

Single-port endoscopic cholecystectomy: a bridge between laparoscopic and transluminal endoscopic surgery

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Abstract

Background and objective The intentional puncture of the normal viscera is likely the most important issue limiting the widespread use of natural orifice transluminal endoscopic surgery (NOTES). We developed a new procedure for cholecystectomy using a flexible endoscope via a single port placed in the abdominal wall without visceral puncture (single-port endoscopic cholecystectomy; SPEC) as a bridge between laparoscopic surgery and NOTES. This study aimed to evaluate the technical feasibility of SPEC.

Methods Five pigs were subjected to SPEC. An endoscope was inserted through a 12-mm port placed in the right upper abdomen. After grasping and retracting the gallbladder using a 2-mm retractor that was directly introduced into the peritoneal cavity, gallbladder excision with ligation of the cystic artery and duct using endoclips was carried out.

Results A complete gallbladder excision was carried out easily and safely in all cases. No major adverse events occurred. The mean operating time was 67 min (range 52–84 min).

Conclusions SPEC is a technically feasible procedure. It is simpler, easier, and safer than NOTES cholecystectomy. SPEC could be a less invasive alternative to the conventional four-port laparoscopic cholecystectomy.

Keywords Single-port · Cholecystectomy · Natural orifice transluminal endoscopic surgery (NOTES) · Single-port endoscopic cholecystectomy

Introduction

Cholecystectomy is the standard treatment for patients with symptomatic gallstone, benign tumor, and acute cholecystitis [1, 2], and laparoscopic cholecystectomy is the most common laparoscopic operation performed worldwide. Recently, natural orifice transluminal endoscopic surgery (NOTES) has been proposed as a less invasive alternative to conventional open or laparoscopic surgery [3]. The most important advantage of NOTES is zero or minimal trauma to the abdominal wall; therefore, it is expected to reduce postoperative pain, wound complications, and length of hospital stay. NOTES procedures performed via transgastric, transcolonic, transvesicle, and transvaginal access have been shown to be feasible in recently published laboratory animal studies [4–18]. More recently, NOTES has entered the clinical arena; several reports on NOTES procedures, such as transgastric percutaneous endoscopic gastrostomy (PEG) rescue [19], transvaginal cholecystectomy [20–23], and transvaginal appendectomy [24], have been published. These reports showed that NOTES is feasible and safe even for humans. However, clinical data in this area is too preliminary for drawing any meaningful conclusion.

The NOTES concept, i.e., no-scar operation, is very attractive in surgical fields; however, it is still unclear if NOTES can be widely acceptable in clinical settings. The intentional puncture of the normal viscera (e.g., stomach, vagina, colon) is one of the most important issues limiting the widespread use of NOTES. Although NOTES can offer no or minimal abdominal scar, it yields visceral scars. The potential intraperitoneal infection resulting from the visceral puncture is also a critical problem. Moreover, we recognize that NOTES procedures, particularly for transgastric NOTES, are technically complicated on the basis of our NOTES experimental study [18].

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We hypothesized that a procedure for intraperitoneal surgery using a flexible endoscope via a single port placed in the abdominal wall (not transluminal access) can circumvent the above-mentioned problems associated with NOTES. Although this approach requires one small abdominal incision, it could simplify the procedure and decrease the invasiveness of the surgery compared with NOTES because visceral puncture is unnecessary. It could also be a less invasive alternative to conventional laparoscopic surgery. This experimental study was performed to determine whether this approach for cholecystectomy (single-port endoscopic cholecystectomy; SPEC, Fig. 1) is technically feasible.

Methods

Animals and equipment

SPEC was attempted in five nonsurvival experiments on pigs (30–40 kg body weight). The ethical review board of the institution approved the protocol for this study. The procedures were carried out under general endotracheal anesthesia.

