, this operation was identical to what would have been done through a conventional laparotomy.

A nasogastric tube was used postoperatively in three patients, but it was removed in all three by the morning after surgery. A liquid diet was begun within 24 hours and was advanced as tolerated. In all but one case, the patients improved immediately, exhibiting the kind of postoperative course typical of laparoscopic cholecystectomy.

Consequently, the intraluminal laparoscopy was successful in all 14 patients, and the cystgastrostomy was successful in 13 of 14 patients. In follow-up ranging from 14 to 2 months, there were no recurrent cysts after an initial success. The patient with the concomitant pleural effusion had had a chest tube inserted and placed on suction several days before surgery. Because this was a chronic cyst, it contained no solid material in need of debridement, and a relatively small (3 cm) cystgastrostomy was adequate. He was able to leave the hospital four days after surgery with the chest tube out, feeling well and eating a regular diet.

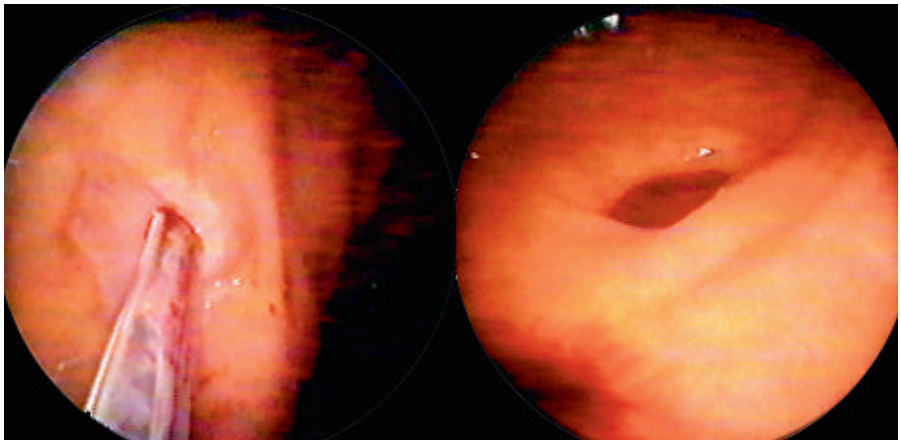

Figure 4. The lumen of the stomach is carefully inspected with a 5-mm scope inserted through one of the R.E.D.'s. Left: nasogastric tube entering the cardia. Right: pyloric ring.

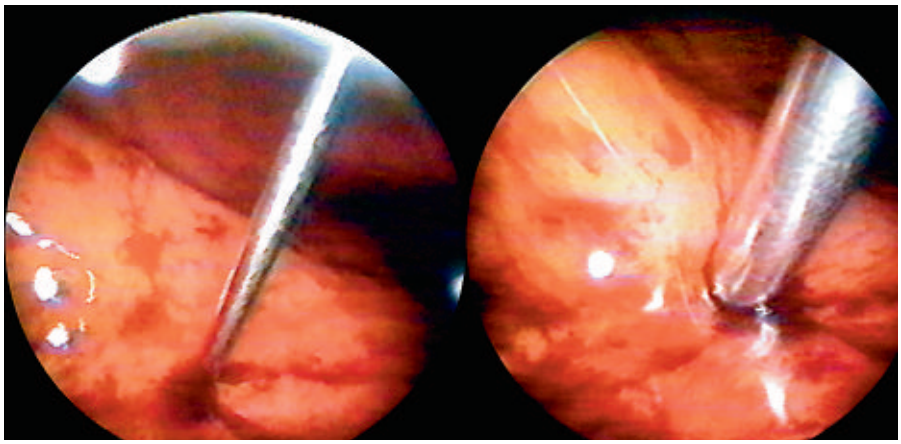

Figure 5. Needle aspiration to confirm position of pseudocyst.

