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DYNAMIC MANUSCRIPT

# A snare-assisted pure NOTES retrograde cholecystectomy using a single channel flexible endoscope: a pilot experiment in a porcine model

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## Abstract

**Background and aim** Natural orifice transluminal endoscopic surgery (NOTES) cholecystectomy is an emerging technology. Interest is ongoing and developments have been rapid but NOTES cholecystectomy has failed to gain traction. Here, we share our experience of snare-assisted pure NOTES retrograde cholecystectomy using porcine models.

**Materials and methods** Under general anesthesia, an incision was created on the posterior vagina wall and an endoscope with a snare attached to the transparent cap was introduced into the pelvic cavity and then upward into peritoneal cavity. After locating the liver and gallbladder, the fundic wall of gallbladder was grasped using a biopsy forceps and the snare was released to ligate the fundus. The gallbladder was then carefully dissected from the gallbladder bed using hook/IT knives with the assistance of the snare. The cystic duct and cystic artery were identified, clipped twice and isolated from the gallbladder using the hook knife to cut between the clips. The specimen was then removed through the vagina using the snare.

**Results** This procedure was successfully performed in 8 consecutive pigs. The average procedure time was 53 min (range 40–60 min). No severe bleeding or other complication was observed either during or after the procedure. Normal diets were given on the same day of the procedure. All animals recovered uneventfully.

**Conclusion** We successfully performed snare-assisted pure NOTES retrograde cholecystectomy in pigs using standard endoscopic instruments. In our experience, pure NOTES cholecystectomy using the retrograde approach performed with a single channel flexible endoscope proved safe and feasible with a short procedure time and quick recovery. The translation of this technique to human subjects seems straight forward and provides a new fitting path to pure NOTES.

**Keywords** NOTES · Retrograde cholecystectomy · Flexible endoscope · Transvaginal

## Abbreviations

| | |
|---|---|
| NOTES | Natural orifice transluminal endoscopic surgery |
| LC | Laparoscopic cholecystectomy |

Gallstones are one of the most common digestive health issues worldwide with a prevalence of 10 to 15% [1–4]. Laparoscopic cholecystectomy has become the first choice treatment of symptomatic cholelithiasis as it is minimally invasive [5–9]. However, in recent years, natural orifice transluminal endoscopic surgery (NOTES) has been developed with advantages of producing no scar and avoidance of an abdominal wall incision as well as incision-related complications [10–14]. However, some reports have described NOTES procedures as complicated, risky, and time-consuming [15, 17]. Such objections arose in part because originally the procedures were performed using rigid or double channel endoscopes not designed for NOTES operations [15–17]. In addition, there are technical obstacles such as difficulty in finding the cystic duct and artery due to Calot's triangle being obscured by fatty tissue during NOTES cholecystectomy.

Bing-Rong Liu and Saif Ullah equally contributed to this article as co-first authors.

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We were inspired by the surgeon's open surgical cholecystectomy technique termed retrograde or "fundus-first" cholecystectomy used during open cholecystectomy and in difficult laparoscopic cholecystectomies. In this approach, the standard dissection starts at the triangle of Calot and progresses towards the fundus of the gallbladder [18, 19]. We attempted a similar approach with NOTES using a snare-assisted retrograde approach in which the gallbladder is removed from the bottom (fundus) downward rather than from the cystic duct. Our use of retrograde dissection was similar to that used in open and laparoscopic cholecystectomy. The aim of this study was to evaluate the feasibility and safety of a newly proposed operative method-pure NOTES retrograde cholecystectomy using a single channel flexible endoscope.

## Materials and methods

### Animals and equipments

Eight female swine with body weights of $35 \pm 2.1$ kg (32.9–37.0 kg) were used in this study. This study was performed at the animal experiment center of Henan University. The study protocol was reviewed and approved by the experimental center of First Affiliated Hospital of Henan university ethical committee and meet all the guidelines of the committee.

A single channel flexible endoscope (EVIS GIF-Q260J, Olympus, Tokyo, Japan) was used to perform the procedure. Other equipment included an insulated tip knife (model KD-610L; Olympus, Tokyo), a hook knife (model KD-620LR; Olympus, Tokyo), a snare (Boston Scientific, Ref; M00562650), a transparent cap (Olympus, Model No: D-201-11804), and clips (ROCC-D-26-195, Micro-Tech (Nanjing) Co., Ltd, Chinaor HX-610-135, Olympus), injection needle (ET2522-C4,Endo-Flex,Germany), and a virtual input & output (VIO) electrosurgical generator (ICC 200 EA INT; ERBE, Tübingen, Germany). The endoscope and all accessories were sterilized prior to use.

