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# The NOTES Approach to Management of Urinary Bladder Injury

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## ABSTRACT

**Background and Objectives:** Inadvertent bladder injury is a potential complication of various urological and pelvic surgeries. Bladder injury can also be a complication of natural orifice transluminal endoscopic surgery (NOTES). The aim of this study was to test the feasibility of a NOTES approach to repair bladder lacerations in a blinded porcine study.

**Methods:** Intentional bladder lacerations were made to mimic accidental injury during NOTES in 7 pigs. In 3 animals, the site of bladder injury was identified and repaired by a blinded endoscopist. Bladder laceration and transluminal access sites were closed with Endoclips. Leak test was performed to confirm adequate closure. Survival animals were monitored postoperatively and surgical sites were inspected for abscess, bleeding, or damage to surrounding structures at necropsy.

**Results:** Complete endoscopic closure of bladder injuries was achieved in all 7 animals with a negative leak test. The site of laceration was successfully identified by the blinded endoscopist and repaired in all 3 animals in which it was attempted. Survival animals had an uneventful postoperative course without any complications.

**Conclusion:** This blinded feasibility study shows that urinary bladder injury occurring during NOTES can be successfully managed via a NOTES approach using currently available endoscopic accessories.

**Key Words:** NOTES complications, Natural orifice surgery complications, Bladder laceration, Endoscopic bladder repair, Natural orifice transluminal endoscopic surgery.

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## INTRODUCTION

The evolution of natural orifice transluminal endoscopic surgery (NOTES) has produced a less-invasive alternative approach to surgery.[1] The NOTES approach has been applied successfully in animal models to various surgical procedures like cholecystectomy, appendectomy, hysterectomy, oophorectomy, splenectomy, nephrectomy, and others, and recently human studies have been reported as well.[2-11] Despite the enthusiasm towards the concept of NOTES, there are still questions and concerns regarding NOTES complications. Could the NOTES endoscopist manage complications? Would a complication mean failure of the NOTES operation and conversion to a laparoscopic or open procedure?

Injury to abdomino-pelvic structures is a potential complication during surgery. Iatrogenic bladder laceration is one type of organ injury that has been described, particularly as a potential complication of urological and pelvic procedures.[12-17] Accidental bladder injury may occur as a complication of 1% to 2% of laparoscopic pelvic surgeries.[16,17] These bladder lacerations may be directly caused by trocar placement, blunt and sharp dissection, or thermal injury to the bladder.[17] In the same manner, it is also possible that bladder injury could be a complication of NOTES procedures as well.

Bladder injuries or perforation may be treated with simple bladder catheterization with or without open or laparoscopic repair.[12,16,18] However, very little data are available regarding management of NOTES complications using flexible endoscopes alone in a pure NOTES fashion.[19,20] For NOTES to gain acceptance as a less invasive surgical approach, the endoscopist should be able to recognize and address surgical complications. In this study, we evaluated the feasibility of using a NOTES approach to repair accidental bladder lacerations caused during NOTES in a blinded porcine study using currently available endoscopic tools.

## MATERIALS AND METHODS

### Subjects

Seven female pigs (sus) weighing 60 kg to 80 kg were obtained from the University of Florida Swine Unit. The Institutional Animal Care and Use Committee approved the study protocol.

### Equipment

Both single- and double-channel gastroduodenoscopes (GIF-140 and GIF-2T160; Olympus Medical Systems, Tokyo, Japan) were used for the study. Endoscopes were high-level chemically disinfected with 3.4% glutaraldehyde solution (CidexPlus, Johnson & Johnson, Irvine, CA). Standard endoscopic biopsy forceps, balloon dilators, and needle knives were used (Boston-Scientific, Natick, MA). Disposable Endoclips (Resolution clips, Boston-Scientific, Natick, MA) were used for bladder closure.

### Preoperative Care and Anesthesia

Animals were housed and maintained at the University of Florida Animal Care Services and were not fed for 24 hours prior to the procedure. Pigs were preanesthetized with Telazol 4mg/kg IM, ketamine 2mg/kg IM, xylazine 2mg/kg IM, and atropine 0.04mg/kg IM. For survival experiments, preoperative enrofloxacin 5mg/kg IM was administered on the day of surgery. Induction was performed with isoflurane 3% to 5% via mask. General anesthesia was administered with Isoflurane 1% to 3.5%. The pigs were intubated and placed on mechanical ventilation.

