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Single-site versus conventional laparoscopic appendectomy: comparison of short-term operative outcomes

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Abstract
Background Recent developments in minimally invasive surgery have introduced scarless surgeries such as natural orifice transluminal endoscopic surgery (NOTES) and single-site laparoscopic surgery. Among surgical procedures, the appendectomy is one of those targeted for early adoption of new minimally invasive surgical techniques. To date, however, only a limited number of case series have been reported. Thus, the current study aimed to evaluate the safety and feasibility of single-site laparoscopic appendectomy (SSLA) compared with conventional laparoscopic appendectomy (CLA).
Methods The study enrolled 43 patients who consecutively received laparoscopic appendectomy and divided them into SSLA and CLA groups. The clinical characteristics and short-term operative outcomes of these patients were reviewed and compared.
Results The 23 patients receiving SSLA did not differ from the 20 patients receiving CLA in terms of clinical characteristics including gender, age, body mass index (BMI), location of appendix, and severity of inflammation. Likewise, operation times and postoperative complication rates did not differ between the two groups. Short-term operative outcomes such as visual analog pain score and hospital stay were not different. The incision was shorter for SSLA (22.9 ± 3.9 mm) than for CLA (29.0 ± 3.0 mm) ($p < 0.001$).
Conclusions The results of the current study suggest that SSLA is a feasible surgical alternative to CLA with an equivalent level of safety. The data also suggest that SSLA results in better cosmetic outcomes than CLA. Data from larger research studies are necessary to confirm these results and validate the use of SSLA over CLA.

Keywords Appendicitis · Laparoscopic appendectomy · Minimally invasive surgery · Single-site laparoscopic surgery

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A laparoscopic procedure using three conventional ports is the current standard technique for performing appendectomies [1]. Indeed, improvements in surgical techniques and laparoscopic surgical instrumentation have led to shorter hospital stays, faster recovery, decreased complications, and less postoperative pain compared with traditional open surgery [2]. Minimally invasive surgical techniques have continued to evolve, with a focus on reducing surgical trauma and improving cosmetic results. The result has been the development of novel concepts such as natural orifice transluminal endoscopic surgery (NOTES) and single-site access surgery [3].

Although a few reports have described human NOTES appendectomy and cholecystectomy cases, the clinical feasibility of NOTES-based appendectomies currently appears to be limited. Conversely, single-site access surgery is a rapidly evolving trend in the surgical field, with increasing numbers of surgeons focusing on this technique. Single-site laparoscopic appendectomies (SSLA) have been attempted with increasing frequency in a number of surgical centers.

However, although several authors have reported series of SSLA cases, comparison studies evaluating SSLA and conventional laparoscopic appendectomy (CLA) have not yet been reported. Thus, in the current study, we reviewed and compared the short-term operative outcomes of SSLA and CLA and evaluated the feasibility and safety of SSLA.

Patients and methods

The study enrolled 43 patients who underwent laparoscopic appendectomies consecutively from March 2008 to July 2009. We started performing SSLA March 2008. This study is a review of the data from a single surgeon (B.S.M.). Among the enrolled patients, 23 received SSLA, whereas the remaining 20 received CLA. Our study protocol was approved by the institutional review board of the ethical committee of our hospital.

A preoperative diagnosis of appendicitis was determined for all the patients by computed tomography. We defined the location of the appendix preoperatively according to radiologic criteria [4] as follows: paracolic (tip of the appendix adjacent to or along the ascending colon), retrocecal (behind the cecum), pelvic (extending down to the pelvis), and anteromedial (extending toward the midline). We also confirmed the location of the appendix by comparing preoperative radiologic images with intraoperative findings.

We performed SSLA for patients who had acute appendicitis regardless of perforation. However, we excluded patients from SSLA who had generalized peritonitis after perforation, severe adhesion after prior surgery, incidental identification of another disease during laparoscopic investigation, severe cardiac and pulmonary disease, pregnancy, ascites, or coagulation disorders.