### Description of technology (pure NOTES retrograde cholecystectomy)

The animals were deprived of solid food for 12 h and water for 6 h before the procedure. Under general anesthesia, all animals were placed in supine position. The vulva and vagina were disinfected with a povidone-iodine solution. An incision was created on the posterior vagina wall 15 cm from the vaginal opening with a hook knife. The endoscope with a transparent cap and a snare attached was introduced into the pelvic cavity proceeding upward into peritoneal cavity. The liver and gallbladder were identified (Fig. 1A). The fundic wall of gallbladder was grasped using a biopsy forceps and the snare was released to ligate the fundus (Fig. 1B). Saline solution was injected into the gallbladder bed to enlarge the space between the gallbladder and liver. The gallbladder was then carefully dissected from the bottom (fundus) downward to the porta hepatis using hook and IT knives with the assistance of the snare (Fig. 1C). The cystic duct and cystic artery were easily identified and segregated, and clipped twice (Fig. 1D) to allow the cystic duct and artery to be isolated from the gallbladder using a hook knife to cut between the clips (Fig. 1E). The gallbladder was removed via the vagina using the snare under endoscopic monitoring without suturing vaginal crevasse (Fig. 1F).

During the procedure, intra-abdominal pressure was not measured and air was removed from the abdomen by

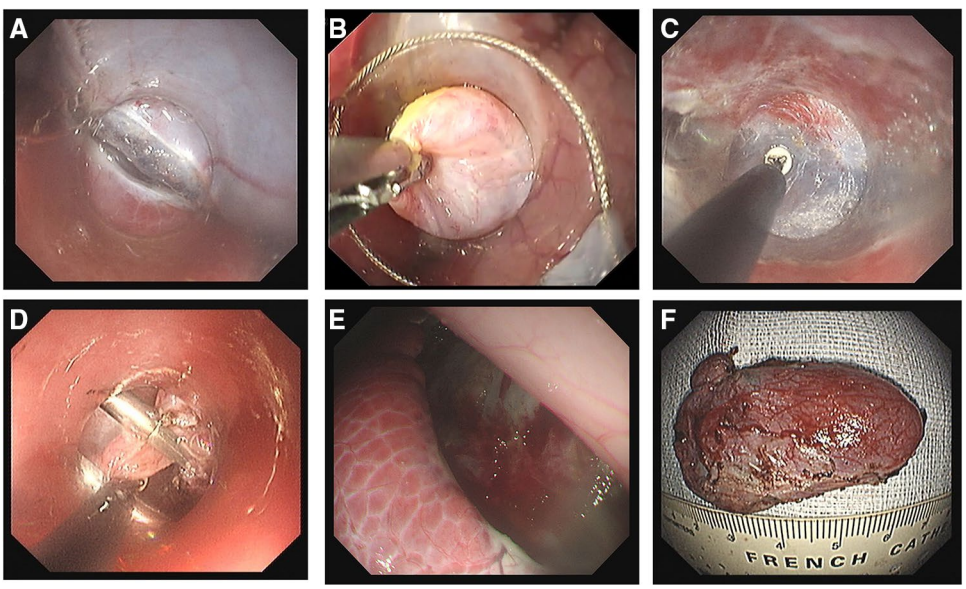


**Fig. 1** **A** Incision at the adherence point of gallbladder and liver. **B** Snare ligation to assist the dissection of the gallbladder. **C** Gallbladder dissection. **D** Endoscopic clipping of the cystic duct and artery. **E** Gallbladder bed (wound) after the cholecystectomy. **F** Gallbladder specimen

aspiration through the endoscope. The anesthesiologist in the team monitored the airway pressure and informed the endoscopist if the pressure in the airways increases which prompts the operator to aspirate air with the endoscope.

### Video description

Video 1 is from a single procedure which shows pure NOTES retrograde cholecystectomy using the porcine model. The endoscope with a snare attached on the transparent cap was introduced into the pelvic cavity through the vagina then proceeding upward into peritoneal cavity. The liver and gallbladder were identified and the fundus of the gallbladder was ligated with the snare and then dissected free from the gallbladder fossa using a Hook/IT knife. The cystic duct and artery were clipped and separated from the gall bladder using a Hook knife. The specimen was then removed through the vagina using the snare.