### NOTES Access and Exploration

The stomach or colon was used for transluminal peritoneal access. For transgastric access, an esophageal overtube (US Endoscopy, Mentor, OH) was placed in the esophagus with a single-channel gastroduodenoscope. The stomach was lavaged with sterile water and then with cefazolin (1g/ 200mL saline solution), over 15 minutes and then suctioned. A double-channel gastroduodenoscope was then advanced through the overtube. A full-thickness incision was made in the wall of the stomach using an endoscopic needle-knife. The incision was balloon dilated to 15mm to allow advancement of the endoscope into the peritoneal cavity. The abdomen and pelvis were explored and major organs were identified. Transcolonic access to the peritoneal cavity was obtained as previously described.[21] After sequential sterile water enemas, antibiotic lavage (cefazolin) followed by internal instillation of povidone iodine solution was performed. The anus and perineum were cleaned with an external povidone iodine scrub. A high-level disinfected double-channel endoscope was inserted and a colotomy performed and balloon dilated to access the peritoneal cavity. Intraperitoneal pressure was monitored and controlled with a manometer (Fisher Scientific manometer, model 8205).

### Bladder Laceration

The endoscope was advanced to the bladder, and an intentional needle-knife laceration was made to simulate accidental transperitoneal bladder injury as a complication of a pelvic or urologic NOTES operation. The bladder was not drained during surgery. Lacerations ranged from 1cm to 3cm in length (1cm in the initial 2 cases), and the needle-knife was advanced into the bladder lumen to confirm a full-thickness laceration **(Figure 1)**. Leakage of urine from the laceration site and resultant decompression of the bladder was seen. The size of the laceration was gauged by comparing its length with an open biopsy forceps.

In 3 animals, repair of the bladder injury was performed in a blinded fashion. The laceration was performed by one investigator, while the repair was attempted by a second investigator who was not present at the time of the initial laceration. The second investigator would have to perform NOTES exploration of the pelvis, find the site of laceration without having prior knowledge of its location, and then attempt endoscopic repair. This would help reduce the bias that lacerations were intentionally made only in sites easily accessible for repair.

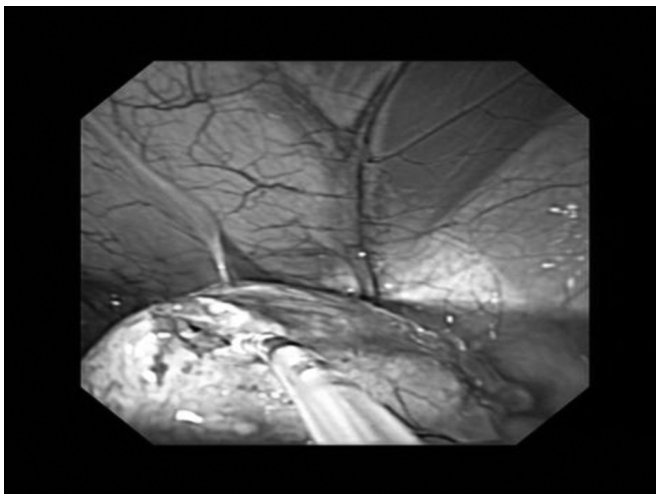

**Figure 1.** Full-thickness bladder laceration with a needle-knife.

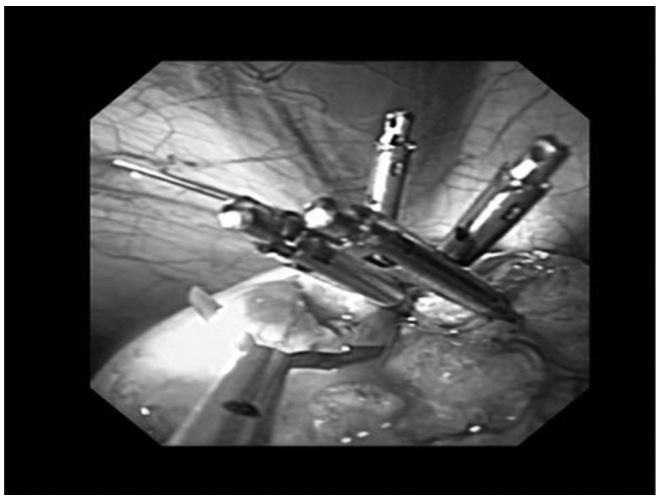

**Figure 2.** Transluminal flexible endoscopic repair of the bladder laceration with Endoclips. The suprapubic needle to be used for leak test is seen in the background.

