Percutaneous Ultrathin Flexible Peritoneoscopy for Detecting Peritoneal Metastasis: A Feasibility Study

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Background/Aims: Preoperative diagnosis of peritoneal metastasis is extremely important to select the appropriate treatment strategy and predict the prognosis for patients with gastrointestinal cancer. However, imaging techniques have a limited capacity for detecting peritoneal metastasis. We therefore evaluated the feasibility of percutaneous ultrathin flexible peritoneoscopy in an animal model.

Materials and Methods: Percutaneous ultrathin flexible peritoneoscopy was performed on two mini-pigs under general anesthesia. We punctured the abdominal wall at the anti-Mcburney and umbilical regions using a 16-gauge angiocatheter. Guidewire was inserted through the angiocatheter and we then enlarged the puncture using a biliary dilation catheter and a 6- to 8-mm balloon dilator catheter. After track formation, we inserted a 4.9-mm ultrathin endoscope into the abdominal cavity. The peritoneal cavity was examined, and peritoneal and liver biopsy was performed. The puncture was closed with a single suture. After the procedure, we monitored the general condition of the pigs for 2 weeks.

Results: Percutaneous ultrathin flexible peritoneoscopy was successfully performed regardless of the puncture site location. Peritoneal and liver biopsy was also successfully executed. The mean procedure time was 20 minutes. Formation of the abdominal track was not easily accomplished with standard endoscopic equipment. Nevertheless, none of the abdominal organs were injured. The post-procedure course was uneventful. Minor scarring was observed at the incision site 2 weeks after the procedure.

Conclusions: Percutaneous ultrathin flexible peritoneoscopy is a relatively simple and technically feasible method. However, dedicated accessories for fascial dilation should be developed to ensure the safety of human patients undergoing this procedure. (Korean J Helicobacter Up Gastrointest Res 2013;13:167-172)

Key Words: Laparoscopy; Endoscopes; Peritoneum; Feasibility studies

INTRODUCTION

The main treatment for most gastrointestinal cancer cases is curative resection. However, curative resection is impossible if peritoneal seeding has developed and there is no modality for effectively treating this condition. Therefore, the identification of peritoneal metastasis is absolutely critical for determining the prognosis and selecting the appropriate treatment for patients with gastrointestinal cancer.¹ However, computed tomography imaging techniques have relatively low sensitivity (63 ~ 79%) for diagnosing peritoneal metastases.²⁻⁴ Despite recently improved imaging techniques and additional modalities such as positron emission tomography, staging laparoscopy is recommended for evaluating patients suspected to have peritoneal seeding prior to curative surgery in order to reduce futile laparotomies and associated morbidity.⁵⁻⁷ Laparoscopy is a minimally invasive surgical procedure, but usually requires general anesthesia and performance by surgical teams. Recently, peritoneoscopy using a natural orifice transluminal surgery (NOTES) technique was developed and performed on humans with promising results.⁸ However, this method requires a high level of endoscopic experience, and safe and reliable transluminal closure remains unsolved.⁹ Therefore, relatively simple and safe laparoscopic techniques are being considered. We conducted the present feasibility study to evaluate the use of percutaneous ultrathin flexible peritoneoscopy (PUFP) to access the peritoneum, and perform peritoneal and liver biopsy.

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MATERIALS AND METHODS

1. Animals

Two 35-kg mini-pigs (Micro-pig; Medi Kinetics Co., Ltd., Pyeongtaek, Korea) were used for this investigation. The pigs did not consume anything except water for 1 day before undergoing peritoneoscopy. The animal room was kept clean by removing their feces and urine from the animal room every day. This study was approved by the Animal Ethics Committee of the Inha University Hospital (INHA 110614-99).

2. Procedure

A 4.9-mm ultrathin endoscope (Olympus, Tokyo, Japan) was sterilized by soaking in a 0.55% ortho-phthalaldehyde (Cidex OPA; Johnson & Johnson, Brunswick, NJ, USA) solution for more than 20 minutes, followed by irrigation with sterilized normal saline and povidone-iodine. The pigs were placed in a supine position while under general anesthesia (Fig. 1A). We approached the peritoneal cavity via a direct puncture made at the left anti-Macburney point and umbilicus using a 16-gauge angiocatheter (Fig. 1B). We next inserted a 0.035-inch guidewire (Boston Scientific, Natick, MA, USA) through the angiocatheter lumen (Fig. 1C). We confirmed by fluoroscopy that guidewire had punctured and entered the peritoneum.

