

Novel method of full-thickness bladder closure with an endoscopic suturing machine: a survival study in a porcine model

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Objective

To assess the feasibility of a pure endoscopic closure method for vesical perforations using fully absorbable material.

Materials and Methods

A pilot experimental study was performed in eight anaesthetized female pigs. Four 10-mm and four 20-mm endoscopic full thickness cystotomies were created. An endoscopic suturing machine (RD-180[®]; LSI Solutions, Victor, NY, USA) was deployed through the working channel of a cystoscope and used to close the incisions with absorbable sutures. Immediate assessment of the quality of the closure was obtained by distending the bladder with saline solution stained with methylene blue under laparoscopic control. After 3 weeks of follow-up, a necropsy examination was performed to check for signs of peritonitis and wound dehiscence and to assess the quality of healing.

Results

The experiment was completed in all eight pigs without complications. The median procedure time was 10 ± 4.3 min. The immediate bladder distention test did not show any methylene blue leakage. The postoperative period was uneventful. The post mortem examination after 3 weeks revealed complete healing of the bladder wall incisions with no signs of infection, wound dehiscence or adhesions in the peritoneal cavity of any of the pigs.

Conclusion

This study describes a successful novel method for endoscopic closure of bladder perforations. The technique was easy, reproducible and safe. Nevertheless, further experimental investigation should be carried out before clinical application of this method.

Keywords

transvesical surgery, NOTES, endoscopy, minimally invasive surgery

Introduction

Natural orifice transluminal endoscopic surgery (NOTES) has represented an area of intense experimental and clinical investigation in the surgical field over the last few years [1–3]. This aim of this technique is to perform surgical procedures using trans-visceral access to the peritoneal cavity, ultimately allowing scarless surgery.

The transvesical route has been described and used for several applications of NOTES, including peritoneoscopy, liver biopsy, thoracoscopy with lung biopsy, nephrectomy, partial cystectomy, varicocelelectomy and appendectomy in experimental settings [4–11]. As with any other route for NOTES, the transvesical port implies the closure of the visceral opening at the end of the procedure. A similar

scenario is presented in the case of iatrogenic bladder perforations, such as those secondary to transurethral bladder resection or to abdominal trauma.

In the field of NOTES, the trend in investigation is expected to be directed towards the refinement of instrumentation and techniques, with the objective of minimizing the technical complexity of its procedures [2].

Our group previously demonstrated the feasibility and the safety of endoscopic closure of bladder perforations with an endoscopic suturing kit in a porcine survival model [12]. In brief, the closure was performed by delivering a suturing device through the working channel of the cystoscope and using absorbable sutures; however, that system presented some limitations as it involved the use of metal clips which were left

in the peritoneal cavity. This leads to a risk of bowel injury and of synthetic small locks inside the bladder, which could represent a lithogenic stimulus. These limitations seemed to negatively affect the minimally invasiveness of the procedure, so further investigation was deemed necessary to further address these issues.

The RD-180® (LSI Solutions, Victor, NY, USA) is a commercially available device which is currently used for the laparoscopic closure of the vaginal cuff in the clinical setting. This device features ergonomic handling, easy loading, and use of fully absorbable sutures, which make it an attractive tool to be tested for other 'off-label' experimental applications. A prototype of the same device has been recently used by Humphreys *et al.* [13] to perform urethro-vesical anastomosis after NOTES radical prostatectomy, both in experimental and clinical settings.

The aim of the present study was to evaluate the feasibility and the safety of a novel method of bladder closure using this device.

Materials and Methods

Study Design

The study was conducted at Minho University, Braga, Portugal, after formal approval by the institution's review board and in accordance with its internal ethical protocol for animal experiments.

Eight female domestic pigs, weighing between 25 and 30 kg, were used. The pigs were not given food or water for 12 h before the procedure. All procedures were performed under general anaesthesia and mechanical ventilation as previously described in detail [12].

Device

The endoscopic closure was performed by using the endoscopic RD-180 5-mm running device (Fig. 1) loaded with braided polyglactin rapidly absorbable sutures.

The device is divided into two components: the suture, which has a short length of modified stainless steel surgical tubing (the 'ferrule') and the suturing machine. The suture is

loaded by fitting the ferrule on the metal jaw of the suturing machine and tractioning it until it becomes fully inserted into the jaw.

Surgical Steps

Figures 2 and 3 and Supporting Information Video S1 show the surgical steps of the procedure.

