Transgastric cholecystectomy using a prototype endoscope with 2 deflecting working channels (with video)

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Background: Transgastric cholecystectomy has been shown to be feasible in animal models and human case reports but cumbersome with current available instrumentation.

Objective: To evaluate a prototype endoscope with 2 working channels with deflectors at the distal tip for performance of transgastric cholecystectomy.

Design: Animal study, nonsurvival and survival.

Animals: Sixteen male pigs.

Setting: University hospital.

Intervention: Transgastric cholecystectomy in 6 nonsurvival pigs by using several different dual-channel endoscopes and 10 survival pigs by using the Olympus dual-channel endoscope with an up-down deflecting channel to the left of the objective lens and a left-right deflecting channel located below the lens. Gallbladder fundic retraction was performed with the aid of one laparoscopic grasper.

Results: Cholecystectomy was successful in all survival animals. Median procedure time was 81 minutes (range 31-163 minutes), with a decrease over time. Visualization of all structures was achieved, and clipping of the cystic duct and artery was successful in all cases. Dissection of the gallbladder via the left-right channel was enhanced with retraction via the up-down deflecting channel. Nine of 10 animals survived without complications. One animal died, on postoperative day 2, secondary to peritonitis due to a leak from the gastrotomy site.

Conclusions: This endoscope, with deflecting working channels, allows transgastric cholecystectomy in pigs. The endoscope was stable enough to be used without an overtube and facilitated retraction and dissection. This endoscope is promising for use in transgastric cholecystectomy in human beings. (Gastrointest Endosc 2009;69:297-302.)

Access to the peritoneal cavity by using the transgastric route was first described in 2004.[1] Since then the concept of natural orifice transluminal endoscopic surgery (NOTES) is being widely studied for possible application in human beings. Cholecystectomy is the most common elective procedure in general surgery and may be amenable to a NOTES procedure. NOTES cholecystectomy has been shown to be feasible in animal models[2-11] and in human case reports.[12-17] Significant challenges currently encountered are closure of the gastrotomy site, retraction for exposure, and precise dissection. Techniques and instruments that overcome these challenges are needed before the wide application of NOTES in human beings.[18]

The aim of this study was to evaluate a prototype endoscope with 2 working channels with deflectors at the distal tip for performance of transgastric cholecystectomy. Commercially available endoscopic accessories were used for retraction and dissection. One laparoscopic port was also used for retraction of the gallbladder fundus.

Abbreviations: ACUC, Animal Care and Use Committee; IV, intravenous; NOTES, natural orifice transluminal endoscopic surgery.

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MATERIALS AND METHODS

Animals

Prior to starting the project, the study protocol was approved by the animal care and use committee (ACUC)

of the University of Missouri–Columbia. A total of 16 pigs underwent transgastric cholecystectomy. Six nonsurvival pigs (20-50 kg) were used to develop and standardize the technique. A variety of endoscopes and instruments were used in the trial, and a consensus was developed by the investigators on the best technique with current instrumentation. Ten male pigs (20-25 kg) underwent transgastric cholecystectomy for survival. All the animals were managed according to a protocol approved by the University of Missouri–Columbia ACUC. All animals received a soft diet the day before surgery and were not given any food by mouth the night before the procedure. Preanesthetic medication consisted of an intramuscular injection of xylazine 2.2 mg/kg and telazole (Fort Dodge Animal Health, Fort Dodge, Iowa) 4.4 mg/kg, and atropine sulfate 0.04 mg/kg intravenously. Intravenous (IV) access was obtained by an IV line placed in a superficial ear vein. All animals received prophylactic antibiotics (1 g cephalexin IV) and 1.5% to 2% isoflurane general anesthesia with endotracheal intubation.

Capsule Summary

What is already known on this topic

- Platform stability and angulation at the tip of endoscopic accessories are currently limiting natural orifice transluminal endoscopic surgery.

What this study adds to our knowledge

- Transgastric cholecystectomy, with visualization of all structures and clipping of the cystic duct and artery, was successfully performed in 10 pigs by using a prototype endoscope with enhanced platform stability and 2 deflecting working channels.