## Results

We successfully performed pure NOTES retrograde cholecystectomy in 8 consecutive pigs. The average procedure time was 53 min (range 40–60 min). No severe bleeding or any other complications were observed either during or after the procedure. A normal diet was given to the animal on the same day, after the procedure. All the animals recovered completely and survived in good general condition with appropriate weight gain until euthanized on day 30. The vaginal incision site completely healed. At necropsy no severe adhesions in the pelvis to the entry point were observed (Fig. 2). At autopsy the peritoneal cavity of each of the animals was examined with particularly paid attention to the site of cystic duct, the clips and the gallbladder. No signs of intraperitoneal infection were observed in any of the animals. The clips were still present in good positions in all the animals. The incision healed well with no signs of injury to the adjacent organ.

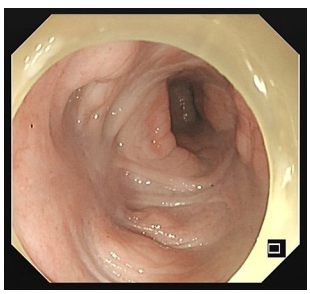

**Fig. 2** Follow up image of the vaginal incision site

## Discussion

Multiple transvaginal NOTES procedures have been described in animal models. Transvaginal access is the most frequently reported NOTES access route in clinical trials. Most cases of transvaginal NOTES procedures reported so far have utilized a hybrid NOTES approach, where at least one laparoscopic port has been used for insufflation, visualization, retraction and/or dissection [20–25]. Although, NOTES cholecystectomy is less invasive, it has failed to gain traction for numerous reasons, including difficulty in separating the gallbladder from the surrounding tissue during transvaginal cholecystectomy. In addition, the cystic duct and artery are a challenge to find due to being obscured in the fatty tissue which results in prolonging the procedure time. Thus, laparoscopy cholecystectomy usually is used. To simplify the operation, we proposed a novel technique which we call it pure NOTES retrograde cholecystectomy. In this study, we successfully completed the procedure in eight consecutive pigs using a single channel flexible endoscope. There were no serious adverse events, postoperative complications or deaths.

Our proposed novel technique mimics the surgical cholecystectomy technique termed retrograde or "fundus-first" cholecystectomy performed during open cholecystectomy and in difficult laparoscopic cholecystectomies where the standard dissection starting at the triangle of Calot and progressing towards the fundus of the gallbladder is considered challenging. The authors' technique involves retrograde dissection from the fundus towards the triangle of Calot via a flexible endoscope introduced transvaginally and assisted by snare traction applied to the gallbladder fundus. This is a potentially important technical innovation if pure NOTES cholecystectomy is to ever reach efficiency that rivals that of laparoscopic cholecystectomy.

Marescaux et al. and others have previously reported examples of transvaginal NOTES cholecystectomy [26, 27]. All of these cases have utilized some form of transabdominal laparoscopic assistance, had longer procedure times, and failed to gain widespread acceptance. One of the possible reasons is the complexity of the procedure due to the need for rigid laparoscopic instruments and double channel endoscopes which are comparatively difficult to control.

Here, we successfully performed snare-assisted pure NOTES retrograde cholecystectomy using the standard endoscopic instruments (biopsy forceps, snare, hook knife, IT knife). In our experience, pure NOTES cholecystectomy using the retrograde approach performed with a single channel flexible endoscope proved to be safe and feasible with a significantly reduced procedure time and quick recovery. This method allowed safe dissection of

gallbladder with the assistance of a snare. The cystic duct and artery were isolated, identified, clipped, and divided at the end of the dissection. In addition, we don't need another abdominal port to ensure no bowl injury. Because when we perform the incision on the vaginal wall, we perform it very carefully making incision on the serosa and enlarge the incision using IT knife. Because IT knife has tip (through that heat/electric can't be transferred) which is safe and helps to prevent damage to the adjacent organs.

The translation of this technique to human subjects seems straight forward and if successful will provide a new path to pure NOTES. However, further investigations and with large sample size and especially those in humans are required for confirm the preliminary observation.

There are some concerns or limitations regarding pure NOTES transvaginal retrograde cholecystectomy. First, this approach is limited to the patients with female reproductive anatomy. Additional experience with this technique is required before starting studies to compare transvaginal retrogade cholecystectomy with conventional laparoscopic and hybrid NOTES approaches.

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## Compliance with ethical standards

**Disclosure** Drs Bing-Rong Liu, Saif Ullah, De-Liang Li, Dan Liu, Li-Xia Zhao, Wenyi Yang, Ling-Jian Kong and Ji-Yu Zhang have no conflicts of interest and financial ties to disclose.