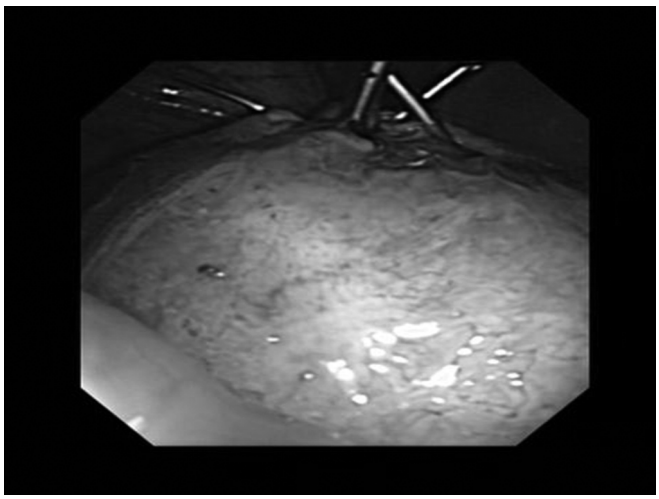

**Figure 3.** Adequate filling and distention of the bladder (after suprapubic needle injection) confirming lack of leak after endoscopic closure.

### Repair of Bladder Laceration

The bladder was grasped with standard endoscopic forceps, and the laceration repaired with endoscopic clips (Resolution clips, Boston Scientific, Natick, MA) placed across the length of the laceration **(Figure 2)**. A leak test was performed by placing a suprapubic needle into the bladder and injecting saline to distend the bladder and endoscopically observe the site of injury for leak **(Figure 3)**. This was confirmed by an independent observer as well. The gastrotomy and colotomy sites were then closed using endoscopic clips.

### Postoperative Care and Necropsy

Acute nonsurvival animals underwent immediate postprocedure euthanasia and necropsy. Survival animals were housed per protocol for 1 week before euthanasia and necropsy. Euthanasia was accomplished with 150mg/kg pentobarbital sodium IV. Survival animals were monitored for signs of distress, behavior changes, loss of appetite, fever, or other signs of illness or complications. At necropsy, the peritoneal cavity and sites of surgery were inspected for abscesses, bleeding, peritonitis, or damage to surrounding structures.

## RESULTS

### NOTES Procedures

Seven pigs successfully underwent NOTES abdominal exploration with urinary bladder laceration. After completion of the NOTES procedure, gastric or colonic access sites were successfully closed with Endoclips. Five pigs were immediately euthanized and necropsied, and 2 pigs were kept alive successfully for 7 days per protocol.

### Bladder Laceration and Repair

In all 7 pigs, successful laceration of the bladder was performed simulating an inadvertent surgical complication. Successful closure of bladder injuries with Endoclips was achieved in all 7 (100%) pigs. Leak test revealed complete closure in all cases. The endoscopist blinded to the exact location and nature of the laceration was able to find and repair the laceration successfully in all 3 pigs in which this was attempted (100%). Each laceration required 2 to 5 Endoclips for complete closure.

### Survival and Necropsy

Survival studies were performed in 2 animals. These pigs were kept alive for 7 days prior to euthanasia and necropsy and had an uneventful postoperative course without any complications. They had good oral intake, ambulated in a normal fashion, and gave no indication of illness or morbidity. Injury and access sites were well healed and without evidence of necrosis, abscess, bleeding, or leakage at necropsy. No complications were noted during any of the NOTES procedures.

## DISCUSSION

NOTES has been proposed as a less-invasive alternative approach to standard surgery. Potential advantages to a

NOTES approach include decreased postoperative pain, decreased risk of hernias and adhesions, shorter hospital stay, faster recovery, and no visible scars. Various surgical procedures have been described in animals and recently in human as well.[2-11] A potential concern about NOTES is that complications can occur that may require aborting the NOTES approach and conversion to standard laparoscopy or open surgery. It would be a major advantage if these NOTES complications could be successfully managed using a pure NOTES approach. We have recently shown the feasibility of using a NOTES approach to manage splenic hemorrhage and small intestinal injuries caused during NOTES.[19,20]

Bladder injury is a known complication that may occur during pelvic and urological surgeries. It is possible that this may also occur during NOTES, during initial transluminal access (especially transcolonic and transvaginal routes), abdomino-pelvic exploration, or during actual surgical resection. There is little data regarding repair of the bladder using flexible endoscopes in a pure NOTES approach with currently available endoscopic accessories. Metzelder and colleagues[22] reported a hybrid NOTES technique with rigid instruments for laparoscopic Endoloop closure of the bladder in a nonsurvival animal study. Lima et al[23] used prototype T-fasteners for cystoscopic closure of the bladder. Partial cystectomy via intravesical transurethral and extravesical transgastric techniques has also been described in a porcine model.[24] These investigators placed Endoloops prior to partial cystectomy in a nonsurvival study. Our pilot study suggests that inadvertent bladder injury may be successfully managed via a pure NOTES approach using currently available endoscopic accessories. This route may obviate the need for conversion to open or laparoscopic surgery.

