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Single-port laparoscopic appendectomy using a needle-type grasping forceps compared with conventional three-port laparoscopic appendectomy for patients with acute uncomplicated appendicitis: a single-center retrospective study

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Abstract

Objective: To compare the clinical outcomes between single-port laparoscopic appendectomy using a needle-type grasping forceps (SLAN) and conventional three-port laparoscopic appendectomy (CLA) for patients with uncomplicated appendicitis.

Methods: We retrospectively collected clinical data of patients with uncomplicated appendicitis who underwent SLAN or CLA from May 2019 to May 2021 in our center. The patients' baseline characteristics, perioperative outcomes, and follow-up data were compared between the two groups. Additionally, baseline characteristics were compared with postoperative outcomes in the SLAN group.

Results: Ninety-six patients were enrolled (SLAN group, n = 32; CLA group, n = 64). The SLAN group had a shorter hospital stay, lower 24-hour postoperative visual analogue scale scores, shorter postoperative fasting time, lower frequency of antibiotic administration, and longer operative time than the CLA group. In the SLAN group, younger patients had a longer appendix and

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male patients had a thicker appendix; additionally, patients with an appendiceal diameter of 0.6 to 1.0 cm had a longer postoperative hospital stay and higher frequency of antibiotic administration. **Conclusions:** Compared with CLA, SLAN may be less invasive, provide faster postoperative recovery, and result in better cosmesis for patients with uncomplicated appendicitis. Further research should be performed to evaluate the long-term outcomes.

Keywords
Single-port laparoscopy, appendectomy, acute appendicitis, retrospective study, clinical outcomes, uncomplicated appendicitis

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Introduction

Acute appendicitis is one of the most common causes of acute abdomen worldwide. It has a high incidence rate and necessitates emergency care. Early surgical intervention is a main treatment strategy.[1–3] With the development of minimally invasive surgical techniques and improvement of surgical instruments, laparoscopic appendectomy has gradually replaced open surgery and is now the most common surgical approach. Many laparoscopic techniques are currently available. However, considering the mild inflammatory status and uncomplicated surgical procedures for patients with acute uncomplicated appendicitis, better postoperative outcomes can be expected if the numbers and length of surgical incisions can be further reduced.

In view of this, our center designed and performed a novel minimally invasive surgical technique termed single-port laparoscopic appendectomy using a needle-type grasping forceps (SLAN), which is the first such technique performed worldwide.[4,5] As our previous clinical observations have indicated, SLAN has the advantages of minimal surgical incisions, satisfactory cosmetic results, and positive patient feedback. Evidence-based medical research is important for the safety and feasibility of this novel technique. However, to our knowledge, no clinical studies have been performed to compare the surgical outcomes of SLAN with those of other procedures. The present study was performed to compare the surgical outcomes of SLAN with those of conventional three-port laparoscopic appendectomy (CLA) in patients with acute uncomplicated appendicitis.

Materials and methods

Patient selection

This retrospective study was performed in Chaoyang Central Hospital, Liaoning Province, China from May 2019 to May 2021 and involved 323 consecutive patients with the diagnosis of acute appendicitis. The primary diagnosis was established based on the patients' medical history, physical examination findings, laboratory results, and computed tomography or ultrasound results. Eighty-two patients had complicated appendicitis and 241 had uncomplicated appendicitis. Among the 241 patients with uncomplicated appendicitis, 101 underwent surgery by 4 senior laparoscopic surgeons in our center. All possible surgical procedures were

introduced to the patients preoperatively, including SLAN, CLA, a two-port approach, and open surgery, and the final strategy was determined by the patients' preference. The possibility and risk of conversion to open surgery during the operation was also explained to the patients. Finally, 96 patients were enrolled in this study.

The reporting of this study conforms to the STROBE guidelines.[6] Written informed consent was obtained from all the patients before surgery. The patients were divided into two groups according to the surgical procedure: the SLAN group (n = 32) and the CLA group (n = 64) (Figure 1). All patients' details were de-identified to protect their privacy. This study was approved by the Ethics Committee of Chaoyang Central Hospital (approval no. 2022-02).