Instruments

The prototype dual-channel endoscope (XGIF-2TQ160R; Olympus Inc, Center Valley, Pa) has a working length of 130 cm and an insertion-tube diameter of 11.7 mm. It has a 140° angle of view. Each tip of the working channels have a diameter of 2.8 mm, and the tip of the endoscope deflects 210° up, 180° down, 100° right, and 100° left (Fig. 1). The endoscopic accessories placed through the channel can be bent. On the left side of the objective lens, a lever results in up-down movement. The endoscopic accessory instrument is placed through the left working channel and through the tip of the endoscope with the up-down channel in a neutral position. A knob at the control dial for the bending section of the endoscope can be pushed down, which results in an upward movement of the endoscopic instrument to approximately 45°. The up-down level can then be adjusted to position the endoscopic accessory appropriately. The tip of the right channel is controlled by a wheel located below the endoscope control dials (Fig. 1). The neutral position is indicated with the alignment of arrows on the control wheel and the endoscope handle. Once the endoscopic accessory is advanced at the channel tip, it can be moved approximately 30° to the left or the right by using the control wheel (Fig. 2).

Endoscopic accessories used included a guidewire, balloon dilator, grasper, hook-knife, and endoclips. The guidewire (JAG Wire; Microvasive Endoscopy, Boston Scientific Corp, Natick, Mass) is 450-cm long and 0.035 cm in diameter, with a floppy tip. The dilator balloon (Microvasive Endoscopy, Boston Scientific Corp) has a maximal diameter of 20 mm. The grasper (Olympus Endotherapy, Tokyo, Japan) is of the rat-tooth variety, with jaws opening to 14 mm. The hook-knife (Olympus Endotherapy) extends 5 mm from the sheath and has a 3-mm hook at the end that extends at a 90° angle. Endoclips (Olympus Endotherapy) are 12 mm in length and could open to 8 mm. The up-down channel to the left is primarily used for the endo-grasper and retraction of the infundibulum. The left-right channel below the lens is primarily used for dissection by using a hook-knife electrocautery (Valleylab, Boulder, Colo), which is set at 30 W of current. Surgical sterilization was accomplished by placing the endoscopes and accessories in Cidex (CIVCO Medical Solutions, Kalona, Iowa) for at least 10 hours. The endoscopes and instruments were then irrigated with sterile saline solution before use in the pigs.

Surgical technique

After preanesthetic medication, the animals were brought to the operating room and were placed in the supine position. Endotracheal intubation was followed by an upper endoscopy to clear the esophagus and stomach of any residual food. The stomach was then irrigated with 500 mL of 5% povidone-iodine solution, which was left in the stomach for 5 minutes. The esophagus was irrigated with 100 mL of the same solution and suctioned with the same endoscope. A standard abdominal-wall preparation and preparation of the mouth and snout, as well as sterile draping, were performed.

The sterile prototype dual-channel endoscope was introduced into the esophagus. The stomach was entered and partially insufflated. A gastrotomy was created as described by our group.[19] Briefly, a site was identified on the anterior body of the stomach by using endoscopy and abdominal-wall palpation. By using a commercially available suture passer (GraNee Needle; R-Med, Inc, Oregon, Ohio), 3 percutaneous transgastric 3-0 Prolene (Ethicon, Cincinnati, Ohio) sutures were placed in the shape of a triangle. A guidewire was then placed in the right working channel of the endoscope, and the tip of the guidewire was placed into the stomach. The GraNee suture passer was then passed through the middle of the stay sutures, and the guidewire was grasped and brought through the abdominal wall. The tip of the wire was