1. Access

After emptying the bladder, a rigid ureteroscope (Karl Storz, Tuttlingen, Germany) was inserted through the urethra and pneumovesicum was obtained by insufflating CO₂. A 0.035-inch flexible tip guidewire was then inserted and the ureteroscope was removed. A urethral dilator was inserted on the guidewire to allow the introduction of a 21-F rigid cystoscope.

2. Bladder incision

Pneumovesicum was maintained by keeping a continuous CO₂ flow through the rigid cystoscope. A full-thickness longitudinal incision of 10 mm (in four animals) or 20 mm (in four animals) was created at the bladder dome (in all cases) with endoscopic scissors (26168A; Karl Storz, Tuttlingen, Germany) introduced through the working channel of the cystoscope. Then, a Veress needle was inserted into the peritoneal cavity to control the pneumoperitoneum.

3. Bladder suture

A 30-F cystoscope with a 6-mm working channel was introduced into the bladder replacing the 21-F cystoscope. Then, the RD-180 5-mm suturing device was introduced through the working channel of this larger cystoscope. One side of the bladder wall was placed in the jaw of the device tip. The needle was advanced forward through the tissue at ~5 mm from the incision margin into the ferrule attached to its suture held in the device tip's distal end. The needle was retracted, which pulled the now engaged ferrule and suture back through the tissue. The suture was reset by advancing the needle with its now engaged ferrule and suture forward through the empty jaw into the device tip's distal end. Release of the lever returned the needle back to its retracted

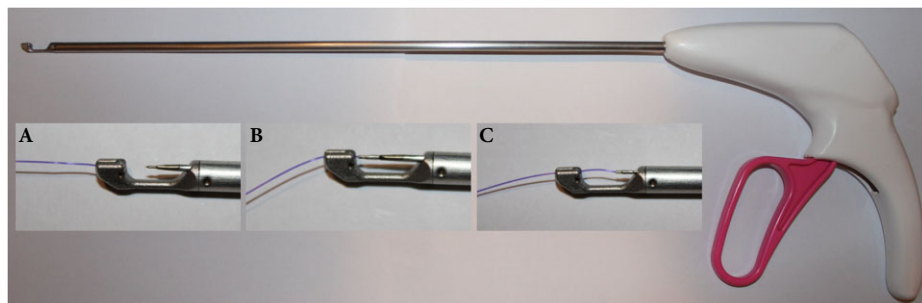
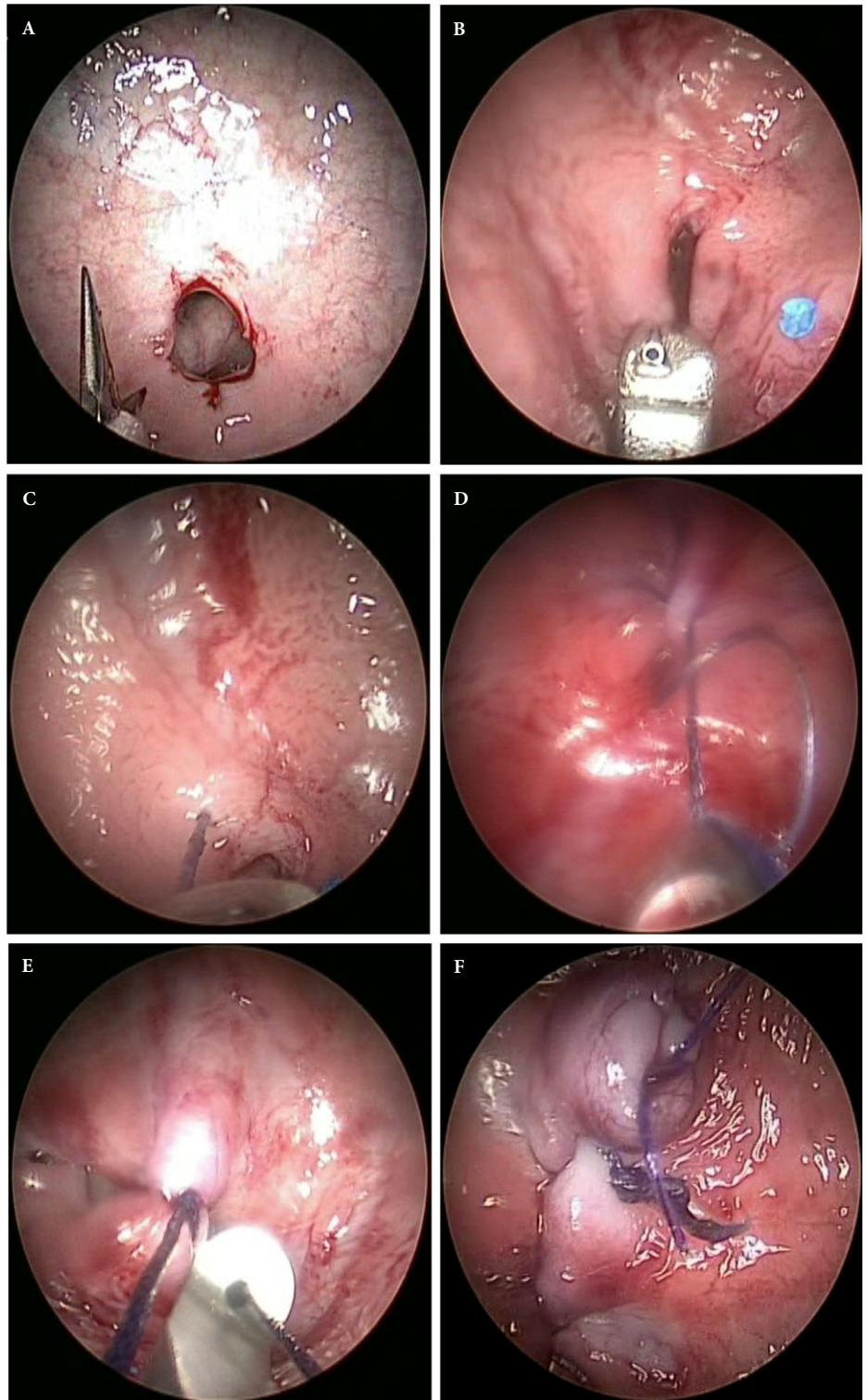