Surgical procedures

All patients underwent general anesthesia. The operations were performed by four senior surgeons who were experienced in laparoscopic surgery. A standard preoperative procedure was followed, and neither a gastric tube nor urinary catheter was inserted in any patients. The operations were performed with a left-positioned surgeon and an assistant in both groups. A 30° optical laparoscope (Karl Storz SE & Co. KG, Tuttlingen, Germany) was used in both groups, whereas a 10-mm laparoscopic camera lens was selected for patients in the CLA group and a 5-mm laparoscopic camera lens was selected for patients in the SLAN group. Carbon dioxide gas was used to establish pneumoperitoneum. Conventional laparoscopic surgical instruments were routinely applied, including disposable trocars, laparoscopic separation forceps, an ultrasonic scalpel, and Hemo-lok clips. A needle-type grasping forceps (approval No. zsyjx 20140056; Hangzhou Kangji Medical Instrument Co., Ltd., Hangzhou, China) was used only in the SLAN group. The detailed surgical procedures were performed as previously described.[4,5]

Patients' characteristics and outcomes

The baseline characteristics of the patients in both groups were analyzed, including sex, definitive diagnosis, age, body mass

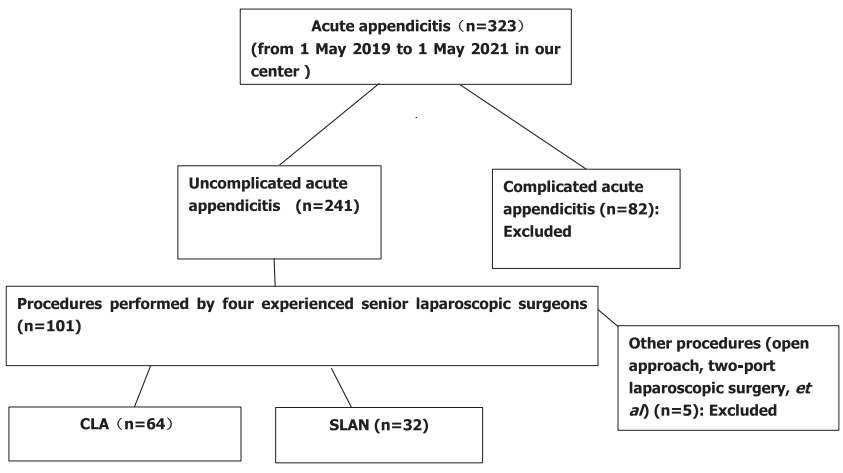

Figure 1. Flow chart of patient selection.
SLAN, single-port laparoscopic appendectomy using a needle-type forceps; CLA, conventional three-port laparoscopic appendectomy.

index (BMI), American Society of Anesthesiologists physical status,[7] history of abdominal surgery, preoperative serum glucose level, routine blood indices, and disease course. Several perioperative observation factors were compared between the two groups, including the incision length, appendiceal length and diameter, operative time, postoperative hospital stay, first postoperative out-of-bed activity time, first postoperative exhaust time, postoperative visual analogue scale (VAS) scores,[8] postoperative complications, cost of hospitalization, fasting time, frequency of antibiotic administration, and follow-up results. The postoperative pathological results were used to judge the length and diameter of the appendix and revise the final diagnosis. In consideration of the COVID-19 pandemic and international experiences,[9] follow-ups until 1 November 2021 were completed by telephone, WeChat, or outpatient service, and complications including incision healing problems and adhesive intestinal obstruction were recorded.

Statistical analysis

Measurement data are presented as mean with standard deviation and were analyzed using two-sample *t*-test analysis. Categorical data were analyzed using the chi-square test. Linear regression analysis was used to analyze the correlation between the operative time and postoperative hospital stay in the SLAN group. A *P*-value of <0.05 was considered statistically significant.

Results

Patients' baseline characteristics

No patients in either group had a history of abdominal surgery. The SLAN group comprised 32 patients, including 14 with purulent appendicitis and 18 with simplex appendicitis. The CLA group comprised 64 patients, including 41 with purulent appendicitis and 23 with simplex appendicitis. There was no significant difference in diagnosis between the two groups. As shown in Table 1, there were also no significant differences in sex, age, BMI, leukocyte count, neutrophil percentage, disease course, or American Society of Anesthesiologists physical status between the two groups. The preoperative serum glucose level was slightly higher in the CLA group than in

Table 1. Patients' baseline characteristics.

	SLAN group (n = 32)	CLA group (n = 64)	*P*-value
Diagnosis, purulent/simplex	14/18	41/23	0.058
Sex, male/female	18/14	32/32	0.563
Age, years	21.88 ± 16.47	27.31 ± 13.13	0.083
BMI, kg/m^2	21.70 ± 6.30	23.10 ± 4.77	0.274
History of abdominal surgery	0	0	
Preoperative serum glucose level, mmol/L	5.61 ± 1.38	6.57 ± 1.67	0.006
Preoperative routine blood indices			
Leukocyte count, $\times 10^9$/L	11.21 ± 4.40	12.54 ± 4.57	0.175
Neutrophil percentage	74.13 ± 15.41	79.73 ± 11.70	0.077
Disease course, hours	23.63 ± 16.88	22.67 ± 15.95	0.787
ASA physical status, I/II	5/27	10/54	1

Data are presented as n or mean ± standard deviation.