The severity of appendicitis was defined based on intraoperative findings as follows: nonspecific inflammation (a minimal to moderate degree of inflammation localized to the appendix), suppurative (severe inflammation with or without involvement of the base of the appendix without definite perforation of the appendix), perforated (perforation of appendix), and abscessed (evidence of a localized abscess pocket around the appendix).

Postoperative pain was measured by visual analog scale (VAS) scoring on postoperative days 1 and 3. The operative time was defined as the duration of surgery, beginning with the skin incision and ending with application of the final wound dressing. The length of hospitalization was calculated by considering the day of operation as day 0. Postoperative complications were followed up for 30 postoperative days.

Surgical procedure

All the patients received preoperative intravenous antibiotics and were placed on the surgical table in the supine position. After standard preoperative preparation, all the patients were given general endotracheal anesthesia. The abdomen was prepared and draped in sterile fashion, with the whole abdomen from the xyphoid process to the suprapubic area exposed for surgery. A 20- to 30-mm transumbilical vertical incision was used for single-site access. The access port was prepared as previously reported [5].

After the transumbilical incision was made, an ALEXIS wound retractor (Applied Medical, Rancho Santa Margarita, CA, USA) was inserted through the incision. A surgical glove was used as an access channel and fixed to the outer ring of the wound retractor (Fig. 1).

At the beginning of the study we used three custom-made 5-mm trocars and a custom-made carbon dioxide (CO_2) gas insertion valve, but we later used two custom-made 5-mm trocars and a 12-mm conventional trocar. The 12-mm trocar was used for either a 10-mm laparoscope or other instruments such as a laparoscopic linear stapler or gauze. The substitution of one 12-mm trocar was useful, especially when the base of the appendix was so severely inflamed that the appendix was removed with the adjacent part of the cecum using laparoscopic linear staplers.

After establishment of pneumoperitoneum, a rigid 30° 5- or 10-mm laparoscope was placed into the peritoneal cavity for visualization (Stryker, San Jose, CA, USA). Two laparoscopic instruments then were introduced into the peritoneal cavity. Two additional articulating 5-mm laparoscopic instruments (Cambridge Endoscopic Device Inc., Framingham, MA, USA) were used as indicated.

Single-site laparoscopic appendectomy was performed using a surgical technique similar to that used for CLA. The mesoappendix was divided using electrocauterization, and appendiceal vessels were ligated using endoscopic metal clips. The appendiceal base was ligated and transected using Endoloops (Ethicon, Cincinatti, OH, USA). Specimen extraction was performed through the transumbilical incision. The wound retractor then was removed securely, and the fascia was closed using continuous 2-0 Vicryl sutures. We did not apply skin sutures, opting

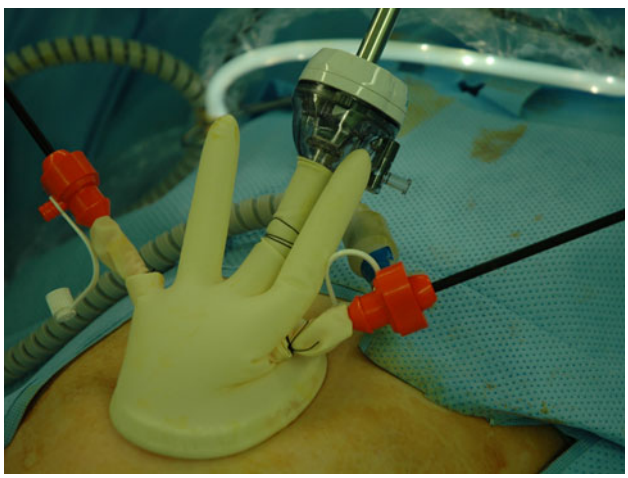

Fig. 1 Full setup of a homemade access port

instead to rely on natural shrinkage. Only simple packing gauze was applied above the umbilical skin incision.

Statistical analysis

Statistical analyses were performed using chi-square tests for categorical variables and Student's *t*-tests for continuous variables.