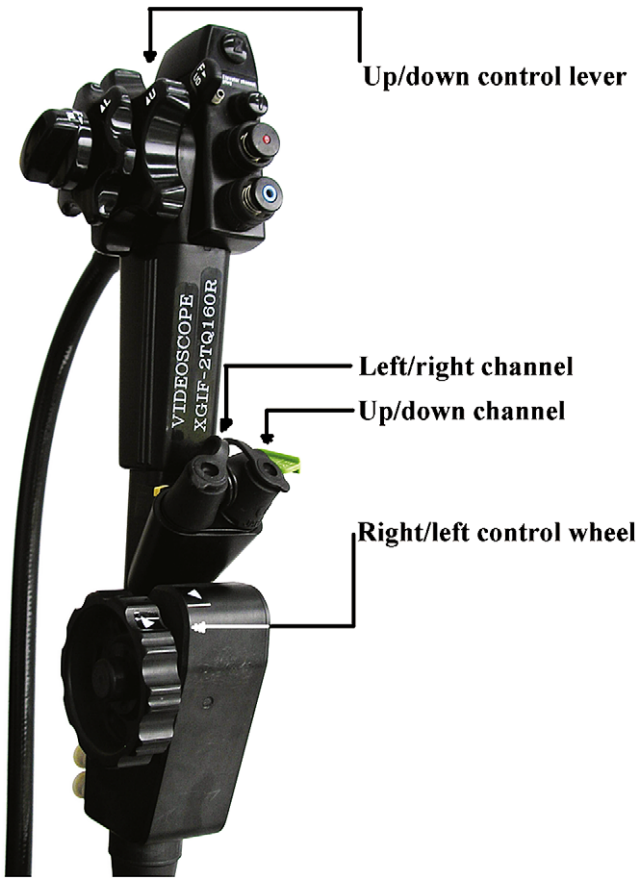

Figure 1. The 160R prototype endoscope handle.

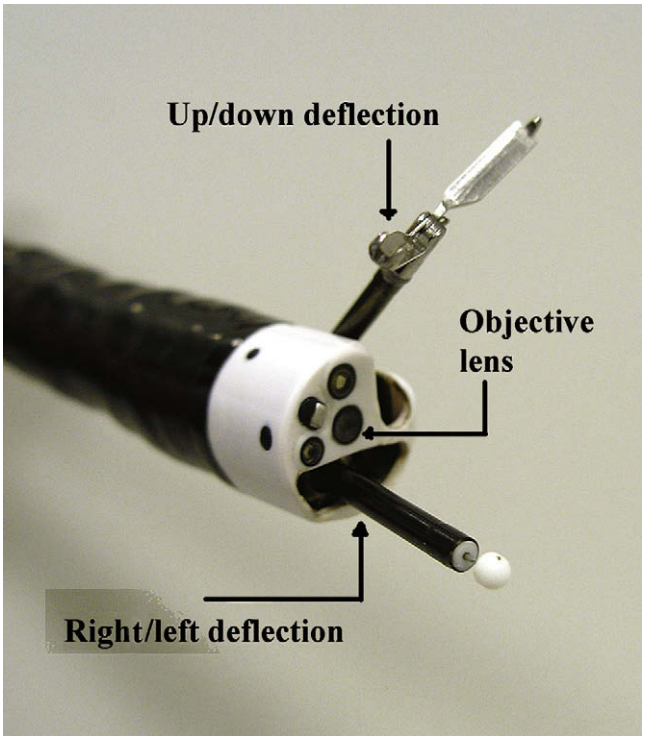

Figure 2. The 160R prototype endoscope tip, showing the deflecting channels.