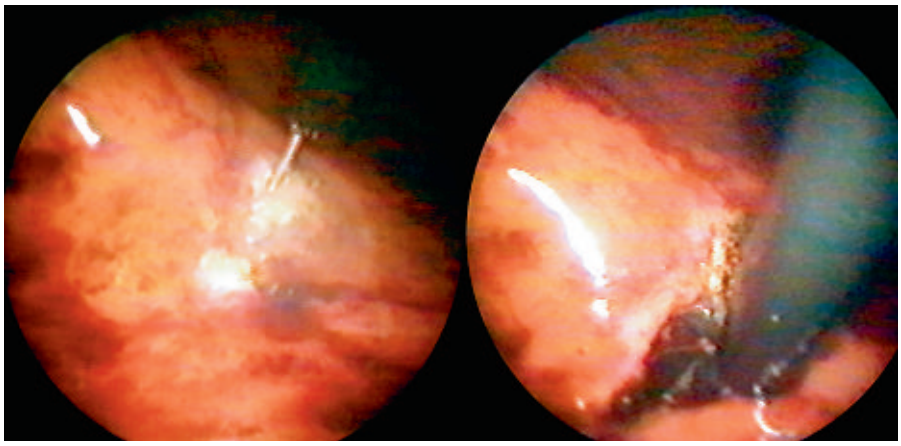

Figure 6. Monopolar hook electrocautery device is used to create cystostomy. Incision is extended to a desired length.

TIPS FOR INTRAGASTRIC CYSTGASTROSTOMY

Our experience provides a number of important technical lessons.

First, it is important to create an incision into the cyst that is large enough to debride the cyst contents and allow adequate drainage postoperatively. Concerns about possible bleeding, which is more difficult to control laparoscopically, tempt us to minimize the length of incision. It is, however, important to make an incision more than half the diameter of the cyst. A contributing factor is the magnification produced by the imaging system, which on gross inspection makes us overestimate the size of the incision. In one early case, the incision proved too small, and a second operation had to be performed. As our experience increased, we learned that bleeding was not going to be as great a technical problem as we had initially thought, and it could always be successfully controlled with electrocautery.

Second, debridement of the cyst contents can be technically difficult, but it is important. Gentle but persistent effort should be made, using forceps and irrigation until the cavity is clean. This can be time consuming. There may be some cysts that cannot be thoroughly debrided because of their size and shape, and these cases may not be suitable for laparoscopic treatment.

The technique used in these 14 cyst-

gastrostomies avoided problems with bleeding altogether, but eventually a case will be encountered where bleeding is more difficult to control. Placing sutures within the small cavity (stomach) was awkward, and tying them intracorporeally was even more of a challenge. Therefore, until substitute devices become available for hemostasis, there should be a low threshold for opening the stomach or converting to open surgery for bleeding.

This method of performing a cystgastrostomy requires the same amount of training and experience as other advanced laparoscopic operations, such as laparoscopic Nissen fundoplication or laparoscopic colectomy. The ability to suture and tie knots is a prerequisite. It would be unsafe to leave the gastric puncture site unsutured. Insufficient training and experience is associated with higher rate of complications in laparoscopic surgery, and the frequency of potentially avoidable complications is a serious concern.

The methods described in this paper are not applicable for the pseudocyst not in juxtaposition to the stomach. Others have performed sutured cystjejunostomies laparoscopically in such cases.

LESSONS LEARNED

The following are lessons learned from our early experience with intraluminal surgery, including both clinical and experimental studies in animals.

Indications and Contraindications

The conditions that can be treated using laparoscopic access techniques have a number of features in common. First, the pathological feature has usually been imaged using flexible endoscopy, and often an unsuccessful attempt at treatment has been made using flexible endoscopic techniques. Second, the patient is suitable for laparotomy, and third, the pathology is considered accessible using laparoscopic intraluminal techniques. The target area for intraluminal surgery should thus be on the opposite side of the cannula's entry. In fixed organs, such as the stomach, the entry point must be the anterior wall, and lesions being treated with this technique should be on or behind and adherent to the posterior wall. Thus the conditions that have lent themselves well to this mode of treatment have typically been symptomatic of pancreatic pseudocysts, which usually adhere well to the posterior wall of the stomach. In this sense, treatment of bleeding ulcers and excision of gastric polyps or a small mucosal area on the posterior wall of the stomach could be performed with this approach.[5-7] The presence of pathology on the anterior wall of the stomach is a contraindication relative to procedures performed by minimally invasive intraluminal techniques. In order to change the place for trocar entries, a substantial amount of dissection would be mandatory, which is, at present, not practical. Examples include Kocher's maneuver for access to the papilla Vater through the lateral wall of the second portion of the duodenum. For the same reasons, lesions on the posterior wall of the cecum, on the ascending and descending colon could be candidates. Lesions on the mesenteric side of these portions of the gut could also be treated with intraluminal surgical technique, since it would require no or minimal dissection for the access. Application of this technique would also be limited to the lesions located on the antemesenteric wall of the gut.