A flexible, forward-viewing endoscope (GIF-Q260J; 9.9 mm in external diameter, 1.35 m in full length; Olympus Medical Systems, Tokyo, Japan) with a water-jet system and commercially available flexible endoscopic accessories were used. The endoscope was not sterilized since this acute experimental study was only designed to

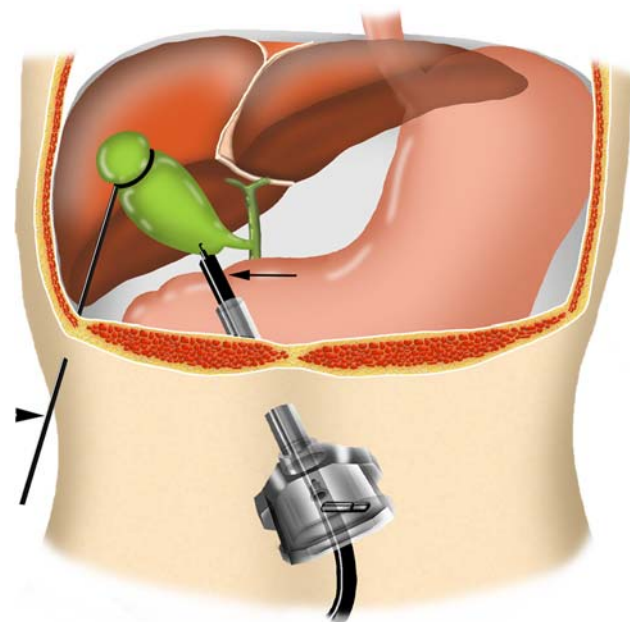


Fig. 1 Schematic of single-port endoscopic cholecystectomy. *Arrow* the flexible endoscope, *arrowhead* the Mini Loop Retractor II

assess the technical feasibility. The endoscopic accessories included a Hook knife (KD-620LR; Olympus), a rotatable clip-fixing device (HX-110QR; Olympus), and endoclips (HX-610-135, HX-610-135L; Olympus). An endosurgical generator (PSD-60; Olympus) was used for incision, dissection, and electrocoagulation during surgery. A 12-mm port (a device for laparoscopic surgery; Endopath Xcel[®]; Ethicon Endo-Surgery, OH, USA) was used, and a Mini Loop Retractor II[®] (a visceral retractor with a mini loop; a device for laparoscopic surgery: 2 mm in external diameter; Tyco Health Care, Tokyo, Japan) was also used for gallbladder retraction.

Techniques

Two of the operators who carried out SPEC were gastroenterological surgeons well-experienced in laparoscopic surgery, advanced therapeutic endoscopy, such as endoscopic submucosal dissection, and transgastric NOTES cholecystectomy [18, 25–28].