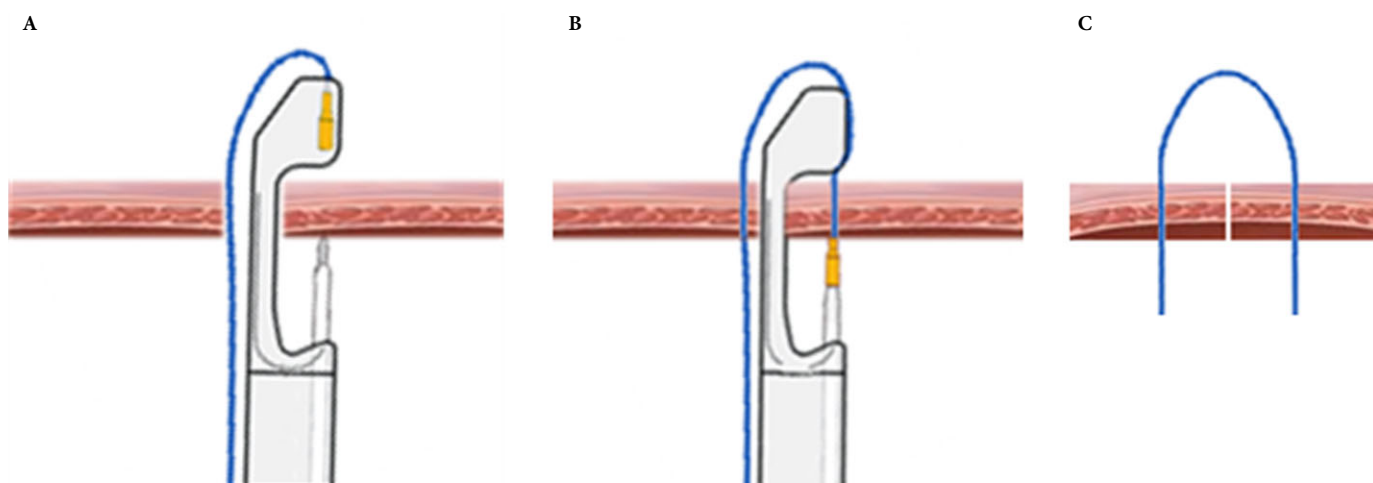
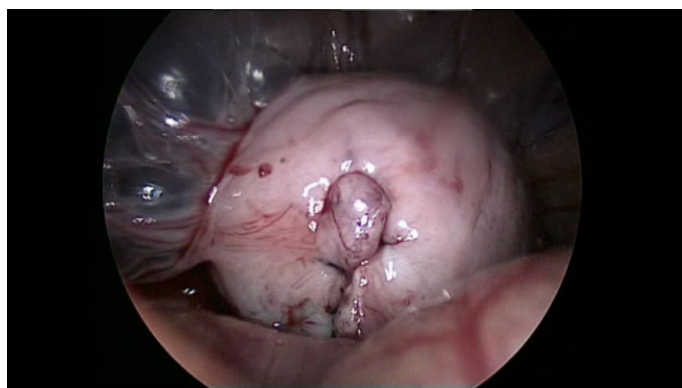
Fig. 1 Device layout. Suturing tip (A) is controlled by pressing the pink knob handle. The suture is fixed to the ferrule (B) in the distal part. When the device is activated the suturing tip attaches to the ferrule and the suture (C) is pulled.

