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SURGICAL VIDEO ENDOSCOPY and Other Interventional Techniques

Hybrid minimally invasive surgery—a bridge between laparoscopic and translumenal surgery

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Abstract
Background: The peroral transluminal approach to the peritoneal cavity appears safe, feasible, and may further reduce the invasiveness of surgery. However, flexible endoscopes have multiple limitations inside the peritoneal cavity, which can potentially be overcome by blending the use of both a laparoscope and a flexible upper endoscope—a hybrid approach. The goal of the present study was to evaluate a hybrid minimally invasive technique for cholecystectomy in a porcine model.
Methods: Hybrid cholecystectomies were performed in acute experiments on 50-kg pigs under general anesthesia. Pneumoperitoneum was created with a Veress needle, and a laparoscopic 10-mm port was inserted. Under laparoscopic observation, the gastric wall incision was done with an endoscopic needle-knife and sphincterotome, and the upper endoscope was advanced into the peritoneal cavity. A laparoscopic 10-mm port was inserted into the right upper quadrant of the abdomen for gallbladder traction to facilitate exposure of the cystic duct and artery. Via the biopsy channel of the flexible endoscope, and using a knife with an isolated tip, a needle knife, and clips, both the cystic duct and artery were identified, clipped, and transected. The gallbladder itself was then dissected and retracted through the mouth, and the gastric wall incision was closed with endoscopic clips.
Results: Five hybrid cholecystectomies were performed without complications. The laparoscopic port enabled a stable pneumoperitoneum, good traction and countertraction, and improved spatial orientation and visualization. Necropsy did not reveal any intraperitoneal complications.
Conclusions: The hybrid approach increases safety of initial gastric puncture and gastric wall incision, improves orientation and navigation of the flexible endoscope inside the peritoneal cavity, simplifies peroral transgastric cholecystectomy, and could be used to decrease invasiveness of laparoscopic surgery and to facilitate development and clinical introduction of transgastric endoscopic procedures.

Key words: Cholecystectomy — Abdominal — Endoscopy — Translumenal — NOTES

Several investigators have reported the feasibility and potential advantages of peroral transgastric endoscopic procedures inside the peritoneal cavity compared to traditional open surgery or laparoscopy [1–8, 10, 11]. However, available flexible endoscopes and their accessories are designed to function inside the gastrointestinal tract and have multiple limitations when used inside the free peritoneal cavity [9]. The most noticeable limitations include restrictions on retraction, small size of the instrumental channel, and spatial incongruity [9].

The aim of the present study was to evaluate a hybrid minimally invasive technique for cholecystectomy in a porcine model—as a bridge between conventional laparoscopic and peroral transgastric surgery.

Materials and methods

Animals

The study was approved by Johns Hopkins University Animal Care and Use Committee. The pigs were fed 6 cans of Ensure (16 oz; Abbott Laboratories, North Chicago, IL) for 2 days and fasted overnight before the experiment. Pre-anesthesia medication consisted of an intramuscular injection of 100 mg/ml Telazol (tiletamine HCL + zolazepam HCL; Lederle Parenterals, Inc, Carolina, Puerto Rico)

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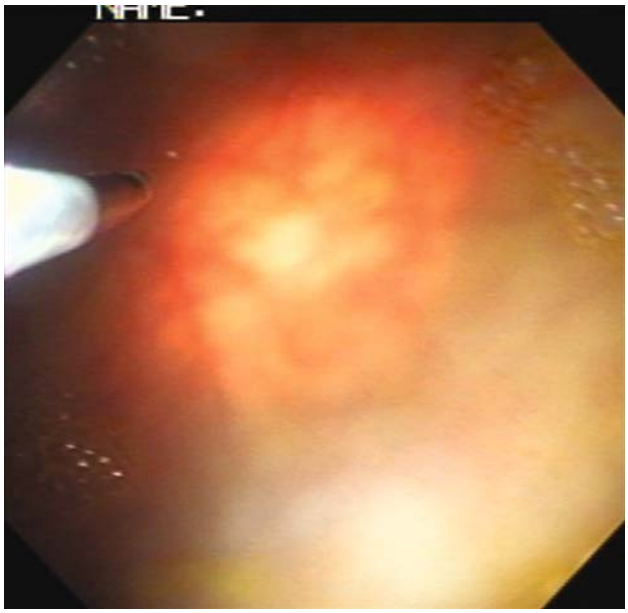

Fig. 1. Gastric wall is transilluminated by the laparoscope in the site of future gastrotomy.

reconstituted with 100 mg/ml ketamine HCL and 100 mg/ml xylazine at a total dose of approximately 0.05 cc/kg. An IV line was placed in the marginal ear vein, and 1 g thiopental sodium was injected at a dose of 6.6 to 8.8 mg/kg IV. All acute experiments were performed on 50-kg pigs (*Sus scrofus domesticus*) under 1.5% to 2% isoflurane general anesthesia, with 7.0-mm endotracheal intubation (Mallinckrodt Co, C.D. Juarez, Chihuahua, Mexico).