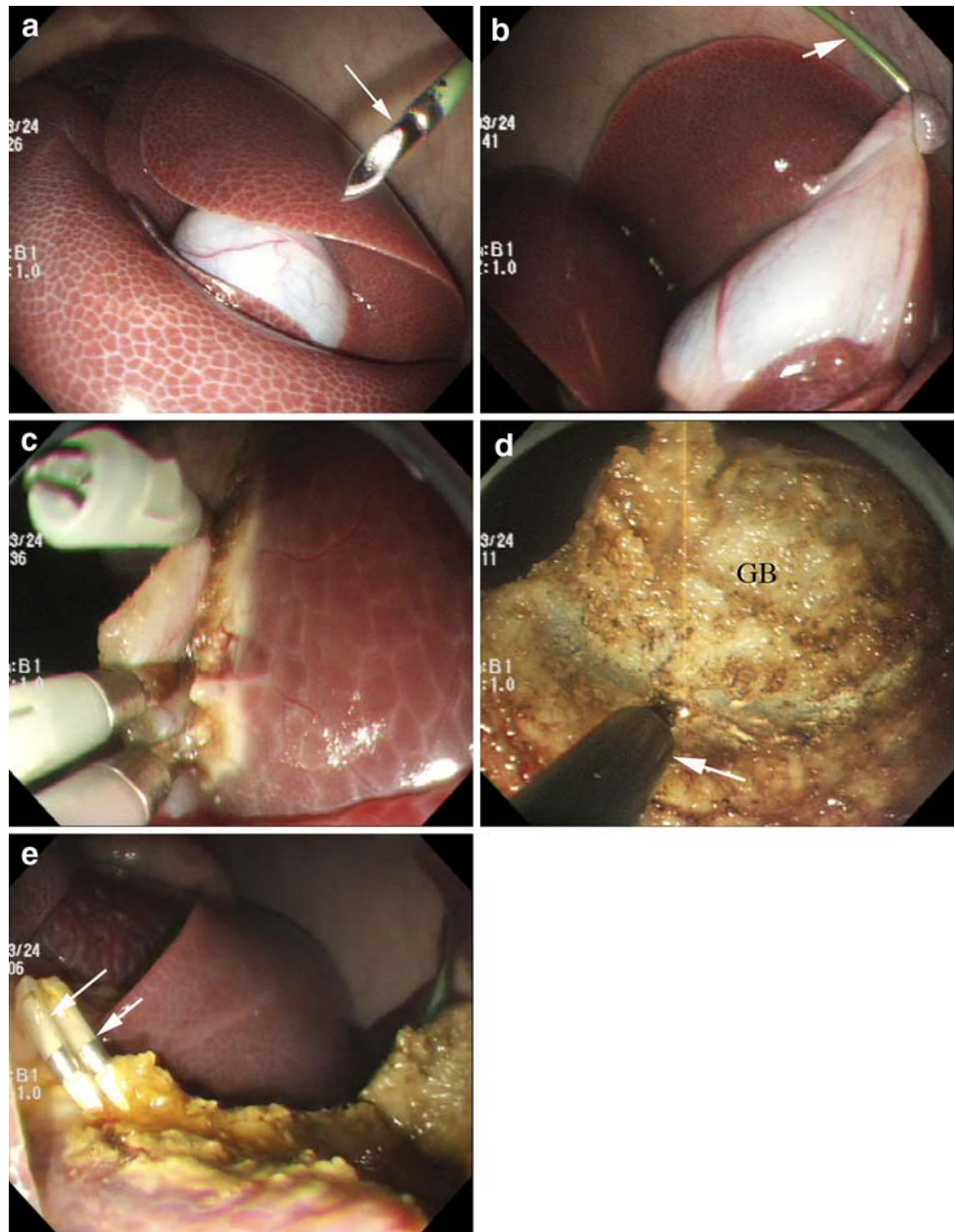
A 12-mm initial access site was established in the right upper quadrant of the abdominal wall by the Hasson open technique. A 12-mm port was introduced into the peritoneal cavity, and a pneumoperitoneum was generated with carbon dioxide at a pressure of 10–15 mmHg using a standard laparoscopic insufflator (UHI-3; Olympus), followed by the insertion of an endoscope through the port into the peritoneal cavity.

Under endoscopic observation, a Mini Loop Retractor II was directly introduced into the peritoneal cavity in the right upper-lateral abdomen (Fig. 2a). The gallbladder fundus was then grasped using the Mini Loop Retractor II (Fig. 2b) and tracted toward the right diaphragm or to the anterior abdominal wall for the necessary exposure of the cystic artery and duct (Fig. 2b). The dissection was begun in close proximity to the gallbladder, at the junction between the infundibulum and cystic artery and duct. After both sides of the cystic artery and duct were dissected, they were clipped twice on the bile duct side and once on the gallbladder side (Fig. 2c) and divided using a Hook knife. The gallbladder was then dissected from the intrahepatic fossa using the Hook knife (Fig. 2d) and retrieved by withdrawing the endoscope through the port site of the abdominal wall. After the cholecystectomy, the surgical site in the peritoneal cavity was lavaged with 100 mL of saline using the endoscope, and then the intraperitoneal fluid was aspirated.