## References

1. Bar-Meir S et al (2001) Gallstones: prevalence, diagnosis and treatment. Isr Med Assoc J 3(2):111–113
2. Pak M, Lindseth G et al (2016) Risk factors for cholelithiasis. Gastroenterol Nurs 39(4):297–309
3. Buffet C et al (2000) Gallstones: epidemiology, physiopathology, diagnosis, treatment. Rev Prat 50(17):1953–1957
4. Pelletier G et al (2002) Gallstones and their complications. Rev Prat 52(4):427–433
5. Kim SS, Donahue TR et al (2018) Laparoscopic cholecystectomy. JAMA 319(17):1834
6. Lirici MM, Tierno SM, Ponzano C et al (2016) Single-incision laparoscopic cholecystectomy: does it work? A systematic review. Surg Endosc 30(10):4389–4399
7. Lyu Y, Cheng Y et al (2019) Single-incision versus conventional multiport laparoscopic cholecystectomy: a current meta-analysis of randomized controlled trials. Surg Endosc. https://doi.org/10.1007/s00464-019-07198-8
8. Evers L, Bouvy N et al (2017) Single-incision laparoscopic cholecystectomy versus conventional four-port laparoscopic cholecystectomy: a systematic review and meta-analysis. Surg Endosc 31(9):3437–3448
9. Matsubara K, Urushihara T, Oshita A et al (2018) Single-incision laparoscopic cholecystectomy for gallbladder torsion: a case report and literature review. Asian J Endosc Surg 11(2):165–168
10. Rattner D et al (2006) ASGE/SAGES working group on natural orifice translumenal endoscopic surgery. Surg Endosc 20:329–333
11. Willingham FF et al (2009) Natural orifice versus conventional laparoscopic distal pancreatectomy in a porcine model: a randomized, controlled trial. Gastrointest Endosc 70:740–747
12. Peng C, Ling Y, Ma C et al (2016) Safety outcomes of NOTES cholecystectomy versus laparoscopic cholecystectomy: a systematic review and meta-analysis. Surg Laparosc Endosc Percutan Tech 26(5):347–353
13. Sodergren MH, Markar S et al (2015) Safety of transvaginal hybrid NOTES cholecystectomy: a systematic review and meta-analysis. Surg Endosc 29(8):2077–2090
14. Bernhardt J, Sasse S et al (2017) Update in natural orifice translumenal endoscopic surgery (NOTES). Curr Opin Gastroenterol 33(5):346–351
15. Khashab MA, Kalloo AN et al (2011) Critical analysis of hot topics in NOTES. Nat Rev Gastroenterol Hepatol 8(10):565–572
16. Lehmann KS et al (2010) The German registry for natural orifice translumenal endoscopic surgery: report of the first 551 patients. Ann Surg 252:263–270
17. Salinas G et al (2010) Early experience in human hybrid transgastric and transvaginal endoscopic cholecystectomy. Surg Endosc 24:1092–1098
18. Kelly MD et al (2009) Laparoscopic retrograde (fundus first) cholecystectomy. BMC Surg 9:19
19. Hubert C, Annet L et al (2010) The "inside approach of the gallbladder" is an alternative to the classic Calot's triangle dissection for a safe operation in severe cholecystitis. Surg Endosc 24(10):2626–2632
20. Khashab MA, Kalloo AN (2010) Natural orifice translumenal endoscopic surgery. Curr Opin Gastroenterol 26:471–477
21. Nassif J et al (2009) Transvaginal extraperitoneal lymphadenectomy by Natural Orifices Transluminal Endoscopic Surgery (NOTES) technique in porcine model: feasibility and survival study. Gynecol Oncol 112:405–408
22. Lomanto D et al (2009) Total transvaginal endoscopic abdominal wall hernia repair: a NOTES survival study. Hernia 13:415–419
23. Allemann P, Perretta S, Marescaux J (2009) Surgical access to the adrenal gland: the quest for a "no visible scar" approach. Surg Oncol 18:131–137
24. Santos BF, Hungness ES (2011) Natural orifice translumenal endoscopic surgery: progress in humans since white paper. World J Gastroenterol 17:1655–1665
25. Zorron R et al (2010) Transvaginal hybrid natural orifice transluminal endoscopic surgery retroperitoneoscopy-the first human case report. J Endourol 24:233–237

26. Marescaux J et al (2007) Surgery without scars: report of transluminal cholecystectomy in a human being. Arch Surg 142:823–826
27. Noguera JF et al (2008) Transvaginal liver resection (NOTES) combined with minilaparoscopy. Rev Esp Enferm Dig. 100(7):411–415