Fig. 2 Surgical steps. **(A)** Bladder incision at the dome. **(B–C)** The suturing tip of the device perforates the tissue and attaches to the ferrule. The suture is pulled and crosses the bladder wall. The same steps are performed in the contra lateral wall. **(D–E)** The knot is tied extracorporeally and pushed through the working channel of the cystoscope with the aid of a knot pusher. **(F)** Final result after multiple sutures.



position in the distal shaft ready for repeat suture placement. After resetting the suturing device, the same steps were taken in the contralateral bladder wall. This led to a suture passing through the two walls. Afterwards, the suturing device was withdrawn and the ferrule was cut. The knot was tied

extracorporeally. With the aid of a knot pusher, the knot was pushed through the working channel of the cystoscope until it reached the bladder wall. The same steps were then repeated until the complete closure of the bladder wall was obtained.

Fig. 3 Diagram of the surgical procedure. (A–C) Schematic representation of the suturing process.**Fig. 4** Leakage test. Instillation of saline solution with 3% methylene blue until the bladder reaches full distention.

Testing

The absence of urinary leakage was tested at the end of experiment in three pigs where a 20-mm incision had been made (Fig. 4). Saline solution with 3% methylene blue was instilled under laparoscopic control until the bladder was fully distended. No urethral catheter was left in the bladder. Then, each pig was assessed daily for 3 weeks. At the end of the follow-up period, a necropsy examination was performed in all the pigs to look for bowel adhesions, signs of peritonitis or wound dehiscence and to assess the quality of healing. In addition, bladder leakage was again assessed.

Data Analysis

The main operating variables were analysed. The duration of the procedure was recorded from the end of the bladder incision till the end of the bladder closure. The pigs were monitored for postoperative events. Necropsy findings were recorded.

Results

The experiment was completed in all eight animals without complications. The median closure time was 10 ± 4.3 min. The procedure allowed the application of each stitch precisely in place and always under good visual control. The knot was tied easily with the aid of the pusher. The procedure was repeated for the number of times necessary until the closure of the incision was obtained. The 10-mm incisions required 1–2 sutures, whereas the 20-mm ones required >3 sutures. There was no limitation on the use of subsequent sutures. The immediate bladder distention test did not show any methylene blue leakage.

The postoperative period was uneventful. The pigs began to void urine normally and tolerated a regular diet which started the morning after surgery. They ambulated freely, exhibiting normal behaviour and no adverse events occurred during this follow-up period. The post mortem examination after 3 weeks showed complete healing of the bladder wall incisions. At the site of vesical perforation, remnants of the sutures were detected, and signs of healing without any evidence of transmural dehiscence or calcification were observed in all pigs. There were no signs of infection, visible methylene blue leakage, or adhesions in the peritoneal cavity of any of the pigs.

Discussion

The present study describes a successful novel method for endoscopic closure of bladder perforations of various lengths using fully absorbable sutures. The technique was easy, reproducible and safe. To our knowledge, this represents the first description of a successful use of fully absorbable material for visceral closure in the field of NOTES.

Several methods and devices for endoscopic closure of the gastrointestinal tract have been described and tested [14]. In urology, the first application of an endoscopic method of suturing was described by Gill et al. [15], who performed percutaneous endopyeloplasty in nine patients with primary PUJ obstruction.

As mentioned, our group has previously applied T-tags for endoscopic closure of bladder perforations [12]. More recently, Metzelder et al. [16] performed bladder closure with a laparoscopic loop via the umbilicus. They introduced a 5-mm Endoloop®, which was placed beneath the bladder dome opening and tightened. This technique required an additional transabdominal access and the use of non-absorbable material. Jeong et al. [11] described a bladder closure technique using a knot attached to metal clips. This technique was also based on the use of non-absorbable clips, with the potential drawback of their migration. Finally, Fyock et al. [17] described the feasibility of a NOTES approach to repair bladder lacerations in a blinded porcine study. The repair was performed with endoscopic clips through a stomach or colon access.