Results

The endoscope provided a perfect view of the intraperitoneal cavity and enabled the easy identification of the

Fig. 2 Procedures for single-port endoscopic cholecystectomy (SPEC)
a Under endoscopic observation, the Mini Loop Retractor II (*arrow*) was directly introduced into the peritoneal cavity in the right upper-lateral abdomen. **b** The gallbladder fundus was grasped and retracted using the Mini Loop Retractor II (*arrow*) to expose of the cystic artery and duct. **c** Endoscopic view after clipping of cystic artery and duct. **d** Endoscopic view during dissection of gallbladder from intrahepatic fossa using Hook knife (*arrow*); GB gallbladder. **e** Endoscopic view of surgical site after cholecystectomy. Note that the endoclips (*arrows*) secured the cystic artery and duct



gallbladder (Fig. 2a). The gallbladder traction using the Mini Loop Retractor II provided excellent visualization and quick access to the cystic artery and duct (Fig. 2b, c). A complete gallbladder excision, with ligation of the cystic vessels and duct using endoclips (Fig. 2c), was completed in all cases. During the detachment of the gallbladder from the liver bed (Fig. 2d), a minor perforation (1 mm in diameter) of the gallbladder using the tip of the Hook knife occurred in one case; however, no significant bile leakage occurred. Liver-surface bleeding occasionally occurred during the course of the dissection. This either stopped spontaneously or was easily managed by electrocoagulation using the Hook knife. The peritoneal lavage using the

endoscope after the cholecystectomy was successfully carried out in all cases. The aspiration of the intraperitoneal fluid through the endoscope was satisfactory. The endoscopic observation after the cholecystectomy revealed that the endoclips secured the cystic artery and duct and that neither bile nor blood leaked from this site (Fig. 2e). The mean operating time was 67 min (range, 52–84 min).

Discussion

In this experimental study, we clearly demonstrated that SPEC using a flexible endoscope is technically feasible and

simple. Although a minor perforation of the gallbladder occurred in one case, a complete gallbladder excision was completed in all cases. If a major bile leakage occurred, the visibility conditions around the gallbladder may decrease. However, the endoscope has an aspiration system; therefore, a complete gallbladder excision could be completed after the aspiration of the bile even under such circumstances. The mean operating time for SPEC (67 min) is much shorter than that of transgastric NOTES cholecystectomy performed in our previous study [18] (e.g., 200 min, data not shown). This simply reflects the feasibility and simplicity of SPEC. In fact, all the procedures in SPEC were less stressful compared with those of transgastric NOTES cholecystectomy. The transgastric NOTES cholecystectomy is complicated because it is necessary to work with a flexible endoscope in a retroflexed position, which leads to spatial incongruity and difficulties in orientation, and even to technical difficulties [18]. In transvaginal NOTES, the safety of inserting long devices between the intestines and having the angle of approach from below rather than from above is questionable. By contrast, in SPEC, the endoscope can directly and straightly approach the gallbladder, which results in simplifying the procedures for cholecystectomy.

The single-port surgery using a flexible endoscope presented herein differs from NOTES, but is characterized by the performance of an exclusive transparietal endoscopic surgery producing minimal postoperative scar and discomfort. It is another step toward NOTES and it is considered a bridge between laparoscopic surgery and NOTES. The most important advantages of the single-port surgery using a flexible endoscope over NOTES are as follows: (1) it can be performed without an intentional puncture of the normal viscera, and (2) a postoperative infection resulting from contamination of gastric or vaginal contents can be ruled out. Conversely, the only considerable disadvantage of the single-port surgery using a flexible endoscope compared with NOTES is the necessity for one small (12 mm in diameter) incision in the abdominal wall. However, the currently reported NOTES procedures applied to humans requires one to three assist ports (3–10 mm in diameter) in the abdominal wall [20–24]. Pure-NOTES, e.g., NOTES without any transparietal support, is technically difficult at present. Therefore, we consider that the single-port surgery using a flexible endoscope in which the entire procedure can be performed from one abdominal incision without visceral puncture is better than the current NOTES in every respect.