Results

Of the 43 patients available for statistical analysis, 23 (14 males and 9 females) underwent successful SSLA without conversion to CLA. The two groups did not differ significantly in terms of preoperative parameters such as age, gender, body mass index (BMI), and comorbidity (Table 1). The anteromedial location of the appendix was the most frequent location in both groups. Suppurative change was the most frequently identified change in both groups. The two groups did not differ significantly in terms of either appendix location ($p = 0.200$) or pathologic severity ($p = 0.382$).

We also investigated the operation outcomes for each group. The mean operation time did not differ significantly between SSLA (61.5 min) and CLA (67.5 min) ($p = 0.901$). Likewise, other short-term operative outcomes including mean postoperative hospital stay (4.2 vs 3.8 days; $p = 0.791$), postoperative pain indicated by VAS (3.4 vs 3.1; $p = 0.728$), and postoperative complications (1 vs 0; $p = 0.495$) did not differ significantly between the two groups (Table 2). The total incision length was measured for SSLA and calculated for CLA as the total length of all the skin incisions (Fig. 3), which was significantly shorter for SSLA ($p < 0.001$). Finally, by plotting the operation time against the sequential case number, we found a significant decrease after the 10th case (Fig. 2).

Discussion

Wheeless [5] was the first to introduce the single-port laparoscopy technique in 1972 by performing a single-port laparoscopic female sterilization using a fiberoptic laparoscope through which an electrocoagulation biopsy forceps was inserted into the peritoneal cavity. He suggested that by eliminating additional incisions, surgeons could reduce operation time, skin complications, and the hazards of visceral perforation from trocar insertion. However, not until recently, since the introduction of the NOTES concept, has the single-port laparoscopic (SPL) technique become popular.

Although SPL has many more similarities to conventional laparoscopic technique than NOTES, SPL and conventional laparoscopic surgery do have a significant number of differences. First, because all the instruments are introduced through a single incision, they parallel and impede each other such that adequate triangulation of traction and countertraction is difficult [6, 7]. This problem may be resolved partly through the use of commercially available roticulating instruments such as the Autonomy Laparo-Angle (Cambridge Endoscopic Device Inc., MA, USA), the RealHand (Novare Surgical System Inc., Cupertino, CA, USA), and the Roticulator (Covidien, Mansfield, MA, USA). However, before using these instruments, all surgeons should ascend the learning curve associated with performing SPL by "reprogramming" their eye–hand coordination [8]. Especially, repeated crossing of instruments requires that surgeons adapt to counterintuitive movements and more dominant use of their left hand. Although the learning curve

Table 1 Preoperative parameters of patient characteristics

Variables	SSLA ($n = 23$) (n)	CLA ($n = 20$) (n)	p Value
Mean age (years)	44.7	39.2	0.301
M:F	14:9	11:9	0.697
BMI	23.5	23.9	0.640
Comorbidity	7	8	0.512
Location			
Anteromedial	12	15	0.200
Paracolic	1	1	
Pelvic	3	3	
Retrocecal	7	1	
Severity			
Nonspecific inflammation	8	4	0.382
Suppurative	9	13	
Perforation	3	2	
Abscess	3	1	

SSLA single-site laparoscopic appendectomy, *CLA* conventional laparoscopic appendectomy, *BMI* body mass index

Table 2 Operation outcomes[a]

Variables	SSLA	CLA	*p* Value
Operation time (min)	61.8 ± 23.6	61.1 ± 13.7	0.901
Total incision length (mm)[e]	22.9 ± 3.9	29.0 ± 3.0	<0.001
Hospital stay (days)	4.2 ± 2.3	3.8 ± 1.7	0.791
VAS[b] on POD1	3.4 ± 2.5	3.1 ± 2.9	0.728
VAS on POD3	1.5 ± 1.2	1.3 ± 1.3	0.604
Complication	1[c]	0	0.495[d]

SSLA single-site laparoscopic appendectomy, *CLA* conventional laparoscopic appendectomy, *VAS* visual analog score, *POD* postoperative day

[a] All values are means ± standard deviations

[b] 0 (no pain) to 10 (worst pain ever)