A 6-mm incision was made in the puncture site with a surgical knife (Fig. 1D), and the opening was widened with a 6~8 mm Hurricane balloon catheter (Boston Scientific). The ultrathin endoscope was introduced into the peritoneum (Fig. 1E) and a moderate volume of carbon dioxide was insufflated via carbon dioxide insufflators to enhance visualization during peritoneoscopy. The peritoneal cavity and internal contents were inspected, and peritoneal and hepatic biopsies were taken with biopsy forceps through the working channel of the ultrathin endoscope. When the procedure was finished, the endoscope was withdrawn and the skin incision was closed with a single suture. The two mini-pigs were observed for 2 weeks after surgery to assess general condition, weight changes, diet, and development of peritonitis signs such as fever. We also monitored the wound and

Fig. 1. The order of the percutaneous ultrathin flexible peritoneoscopy. (A) The pig was placed in a supine position. (B) The abdominal wall was punctured using a 16-gauge angiocatheter. (C) A 0.035-inch guidewire was introduced through the 16-gauge angiocatheter. (D) A Hurricane balloon catheter was introduced through the 0.035-inch guidewire. (E) After abdominal track formation, a 4.9-mm ultrathin endoscope was inserted into the peritoneum.
healing process for 2 weeks.

RESULTS

1. Peritoneal access

An angiocatheter was inserted without any difficulty into the peritoneum followed by insertion of a 0.035-inch guidewire. When the angiocatheter entered the peritoneal cavity, its lumen became foggy due to the difference in temperature between room air and the peritoneum. The balloon catheter did not pass through the fascial layer along with the 0.035-inch guidewire due to toughness of fascia. Therefore, we initially widened the puncture site with a Soehendra Biliary Dilation Catheter (Winson-Cook Medical, Winston-Salem, NC, USA) and increased the size of the opening from 6 mm to 8 mm with a Hurricane balloon catheter in order to insert the ultrathin endoscope. We were able to dilate the subcutaneous tissue and muscle layer but we failed to dilate the fascial layer due to the toughness of this layer (Fig. 2). Therefore, we cut the fascial layer with a surgical knife or Savary-Gilliard Dilator (Winson-Cook Medical) to further widen the opening in the fascial layer.

2. Peritoneoscopic examination

The peritoneal cavity was grossly inspected; it took approximately 20 minutes to survey the entire region (Fig. 3). The gastroenterologists performing the procedure were not familiar with pig anatomy and or spatial orientation of the animals. Therefore, it took additional time to identify the internal organs with the assistance of a veterinarian. In addition, there was no support structure in the

Fig. 2. Transabdominal approach. (A) After balloon dilation, the incision in the subcutaneous layer was widened. The opening in the fascial layer was not sufficiently dilated. (B) Fluoroscopic image of the balloon dilation. The “waist” (arrow) was not eliminated by balloon dilation.

Fig. 3. Peritoneoscopic view. (A) Peritoneoscopic view of the peritoneum. (B) Peritoneoscopic view of the hepatic surface.
abdominal cavity to help navigate the endoscope. Therefore, we approached in the desired direction with assistance of external compression.

3. Peritoneoscopic biopsy

Biopsy was performed under direct visualization using biopsy forceps. Peritoneal biopsy did not cause bleeding (Fig. 4A) whereas biopsy performed on the hepatic surface caused mild to moderate bleeding (Fig. 4B, C). However, the bleeding quickly stopped and no complications such as hemoperitoneum or abdominal pain developed.

4. Observation after peritoneoscopy

No complications developed on the day of the procedure. During the next day, the pigs resumed normal activities and feeding behavior. Sequelae associated with the procedure did not develop. Weight loss was not observed and normal weight gain progressed during two weeks.

5. Skin examination

The incised skin was sutured using nylon thread without fascial layer closure. The wound was dressed every other day and the wound healing process was observed using a digital camera. Two weeks after the procedure, a minor scar remained without an incisional hernia (Fig. 5).