A few features of our study need to be highlighted: (1) complete closure of the bladder laceration was successful (with a negative leak test) using commercially available endoscopic clips. This may allow greater acceptance of NOTES procedures since endoscopists and surgeons are familiar with these standard endoscopic accessories. Endoclips are designed for hemostasis and are routinely used in the endoscopic therapy of gastrointestinal bleeding. These clips are also being increasingly used nowadays for endoscopic closure of perforations and fistulas, and especially in NOTES. (2) Creation of an adequate full-thickness bladder laceration and its subsequent closure was confirmed by an independent observer. (3) Three cases were performed in a blinded fashion. One endoscopist performed the laceration, and a second "blinded" endoscopist not present at the time of the laceration then attempted NOTES repair. In all cases, the site of injury was successfully identified and repaired. This blinded aspect of our study may help reduce the potential bias that only those lacerations were created that were amenable to NOTES closure.

We also acknowledge the limitations of this initial feasibility study: (a) Small number of animals. Also, findings in a porcine animal study may not be directly extrapolated to humans due to differences between porcine and human bladder anatomy (porcine bladder is thin walled and mainly intraperitoneal). However, this study was designed as a feasibility study, and clips and other endoscopic surgical tools specifically designed for human use will be needed to address management of such complications in human NOTES. (b) Lack of data on long-term effects and complications of bladder injury and NOTES repair. (c) Lack of comparison with standard surgical repair or control group without any closure of the bladder injury to assess spontaneous healing with urinary drainage (indwelling bladder/Foley catheter) alone. However, the latter approach would be practically difficult in the porcine model and hence not performed as part of this initial feasibility study. In addition these were all intraperitoneal bladder injuries, which if left unrepaired would lead to a higher risk of intraabdominal abscess and sepsis compared to an extraperitoneal injury. Small extraperitoneal bladder injuries may be managed by Foley drainage alone and may not require formal closure. In our study, we addressed intraperitoneal injuries and their management. Also, the aim of this study was not to compare NOTES closure with surgical closure but to assess if bladder injuries could be repaired via a pure NOTES approach. In addition, further development of instruments and techniques to perform intracorporeal suturing by NOTES will likely alleviate any concern about larger bladder injuries. Nevertheless, we believe that our technique of clip application is likely safe and effective. (d) There may be some concern that clips used for repair may induce stone formation. However, the clips used in our study were placed on the external surface of the bladder and not on the mucosa. Therefore, risk of stone formation inside the bladder should be minimal. Certainly future development of absorbable clips is necessary and would eliminate this concern. (e) Another concern in this type of surgery is that the presence of suture lines in the colon and bladder may be a good precondition for fistula development. Fistula formation was not seen in the (short-term) survival cases in our study. However, we acknowledge that long-term survival data will be needed to truly address this point. If

this type of surgery were to be performed in humans, interposition of fat between the colon and bladder suture lines could be performed to minimize the risk of fistula formation. (f) This study treated complications that were created by the investigators themselves. It could be argued that bladder lacerations were only created in locations that were easily accessible for NOTES endoscopic repair. However, bladder injuries were treated in a blinded fashion in 3 cases in our study and may help reduce this bias. In this group, lacerations were performed by one endoscopic surgeon, while repair was performed by a second blinded endoscopist who was not present at the time of the initial bladder injury. This blinded endoscopist was able to successfully locate and repair the bladder laceration in all cases where this was attempted. Of note, the blinded surgeon found the laceration in the bladder, but was not blinded to the presence of the laceration. This may have favored successful repair in all cases in the blinded arm. If the presence of the laceration was not known, but suspected, instillation of methylene blue in the bladder could be performed to delineate the site of injury. (g) Our study addressed an immediate complication (ie, bladder injury) detected intraoperatively during the initial NOTES procedure. This could be considered easier to manage due to the acuity of the event, relatively clean surgical field, absence of peritonitis and local infection (which may be seen with delayed detection of the adverse event), and absence of subsequent hemodynamic and systemic inflammatory consequences, which would make surgery difficult and higher risk. More relevant complications may be those much harder to control via natural orifices when detected in the postoperative period after NOTES (hours or days after surgery). However, this study focused on intraoperative complications and their management using currently available standard endoscopic tools and not on delayed complications. Despite these limitations, this study shows that intraoperative bladder injury during NOTES can be managed using standard endoscopic clips familiar to endoscopists. Using our technique, the bladder repair proved to be complete without extravasation during leak testing in the immediate period following repair. From a practical standpoint, if bladder injury were to have occurred in a human patient, a NOTES bladder repair would be accompanied by a period of bladder drainage with a urethral catheter. However, despite not having bladder drainage in the 2 surviving animals in our study, no intraperitoneal abscess or collection developed, further substantiating the completeness of our bladder repair.

## CONCLUSION

This blinded pilot study suggests that bladder injury occurring during NOTES can be successfully managed via a NOTES approach using currently available standard endoscopic clips.

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