then grasped with a clamp at the level of the skin. A grasping forceps was placed in the left working channel of the endoscope, and the stomach was grasped and pulled toward the endoscope. With this counter tension, the floppy end of the wire could be reliably looped into the peritoneal cavity. The balloon catheter was then placed over the wire, and the gastrotomy site was dilated to 20 mm. The tip of the endoscope was placed in the peritoneal cavity by following the inflated balloon. The endoscope was passed to the pelvis and retroflexed so that the gallbladder could be identified. An endoscopic grasper was then introduced in the left channel, the gallbladder was grasped, and the endoscope loop was reduced. This allowed good visibility of the gallbladder with a 60° to 120° angulation on the bending section of the endoscope. A 5-mm laparoscopic trocar was then placed 2 cm lateral to the umbilicus on the right side. A 5-mm laparoscopic grasper was introduced to retract the gallbladder fundus toward the right upper quadrant. Pneumoperitoneum was monitored via the laparoscopic port. The gallbladder was grasped at the infundibulum with the endoscopic grasper, and a hook-knife was introduced in the right channel. Dissection started at the cystic duct and artery by opening the peritoneum on both sides. The 2 structures were identified, dissected, and clipped with endoclips, 2 proximal and 1 distal (Fig. 3). The duct and artery were divided with the hook-knife. The gallbladder was then dissected off the liver bed with the hook-knife (Fig. 4). The endoscopic grasper in the left channel grasped the infundibulum and helped expose the gallbladder bed for dissection. The grasper was repositioned as needed to give adequate visualization for dissection. The gallbladder was dissected off the liver bed by a right-to-left motion of the hook via the right endoscopic working channel. The gallbladder bed was irrigated, and hemostasis was obtained. The gallbladder was retrieved with the endoscopic grasper and extracted through the mouth. The gastrotomy site was closed by tying the 3 previously placed stay sutures. In 3 of the pigs, additional transcutaneous sutures were placed to assure complete closure. Adequate gastrotomy closure was confirmed by endoscopic insufflation and laparoscopy. All animals were followed-up daily by the veterinary team for any signs of behavioral change or decreased appetite, which may indicate infection.

The procedure can be viewed in Video 1 (available online at www.giejournal.org).

Necropsy

The animals were euthanized on postoperative day 14. A necropsy was performed by the same surgeons and surgical research fellows who performed the cholecystectomies. After a midline incision, the peritoneal cavity, gallbladder bed, the clips on the cystic duct and artery,

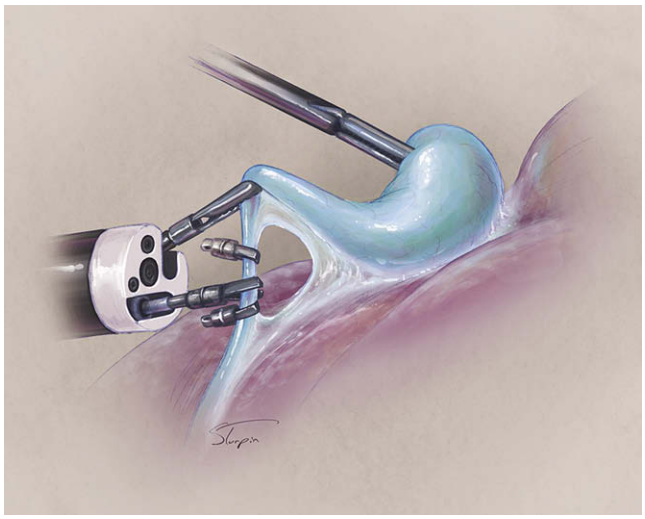

Figure 3. Clip placement to the cystic duct and artery.

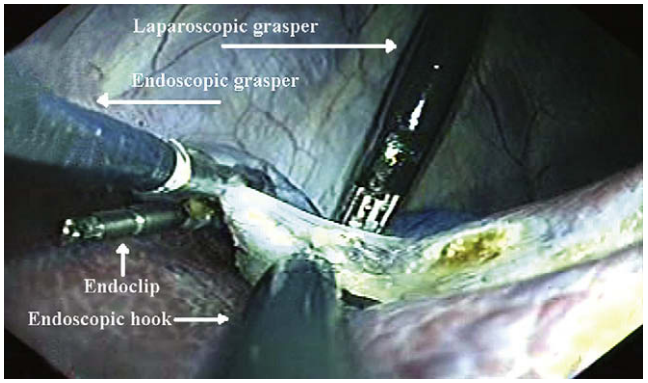

Figure 4. Endoscopic view: gallbladder dissection by using a hook-knife. The gallbladder is dissected off the liver bed by using endoscopic retraction through the up-down channel and dissection through the left-right channel.

and the gastrotomy site were evaluated for pathologies and all findings were documented.

Statistical analysis

Statistical analysis was performed for the operative time by using the Mann-Whitney test. The time of the operation in the first 5 animals was compared with the time in the last 5 animals. A $P \leq .05$ was considered statistically significant.