DISCUSSION

Laparoscopy is a well-established diagnostic tool for staging intraabdominal malignancies and evaluating unexplained ascites.6 Despite its minimal invasiveness, this technique usually requires general anesthesia that is burdensome to both patients and physicians. Therefore, staging laparoscopy is not typically performed. NOTES has
been performed since 2004 and has the advantage of leaving no scars in the abdominal wall. This method can be performed under conscious sedation. However, NOTES in its current state is associated with many shortcomings. First of all, safety of this technique has not been established. In particular, a reliable method for transluminal closure still needs to be developed even though several methods have been evaluated. Secondly, transluminal procedures are associated with a risk of infection. Despite the low incidence of NOTES-related infection, transgastric, transcolonic, and transvaginal approaches inevitably lead to intraperitoneal infection. Third of all, NOTES requires high levels of endoscopic and surgical experience. Training for NOTES is unique and necessitates specialized knowledge. However, it is difficult to acquire the knowledge and skills for successfully performing NOTES because surgeons are not familiar with flexible endoscopy procedures while most gastroenterologists are not familiar with the surgical techniques or peritoneal anatomy. Therefore, we hypothesized that PUFP would ameliorate the drawbacks of NOTES and conventional laparoscopy.

The expected benefits of our approach were as follows. First, PUFP can be performed under conscious sedation rather than general anesthesia. During laparoscopy, skin lifting and insufflation of large volumes of carbon dioxide are needed for trocar insertion. This requires general anesthesia to avoid patient discomfort. However, our method does not require skin lifting or CO₂ pre-insufflation during peritoneal access and tract dilation. Therefore, PUFP can minimize peritoneal irritation and may be performed on patients under alert consciousness with local lidocaine anesthesia. In addition, although there was no report that PUFP was undergone under conscious sedation, there were several articles that simple laparoscopic procedure was performed effectively under conscious sedation.

Secondly, PUFP does not require fascial suturing. Current recommendations suggest closing fascial defects greater than or equal to 10 mm in size to avoid port-site herniation. Routine laparoscopy requires fascial suturing because the trocar diameter is generally larger than 10 mm. Furthermore, one or more separate small holes are made to perform additional procedures such as biopsy. In the present study, we created only one hole with a diameter of 0.6 cm to 0.8 cm. Therefore, the risk of incisional hernia development was low without fascial closure. Smaller abdominal incisions also reduce post-procedural pain and provide excellent cosmetic results. Recently, a single port laparoscopic technique was developed that leaves only one scar. However, a 20-mm abdominal incision must be made to insert the 18- to 20-mm diameter multi-lumen trocar. Third, PUFP does not use a transluminal approach and thus has a lower risk of infection compared to NOTES. The gastric wall is difficult to suture properly via an endoscope, and subsequent complication rates of gastric leakage may be significant. However, the hole made in the abdominal wall during PUFP is easy to close. Finally, the length of the intracorporeal endoscope used for the transumbilical approach is much shorter than that used for the transgastric approach, so the endoscope can be manipulated more efficiently and precisely.

Our findings showed that PUFP is a feasible method, and peritoneal and liver biopsy can be performed using this technique. No major complications associated with the procedure were observed and the skin wound was minor. Despite these encouraging results, our investigation has several limitations. First, the goal of this study was to prove the feasibility of a relatively simple laparoscopic modality compared to conventional laparoscopy and NOTES. In this respect, our experiment was unsatisfactory because our procedure was not simple and various endoscopic accessories were required when dilating the fascial layer wound. Common endoscopic instruments were inadequate for accessing the peritoneal cavity, especially the fascial layer. Therefore, new devices for transabdominal access should be developed to safely perform our procedure on humans. Second, as gastroenterologists we were not familiar with the peritoneal structure and spatial orientation of pigs. Therefore, we identified the internal organs with the assistance of a veterinarian. We should acquire more experience to successfully perform peritoneoscopy. Third, it is not easy to access to the desired location within the peritoneal cavity using the flexible endoscope due to flexibility of the endoscope shaft. We used an ultrathin flexible endoscope that was originally developed for per-
forming transnasal endoscopy on non-sedated patients.\textsuperscript{19} Recently, this device was used for direct peroral cholangioscopy because of its narrow diameter (4.9 mm).\textsuperscript{20} Similar to a conventional upper endoscope, the ultrathin endoscope has a four-way tip deflection capability and 2-mm diameter instrument channel that facilitates forceps biopsy. Therefore, the ultrathin endoscope is useful for simple diagnostic laparoscopy despite its limitation. In summary, we developed a new laparoscopic technique. Our procedure was successfully tested in mini-pigs. With the development of new accessories, PUFP could be widely used and has the potential to be an alternative for diagnostic laparoscopy.

**REFERENCES**