Surgical technique

A pneumoperitoneum was created with a standard Veress needle and a 10-mm laparoscopic port was inserted into the abdomen for a 10-mm laparoscope (Karl Storz Endoscopy, Culver City, CA).

An overtube (Olympus Optical Co, Ltd, Tokyo, Japan) was placed into the pig's mouth and advanced to the esophagus and stomach with a forward-viewing double-channel endoscope (GIF-2T160; Olympus Optical LTD, Tokyo, Japan) inside the overtube. An anterior gastric wall was punctured under direct laparoscopic observation (Fig. 1) using an endoscopic needle knife (KD-10Q-1.A; Olympus Optical LTD, Tokyo, Japan) with a combination of 20 W coagulation and 30 W cut current (Valleylab, SSE21; Tyco Healthcare Group LP, Boulder, CO). This opening was enlarged to 20-mm with a pull-type sphincterotome (210Q-0720; Olympus Optical LTD, Tokyo, Japan), and the endoscope was advanced into the peritoneal cavity, rotated, retroflexed, and advanced toward the gallbladder. The laparoscope was used to observe the position of the flexible endoscope and to facilitate its orientation inside the peritoneal cavity. Once the gallbladder was identified, a 10-mm laparoscopic port was inserted in the right upper quadrant of the abdominal wall under direct observation through the flexible endoscope, and a laparoscopic grasper (Endo Babcock® 174001, US Surgical Corporation, Norwalk, CT) was introduced into the peritoneal cavity to provide traction and facilitate exposure of the gallbladder (Fig. 2A and 2B, Video 1). The cystic duct and artery were identified, and ligated with endoclips using a prototype endoscopic multiple clip applicator designed for use through the biopsy channel of the flexible endoscope (Ethicon Endo-Surgery, Inc). The cystic duct and artery were transected between the clips using the needle knife (KD-10Q-1.A; Olympus Optical LTD, Tokyo, Japan) or an isolated tip (IT) knife (KD-610L Olympus Optical LTD, Tokyo, Japan) through the biopsy channel of the flexible endoscope (Figure 3, Video 2). The gallbladder was dissected from the liver (Figure 4, Video 3) with the isolated tip (IT) knife (KD-610L Olympus Optical LTD, Tokyo, Japan) and the needle knife (KD-10Q-1.A; Olympus Optical LTD, Tokyo, Japan) through the biopsy channel of the flexible endoscope and retrieved by withdrawing the flexible endoscope into the stomach and through the mouth. The gastrotomy was closed from inside the gastric lumen with endoclips by approximating the incision edges together under visualization through the laparoscope from inside the peritoneal cavity.