One disadvantage of performing the procedure using trocars to access the lumen of the gut is that intracorporeal suturing is technically more demanding than it would be with the standard laparoscopic setup, because of the awkward port positions and the reduced working space. Therefore, if suturing is a major part of the procedure, the mode

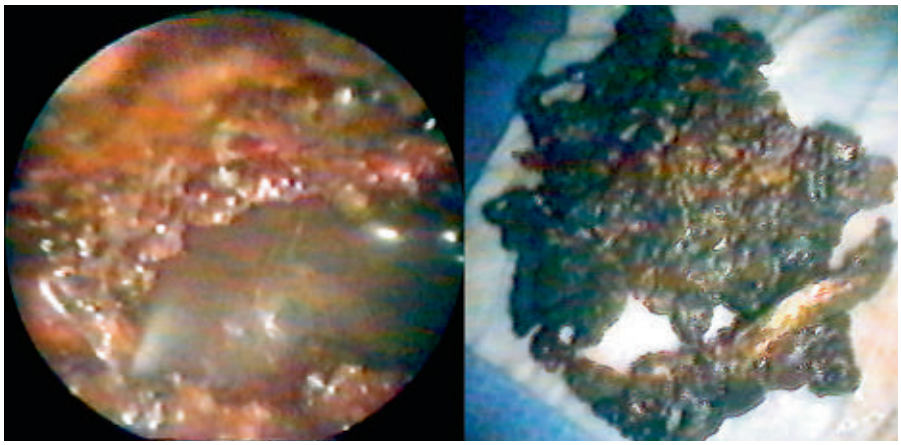

Figure 7. Left: view within the cyst. Right: debrided material from the cyst.

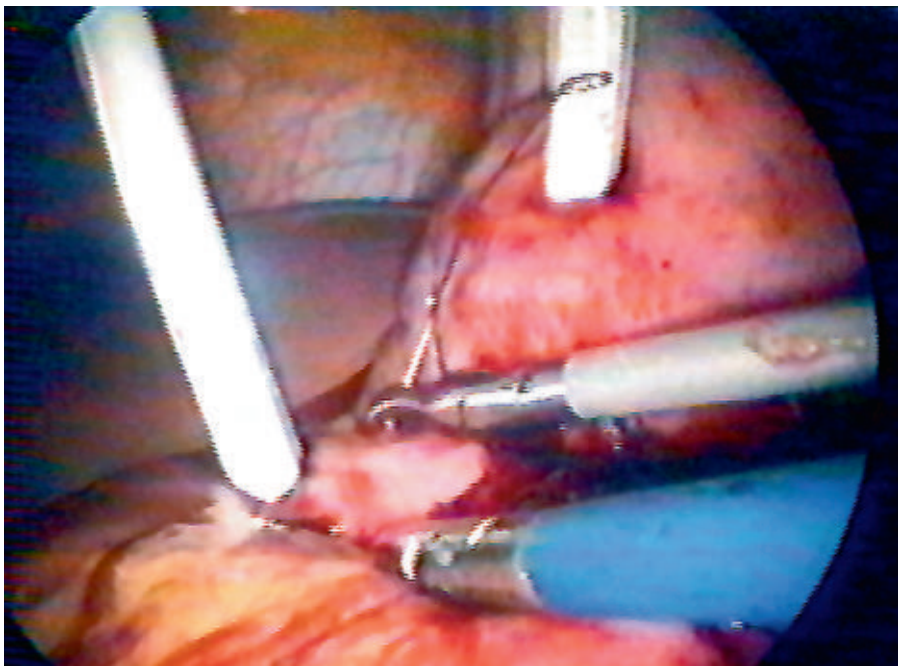

Figure 8. The holes in the anterior wall of the stomach are each closed with one, or occasionally two, interrupted Lembert sutures with standard laparoscopic setup.

of access may have to be modified accordingly, depending partly on the surgeon's skill in performing intraluminal suturing. Standard laparoscopic surgery with an enterotomy for access may be suitable for these conditions.