[c] Deep surgical-site infection, which was resolved with antibiotics therapy

[d] Fisher's exact test

[e] The summation of 3 trocar-site incisions

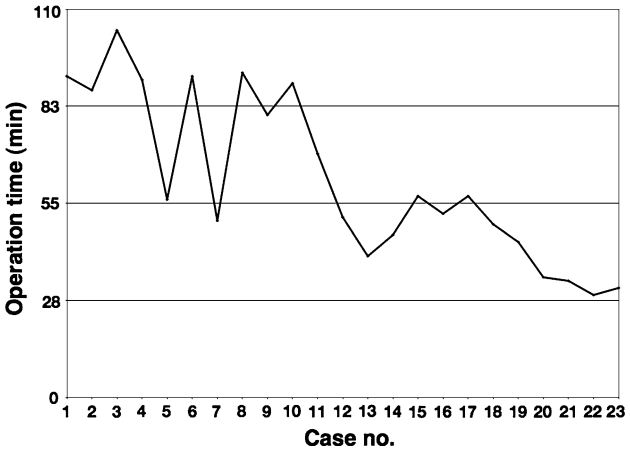

Fig. 2 Operation time (min) by experience (case no.)

associated with this "reprogramming" has not been addressed in previous studies, we found the operation time decreased dramatically after approximately the 10th to 13th case performed. Based on this finding, our data suggest that SSLA has a relatively gradual learning curve of 10 to 13 surgeries for experienced surgeons. (Fig. 3)

The second important issue for SSLA is that of the entry port. Although a few single-port devices are commercially available, none had been approved by the Korean Food and Drug Administration at the time of this study. Thus, for this study, we used a homemade multichannel port system as described previously [6, 7, 9, 10]. The use of this system had some benefits. First, it was more cost effective than any other currently available entry system. Second, we were able to design the number and size of the trocars, which consequently allowed for more freedom in the choice of instruments. We used three 5-mm trocars in early series, then moved to two 5-mm trocars and one 12-mm trocar.

Fig. 3 Umbilical wound in the immediate postoperative period

The trocars were not fixed in the abdominal wall but were floating loosely held by a surgical glove so that we did not need to lengthen the incision for the addition of a 12-mm trocar. In addition, use of the wound retractor provided the additional benefit of preventing subcutaneous emphysema, port-site infection, and bleeding. Through the use of this system, the surgical specimen was easily and quickly extracted through one finger of the entry port system without the use of a specimen-packing pouch.

We found that the short-term operative outcomes and postoperative complications with SSLA were not significantly different from those with CLA, including perforated and abscess-forming appendicitis. Although several series have reported successful outcomes through the use of other single-incision procedures, most have not included perforated or abscess-forming appendicitis [11, 12]. As a result, such single-incision procedures may have limited feasibility as alternatives to CLA.

One case of postoperative deep surgical-site infection occurred in the SSLA group, which likely resulted from inadequate drainage of debridement from the abscess-forming appendicitis. The case was successfully managed by radiologic intervention. After this case, when drain insertion was indicated, it was successfully substituted with vigorous intraoperative irrigation and insertion of a large-bore catheter under direct vision of the laparoscope.

The SSLA technique has many potential advantages over CLA in terms of better cosmesis and fewer wound-related problems. We can assume that the superior aesthetic results of SSLA are due to the shorter total skin incision. Moreover, because the incision site for SSLA is made in the umbilicus, it is hidden, becoming almost invisible after one postoperative month.

Wound-related problems such as hernia, pain, and infection may occur less frequently with SSLA than with

CLA because the number and the size of incisions are less with SSLA. However, we were unable to obtain supporting data to test this hypothesis during this study.

In conclusion, the findings show that SSLA as an alternative to CLA is both feasible and safe. The findings also identified the possibility of better outcomes with SSLA in terms of cosmesis. However, confirmatory data from larger patient studies will be necessary before this can be used as an indication for the SSLA procedure.

Disclosures Min-Soo Cho, Byung Soh Min, Young-Ki Hong, and Woo-Jung Lee have no conflicts of interest or financial ties to disclose.

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