In the present study, we adapted a device originally designed for laparoscopic surgery to obtain the closure of the bladder incisions. A similar device from the same company had already been used to successfully perform vesico-urethral anastomosis during NOTES radical prostatectomy; however, in that experience non-absorbable material was used to achieve cinching of the tissue together for mucosal-to-mucosal apposition [13].

Several solutions to the limitations we had previously identified [12] have been addressed in the present study. A potential concern was the risk of intra-abdominal viscera perforation at the time of the placement of the suture through the bladder wall. This was addressed by manually controlling the depth of the suture placement. We found the RD-180 device allowed a substantial reduction of this risk. The bladder wall is placed inside the jaw of the device tip and the needle perforates the tissue till it reaches the ferrule attached to its suture held in the device tip's distal end. Thus, the distal end of the device prevents contact of the needle with the intra-abdominal viscera. The likelihood of iatrogenic injury is minimized. The configuration of the device ultimately allows complete control of the depth of the suture placement.

Another limitation of the previous technique was the increased risk of lithogenesis secondary to the use of non-absorbable material inside the bladder (i.e. T-tags) to sustain the stitches. Although we postulated that after a period of 4–6 weeks the tags could be voided in the urine through the urethra, a risk of stone formation was unquestionable. The method described in the present study has the advantage of using only fully absorbable material, completely eliminating the potential problem of a lithogenic effect.

Nevertheless, some limitations of the present technique and experiment should be noted. As previously described in other studies, the leakage of CO₂ into the peritoneal cavity requires the insertion of a Veress needle to maintain an adequate pneumoperitoneum [12]; however none of the animals developed cardiorespiratory compromise and the visibility of the perforation was maintained at all times.

Another limitation is the need to use a 30-F cystoscope to allow the passage of the RD-180 device, because the device was originally designed for laparoscopic surgery. This limits its potential use in the human urethra, especially in the male urethra. To overcome this problem a device with a smaller diameter would be needed, to enable its passage in a smaller cystoscope. The next experimental step could be to undertake a proof-of-concept study in a male cadaver model.

The experiment was conducted by performing incisions only at the level of the bladder dome. The rigid structure of the device may increase the difficulty of closing incisions in different anatomical locations of the bladder. The objective of this protocol was to test the efficacy of bladder closure in the locations where the incision for transvesical NOTES surgery is performed and also to test the closure of totally extraperitoneal incisions.

A relative indication of this method may be intraperitoneal bladder perforations. Although some authors have described a conservative approach for bladder injury, through bladder drainage with or without concomitant peritoneal drainage to reduce surgical morbidity, 1 cm is regarded as the threshold to trigger a formal closure of the bladder wall [18,19]. In the case of traumatic intraperitoneal bladder perforations >1 cm and some clinical situations of iatrogenic ruptures during transurethral resection of bladder tumours, our endoscopic transvesical technique could be used clinically to avoid more invasive surgical methods.

A porcine model, despite being anatomically appropriate, carries some intrinsic limitations. Bleeding in the porcine model does not exactly replicate that in humans. In this regard we can speculate that visualization might be facilitated by the insufflations used during the procedure to distend the bladder. As with standard laparoscopic surgery, an increase in intra-abdominal pressure with CO₂ insufflation would be a way of improving visualization when bleeding occurs.

The lack of a control arm represents an intrinsic limitation of the present experimental study; however, the study protocol was intentionally prepared without including control cases, as previous experimental experience at our centre had shown that non-closure of the bladder ultimately results in the death of the animals. As any protocol involving living animals is assessed by our Institutional Animal Care and Use Committee, the inclusion of such a control arm would have resulted in non-approval of the study protocol itself.

Overall, although the encouraging findings from the present experimental study need to be supported by additional investigation, we believe that this method might constitute a significant advance in the challenging field of transvesical NOTES procedures.

In conclusion, the present study demonstrates the feasibility in a porcine model of an easy, reliable and effective endoscopic technique for closure of the bladder wall. The present findings can be regarded as an additional significant step in the field. Nevertheless, further experimental investigation is required before the clinical application of transvesical NOTES can be recommended.

Conflict of Interest

None declared.

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Abbreviation: NOTES, natural orifice transluminal endoscopic surgery.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Video S1 This video shows the main surgical step involved in this experimental study. Can be seen with special emphasis is the endoscopic closure of a bladder perforation with an endoscopic suturing machine.