Generally, techniques involving four ports have been used for the current standard laparoscopic cholecystectomy. Several attempts have been made to reduce operative trauma by further decreasing the number and size of the ports used in laparoscopic cholecystectomy [29–33]. The

use of three [33, 34] or two [31, 32, 35] ports instead of the conventional four, and the use of mini-instruments [29, 30], or the use of three ports placed through the umbilicus (natural orifice transumbilical surgery; NOTUS) [36], is definitely a step in this direction. These studies demonstrated that less postoperative pain is associated with the reduction in either the size or number of ports. A transvaginal approach using laparoscopic instruments with transparietal support via a single port placed in the umbilicus has also been reported [37, 38]. Recent surveys [39, 40] have shown that patients would largely favor NOTES over the standard laparoscopic surgery, except if NOTES is much riskier than laparoscopic surgery. This result may confirm the importance of body image trauma associated with surgical procedures and warrants surgeons to consider ways of decreasing the number and size of ports [41]. Our approach, namely, single-port surgery using a flexible endoscope, can reduce the number of incisions by up to 80% as well as morbidity related to incision compared with the standard laparoscopic cholecystectomy.

Recently, single-incision laparoscopic surgery (transumbilical) has been a rapidly evolving field as it combines some of the cosmetic advantages of NOTES and allows the surgical procedure to be performed with standard surgical instruments [41–44]. This type of surgery may offer the advantage of reduced postoperative pain and is considered as a possible derivative of NOTES. Transumbilical access surgery could be the route of choice for complex scarless laparoscopic procedure in the future. Tacchino et al. [43] and Merchant et al. [44] reported successful single-incision transumbilical laparoscopic cholecystectomy with no intraoperative adverse events or major perioperative complications. The concept of such single-incision laparoscopic surgery, i.e., no-visible scar operation, seems to be attractive; however, it is still unclear if this surgery can be widely acceptable by most surgeons. In fact, single-incision laparoscopic surgery has never been carried out in Japan.

This experimental study was only designed to assess the technical feasibility and benefits of our novel approach for cholecystectomy using a flexible endoscope. It will require many experiments on animals and survival studies before the true utility of this new approach is established. Although SPEC has not yet been applied to humans, we consider that it will be more widely accepted than NOTES both by physicians and patients. SPEC can be considered for routine practice by surgeons who are familiar with laparoscopic cholecystectomy and advanced endoscopic techniques. SPEC could both reduce incisional pain and improve the cosmetic result. SPEC through the umbilicus may leave no visible scars; therefore, most patients would easily favor such approach. The potential for hidden scars may appeal to patients. The minimal equipment requirement in SPEC may

also be an important advantage over the conventional four-port laparoscopic cholecystectomy. Introducing SPEC would yield maximum economic benefit. The self-cleaning lens capability of the flexible endoscope may simplify the procedures of the cholecystectomy, which is an important advantage over the conventional laparoscopic surgery. Much time may be saved by avoiding repeated laparoscope removal, cleaning, and reinsertion. On the other hand, the indication of SPEC in the clinical setting remains uncertain. We consider that, for safety reasons, SPEC should be initially indicated only for patients with symptomatic cholelithiasis without history of cholecystitis.

Palanivelu et al. [45, 46] recently carried out the first successful transumbilical cholecystectomy and appendectomy using a flexible double-channel endoscope in humans. In their procedures, two ports (a 15-mm port in the umbilicus for the working flexible endoscope and a 3-mm port in the left hypochondrium or the right lower abdomen for the gallbladder or appendix retraction) were placed on the abdominal wall. Although their technique differs from the single-port surgery such as SPEC presented herein, it is a step toward an even less invasive surgical procedure. Unfortunately, they had high conversion (to laparoscopic surgery) and complication rates [45]; therefore, the safety of the transumbilical surgery using a flexible endoscope may be questionable in humans at present. However, further instrument and accessory improvements will increase both the success rate and acceptance of cholecystectomy or appendectomy using a flexible endoscope [45]. Should any problem arise, such procedures using a flexible endoscope including our SPEC can always be easily converted to a standard laparoscopic surgery, with no need for a change in operative position.

In conclusion, SPEC is a technically feasible procedure. It may be simpler, easier, and safer than transgastric NOTES cholecystectomy. SPEC could be a less invasive alternative to the conventional four-port laparoscopic cholecystectomy. The single-port surgery using a flexible endoscope may serve as a bridge between the present laparoscopic surgery and future NOTES.

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