Imaging System

We wondered whether a fiber-optic gastroscope could be used more easily than the laparoscope for imaging, obviating the need for one of the gastric trocars. We tried this approach in one case of cystgastrostomy and found that the quality of the picture is inferior. Controlling what was on the screen was much more difficult with the gastroscope than with a 5-mm laparoscope adjusted by the surgical team. Nevertheless, this might be a satisfactory arrangement in less demanding procedures.

Localization of the Lesion and Placement of Trocars

Preoperative evaluation, in addition to that characteristic for the surgical condition being treated, should be aimed at localizing the pathology. As in standard laparoscopic surgery, the trocar and cannula device would considerably reduce the kinesthetic sensation so that palpation with an instrument for localizing the lesion is not usually successful. In our series of pancreatic pseudocyst, a needle puncture through the posterior gastric wall and the cyst wall has most commonly been used. A recent CT scan is therefore mandatory both to confirm the diagnosis and to locate the lesion. A preoperative Barium study is often helpful in localizing lesions within the lumen of the stomach. An intraoperative or immediately preoperative flexible endoscopy may be useful in deciding the most appropriate means of access to the lumen (i.e., using trocar and cannula devices or making a large enterotomy) and also in helping the surgeon to place the trocar positions or enterotomy opposite the lesion. To date, we have not used laparoscopic ultrasonography for localizing the lesion, as it is bulky and has a fixed angle of scanning. Improvement in technology would widen the use of ultrasound in laparoscopic surgery, and ultrasound would be employed for localization of the lesion.[8]

FUTURE DIRECTION OF INTRALUMINAL SURGERY

We anticipate that it will be possible to treat a number of other conditions by similar techniques, since this approach does not define operations; they merely provide access to the lumen of the hollow organs. Examples include partial excision of the gastric wall for benign and malignant lesions, upper GI bleeding which cannot be handled with flexible endoscopes, excision of broad-based cecal polyps, etc. Intraluminal laparoscopic surgery may appear to compete with therapeutic fiber-optic endoscopy, since in both instances, procedures can be done within the lumen of the stomach, duodenum, or colon. Real competition is unlikely, however. Therapeutic endoscopy has the advantage of not requiring general anesthesia, while intraluminal laparoscopy can accomplish more complex technical tasks. In the balance, the former will continue to be used in the instances where it has already proved to be effective, and the intraluminal laparoscopic surgery will tackle the more difficult problems, including some of the failures of therapeutic endoscopy. Intraluminal surgery may also be of use in organs inaccessible to conventional endoscopy. For example, small bowel endoscopy is possible using these methods.

The same techniques have been successfully used for in utero fetal surgery in animal models (i.e., fetoscopic surgery). In humans, open fetal surgery has been performed for serious malformations, such as congenital diaphragmatic hernia, cystic adenomatoid malformations, obstructive uropathy, and massive sacrococcygeal teratoma.[9-10] Prenatal repair of these lesions presently requires open hysterectomy, which may result in preterm labor. The only clinical application of fetoscopic surgery to date is cord ligation for twin-twin transfusion.[11] If this technique can be refined, however, fetoscopic surgery may be used in the treatment listed above and for other malformations, such as cleft lip and palate and neural tube defects.[12]

CONCLUSIONS

Using the techniques described in this paper, intraluminal gastric surgery can be safely and effectively performed for the treatment of pancreatic pseudocysts and also for some other lesions within the stomach. The surgery is greatly facilitated by using the special device described. The same techniques may also be used to access other hollow organs and perform a wider array of procedures, although such experience is limited. We predict that the lumen of the hollow organs will become a more common arena for the laparoscopic surgeon.

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