RESULTS

Because of problems reaching the right upper quadrant in larger pigs from looping of the endoscope, we used pigs of 20 to 25 kg for the survival portion of the study. Transgastric cholecystectomy was successful in all survival animals. The median excision time of the gallbladder was 81 minutes (range 31-163 minutes), with 163 minutes in the first pig and 31 minutes in the last pig. The mean (SD) operation time for the first 5 animals was 120 ± 28 minutes compared with 51 ± 17 minutes for the last 5 ($P = .009$). The learning curve, with a decrease in operative time in the pigs done later in the study, is depicted in Figure 5. Adequate anatomic exposure of all structures, as well as clipping of the cystic duct and artery in the appropriate place, was successful in all cases. The entire gallbladder could be removed under direct vision. One injury of the cystic artery was safely controlled with 2 hemoclips. The ability to deflect the grasper up-down to the left of the lens improved exposure.

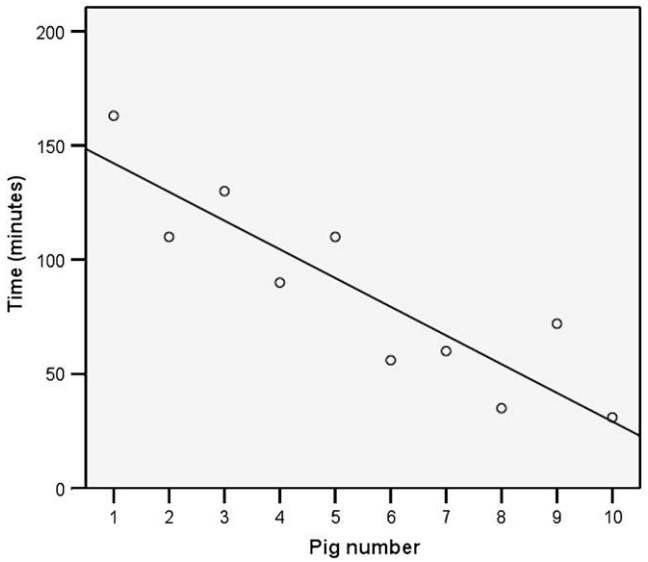

Figure 5. Graphic showing the procedure time for transgastric cholecystectomy in each pig.

Perforation of the gallbladder occurred during dissection in 9 of 10 animals. The last 3 perforations were minimal; they were point perforations. The last gallbladder removed had no perforation. All perforations were created by using electric cautery with the hook dissector. The postoperative course was uneventful in all animals but one. This animal died 2 days after surgery, secondary to peritonitis because of a leak from the gastrotomy site. In this animal, the gastrotomy site extended beyond the sutures. Necropsies in the remaining 9 animals showed a healed gastrotomy site and a healed gallbladder bed in each animal. The clips at the cystic duct and/or artery were found in place in all animals. No signs of bile leakage or infection were found. Minimal filmy adhesions to the gallbladder bed and liver edge were found in 6 animals.

DISCUSSION

Laparoscopic cholecystectomy was introduced in the late 1980s and became the standard of care within 5 years. Currently, most surgeons resect the gallbladder by using

a 4-trocar technique. However, this technique has associated complications, such as abdominal-wall infection, hernia formation, and pain.

NOTES cholecystectomy has been performed by using different endoluminal routes in animals,[2-11] and several centers around the world have used the transvaginal route in human beings.[12-16] The ease of opening and closing the vaginal wall and a straight view of the gallbladder and adjacent structures are major reasons why the transvaginal route is being used. The transvaginal route will likely predominate in early NOTES. The gastric route is more challenging but can potentially be used in both sexes.

Two of the technical hurdles described by the White Paper[20] are the need for a stable, multilumen platform, and the ability to angulate instruments to the point of dissection. Current commercially available endoscopic tools are still unstable and do not allow instrument angulation. New tools are being developed with the aim of overcoming these challenges.[18,21] The prototype dual-channel endoscope (XGIF-2TQ160R; Olympus) enhances platform stability and allows angulation at the tip of the endoscopy accessories. We believe this is a significant advance in obtaining retraction and aids in dissection in NOTES surgery.