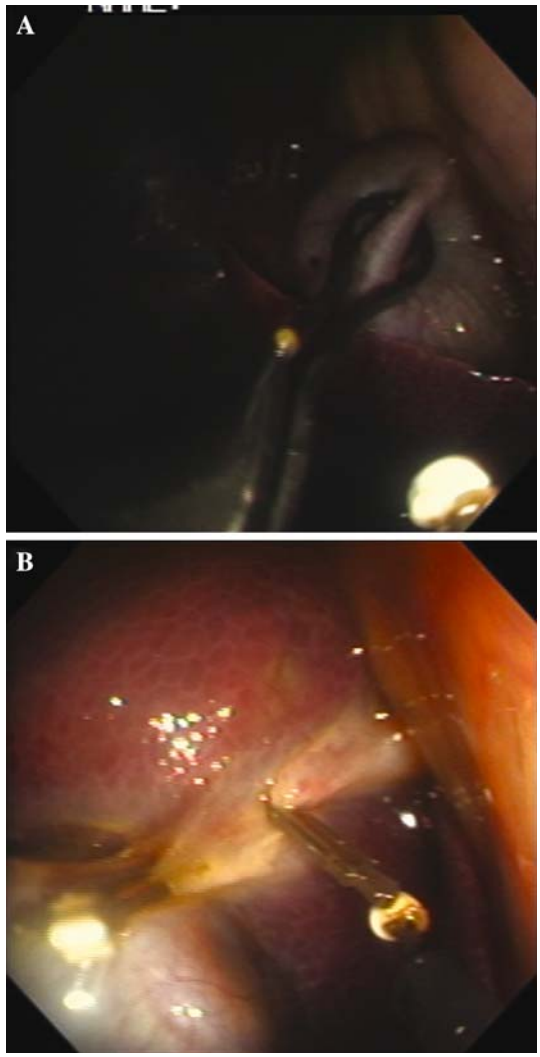

Fig. 2. Gallbladder traction with laparoscopic grasper facilitates access to the cystic duct and artery: **A.** Laparoscopic grasper applied to the fundus of the gallbladder. **B.** Cystic duct and artery are exposed by the gallbladder traction and ligated with endoscopic clips. Video 1. Traction with laparoscopic grasper improves exposure of the gallbladder for the flexible endoscope. The video can be viewed in the Electronic Supplementary Material.

Necropsy

Post experiment the animals were euthanized and the necropsy was performed. The intraperitoneal organs, resection bed, cystic stump, gallbladder specimen, and gastrotomy sites were thoroughly examined.

Results

Five pigs underwent hybrid minimally invasive cholecystectomies. There were no problems or complications related to insertion of the Veress needle and the laparoscopic ports, or with creation of pneumoperitoneum.

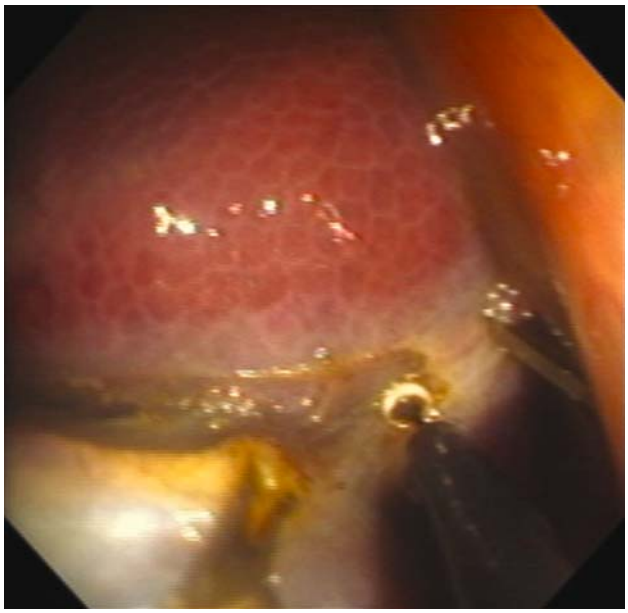

Fig. 3. Cystic duct and artery are transected with the IT knife. Video 2. The cystic duct and artery are transected between the clips using the isolated tip knife through the biopsy channel of the flexible endoscope. The video can be viewed in the Electronic Supplementary Material.

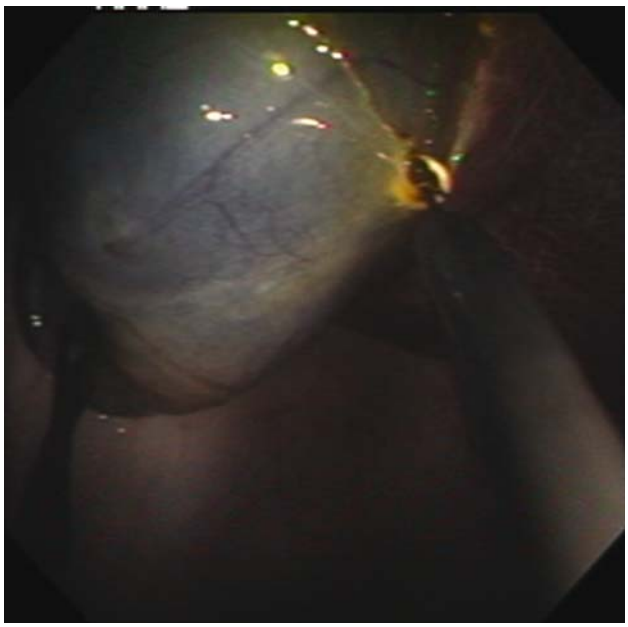

Fig. 4. The gallbladder is dissected from the liver with the IT knife. Video 3. The gallbladder is dissected from the liver using the isolated tip (IT) knife through the biopsy channel of the flexible endoscope. The video can be viewed in the Electronic Supplementary Material.

Gastric puncture and gastric wall incision were easily performed under direct laparoscopic observation without any injury to adjacent organs. Direct laparoscopic observation facilitated manipulations and orientation of the flexible endoscope inside the peritoneal cavity. The gallbladder was identified in all cases without any difficulty, although gallbladder traction with laparoscopic forceps significantly improved visualization and access to the cystic duct and artery. Use of a double-channel flexible endoscope facilitated ligation of the cystic duct and artery by using two instruments at the same time: a clip applicator through one channel and grasping forceps through another channel. The endoscopic multiple clip applicator was easy to use and provided good hemostasis and reliably closed the cystic duct.

The double-channel endoscope also facilitated dissection of the gallbladder by allowing use of the grasping forceps through one channel and the needle knife through the second instrumental channel. The laparoscopic camera port was used only for observation. There was no need to use this port for additional instruments because it was possible to manipulate two different instruments simultaneously through the flexible endoscope.

All cholecystectomies were performed without complications. Gastric wall incision was successfully closed with 3–4 endoscopic clips under visualization through the laparoscope from inside the peritoneal cavity. Postmortem examination did not reveal any intraperitoneal complications. The cystic duct stump and artery were securely closed with the endoclips without any bleeding or bile leakage. The gastrotomy site was closed completely with endoclips without injury to the surrounding tissues.

Discussion

Several investigators have reported the feasibility and potential advantages of peroral transgastric endoscopic procedures inside the peritoneal cavity in comparison to traditional open surgery or laparoscopy [1, 2, 4–8, 10, 11]. However, available flexible endoscopes and their accessories are designed to function inside the gastrointestinal tract, and they have multiple limitations when used inside the free peritoneal cavity [9]. The most noticeable limitations include restrictions on retraction, small size of the instrumental channel, and spatial incongruity [9].

The aim of the present study was to evaluate a hybrid minimally invasive technique for cholecystectomy in a porcine model as a bridge between conventional laparoscopic and peroral transgastric surgery. The hybrid approach consisted of peroral transgastric insertion of a flexible upper endoscope into the peritoneal cavity and cholecystectomy performed with endoscopic tools through the instrumental channel of the flexible endoscope under observation via a traditional laparoscope with occasional help (mostly traction) from laparoscopic grasping forceps.

This hybrid minimally invasive approach demonstrated several advantages over the previously reported peroral transgastric cholecystectomy [8] without laparoscopic assistance:

Blunt puncture of the gastric wall and gastric wall incision can potentially damage the adjacent organs, resulting in intraperitoneal bleeding or perforation. With the hybrid approach, the initial gastric puncture and gastric wall incision were safely done under direct

laparoscopic observation without any injury to adjacent organs.

Previously reported transgastric endoscopic procedures demonstrated that transgastric manipulations on pelvic organs (tubal ligation and resection of tubes, uterus, and ovaries) are technically easy due to a straight pass from the stomach to the pelvis [2, 7, 10, 11]. At the same time, transgastric procedures on epigastric organs (liver, spleen, gallbladder) are more complicated because it is necessary to work with the flexible endoscope in a retroflexed position, which leads to spacial incongruity and difficulties in orientation [9]. These difficulties have prevented adequate visualization of intra-abdominal organs in 5 out of 9 animals in transgastric experiments reported by Wagh et al. [10]. The hybrid approach with laparoscopic observation dramatically improved orientation of the flexible endoscope inside the peritoneal cavity—we were able to visualize the gallbladder in all animals and never had any problems with orientation or spacial incongruity when the flexible endoscope was navigated inside the peritoneal cavity under laparoscopic observation.

The ability to accomplish tissue retraction inside the peritoneal cavity with the transgastric approach is limited by excessive flexibility of the endoscope and the small caliber of the endoscopic accessories, preventing grasping and holding of an adequate amount of tissue [9]. The hybrid approach resolved this issue: the gallbladder traction achieved with larger laparoscopic grasping forceps significantly improved visualization and access to the cystic duct and artery.

All hybrid procedures were performed under observation with a 10-mm laparoscope available in our animal operating room. However, the actual procedure—the cystic artery and duct ligation, gallbladder dissection and removal of the gallbladder from the peritoneal cavity—was done with the flexible endoscope and endoscopic instruments. Such hybrid procedures potentially can be done with the use of smaller (2.7-mm) laparoscopic instruments and an optical Veress needle (2 mm in diameter). Thus hybrid procedures can significantly decrease the invasiveness of laparoscopic surgery.

In conclusion, the hybrid approach increases safety of initial gastric puncture and gastric wall incision, improves orientation and navigation of the flexible endoscope inside the peritoneal cavity, simplifies peroral transgastric cholecystectomy, and overcomes some of the limitations of current translumenal instrumentation. This hybrid minimally invasive approach could be used to decrease invasiveness of laparoscopic surgery for combined flexible endoscopic and laparoscopic resections of submucosal or deep penetrating lesions of the gastric and intestinal wall, for creation of gastroenteric and enteroenteric anastomoses, and to facilitate development and clinical introduction of transgastric endoscopic procedures.

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