Investigators who use the transgastric route for cholecystectomy described difficulties because of the retroflexed and often poor anatomic view of the operative field.[2,3,7,9,11,20] By looping the endoscope and then reducing it with the aid of an endoscopic grasper, we were able to position it to obtain a laparoscopic-like image in all procedures. We cannot make any conclusions as to whether the prototype endoscope or the smaller animals chosen for our survival group were responsible for the improvement in consistency in achieving an adequate anatomic view.

Retraction is another problem that needs to be addressed. Laparoscopic retractors have been used by most investigators. Scott et al[10] used magnets placed through the transvaginal port to retract the gallbladder, which avoided the use of the laparoscopic port. Our procedures were primarily performed by endoscopy, but we still required a laparoscopic port for gallbladder retraction.

For our survival study, we used the prototype dual-channel endoscope (XGIF-2TQ-160R; Olympus). This improved our technique compared with a standard 2-channel endoscope used in the acute model. We were able to successfully perform cholecystectomies in all the survival animals and to decrease the operative time significantly. Exposure was adequate, and dissection was possible. Perforations of the gallbladder did not lead to any postoperative complications. Our last 5 procedures had times similar to laparoscopic cholecystectomy, which indicated a short learning curve. The strength of this technique is the consistent success in a standardized model. Visualization and orientation similar to laparoscopic surgery could be accomplished with the prototype endoscope. Gastrotomy closure was quick, easy, and predictable, with the exception of 1 animal. In this animal, we made a technical error by extending the gastrotomy beyond the closing sutures and then not recognizing it at the time of closure. A necropsy revealed that the gastrotomy was not placed in the center of the stay sutures but extended a little beyond them. We do not think it was related to the manipulation of the endoscope. Expansion of the tear laterally, when dilating with the balloon, is the possible cause of this complication. This mortality, therefore, was not related to the cholecystectomy itself. The initial use of more stay sutures a greater distance from the center may reduce the risk of this complication. The mortality that resulted from this complication again shows that safe closure of enterotomies for NOTES is paramount.[20,22]

The primary weakness of transgastric cholecystectomy is the lack of precision during dissection. Although we could improve precision with this prototype endoscope, we had a gallbladder perforation in 9 of 10 pigs. Such perforations are not uncommon during laparoscopic surgery, but not with such a high rate. In the last 3 animals, only point perforations were seen, and the last gallbladder could be removed intact, which reflected a learning curve during this study period. We believe that, with further experience, gallbladders could be removed by using this prototype, with perforation rates comparable with laparoscopic surgery. Precision is dependent on a stable operative field at the end of a flexible endoscope, orientation, and flexibility of the working channels with movements in more than 1 plane. The stability and precision of NOTES cholecystectomy can likely be improved with an antegrade approach via the transvaginal or the transcolonic route.[5,10]

Further improvements for the transgastric route can be accomplished with the development of overtubes or transport systems that will allow a more stable and precise dissection.[8] The use of transluminal gallbladder retractors or magnetic anchoring systems hopefully will help to make it a pure NOTES procedure.[10] To our knowledge, this study represents the largest survival animal study of NOTES cholecystectomy with laparoscopic assistance as a hybrid procedure.[2,4,11] We were able to complete all of our procedures without significant intraoperative complications and successfully removed the gallbladder in all cases. The learning curve is acceptable, and the technique can be learned by experienced endoscopists. We believe that the technology presented here can be further standardized with 1 transabdominal port for laparoscopic assistance, and then it can be safely introduced into clinical practice.

In conclusion, transgastric cholecystectomy as a hybrid procedure by using the prototype dual-channel endoscope (XGIF-2TQ160R; Olympus) with 2 deflecting working channels is feasible. Visualization of all structures and exposure for dissection could be consistently done

in the survival pigs. The learning curve was short, and procedures improved toward the end of the study, which reached times similar to laparoscopic cholecystectomy. There was a need for laparoscopic retraction to aid with exposure. New instrumentation needs to be developed to perform a pure transgastric cholecystectomy without transabdominal assistance.

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