SLAN, single-port laparoscopic appendectomy using a needle-type forceps; CLA, conventional three-port laparoscopic appendectomy; BMI, body mass index; ASA, American Society of Anesthesiologists.

the SLAN group (6.57 ± 1.67 vs. 5.16 ± 1.38 mmol/L, respectively; $P = 0.006$); however, the serum glucose levels in both groups were close to the normal range according to current international serum glucose standards (Table 1).[10,11]

Perioperative outcomes

The patients in the SLAN group received a single 1-cm skin incision under the umbilicus, whereas the patients in the CLA group received three skin incisions with a total length of 2.5 cm (a 1-cm umbilical incision, a 0.5-cm incision above the pubic symphysis, and a 1-cm incision at the edge of the right rectus abdominis). The length of the appendix was significantly longer in the SLAN group than in the CLA group (7.06 ± 1.56 vs. 6.30 ± 1.28 cm, respectively; $P = 0.012$). In addition, the operative time was significantly longer in the SLAN group than in the CLA group (66.25 ± 20.42 vs. 49.28 ± 17.28 minutes, respectively; $P < 0.001$). Moreover, the postoperative hospital stay was significantly shorter in the SLAN group than in the CLA group (2.45 ± 0.86 vs. 3.09 ± 1.16 days, respectively; $P = 0.008$). Although there was no significant difference in the mean preoperative VAS score between the two groups (2.94 ± 0.35 vs. 2.97 ± 0.56), the mean 24-hour postoperative VAS score was significantly lower in the SLAN group than in the CLA group (0.38 ± 0.79 vs. 1.05 ± 0.86, respectively; $P = 0.0004$). Eight patients in the CLA group underwent insertion of an indwelling drainage tube during the operation, whereas no patients in the SLAN group underwent drainage tube insertion. The postoperative fasting time was significantly shorter in the SLAN group than in the CLA group (0.92 ± 0.52 vs. 1.26 ± 0.52 days, respectively; $P = 0.004$). Moreover, the frequency of postoperative antibiotic administration was significantly lower in the SLAN group than in the CLA group (4.25 ± 1.16 vs. 6.09 ± 2.22 times, respectively; $P < 0.001$). Although a postoperative incision infection developed in one patient of the CLA group, the difference between the groups was not statistically significant. There were no significant differences in other outcomes, including the appendiceal diameter, first postoperative out-of-bed activity time, first postoperative exhaust time, cost of hospitalization, and follow-up time, between the two groups (Table 2).

Trends in operative time of SLAN group

The operative time of the consecutive patients in the SLAN group showed a wavelike curve. The longest operative time was 120 minutes, which occurred in Patients 18 and 19, and the shortest time was 40 minutes, which occurred in Patients 25 and 26. The operative time of Patients 1 to 10 fluctuated up and down by 60 minutes, whereas that of Patients 11 to 20 patients fluctuated from 40 to 120 minutes. Finally, the operative time of Patients 20 to 32 fluctuated stably between 40 and 80 minutes; among these patients, the operative time was <60 minutes in nine patients and 40 minutes in two patients. The overall operative time showed a downward trend (Figure 2). No significant relationship was found between the operative time and postoperative hospital stay (Figure 3).

Comparison between clinical characteristics and postoperative outcomes in SLAN group

As shown in Tables 3 and 4, the patients were divided into three groups according to the length of the appendix (<6, 6–8, and >8 cm). The results showed that younger patients had a longer appendix (43.50 ± 23.10 vs. 19.60 ± 13.67 vs. 12.00 ± 3.46 years, $P = 0.010$). Nevertheless, there were no significant differences in the operative

Table 2. Perioperative outcomes and surgical complications.

	SLAN group (n = 32)	CLA group (n = 64)	*P*-value
Total length of incision, cm	1	2.5	
Appendiceal length, cm	7.06 ± 1.56	6.30 ± 1.28	0.012
Appendiceal diameter, cm	0.91 ± 0.32	0.96 ± 0.28	0.451
Operative time, minutes	66.25 ± 20.42	49.28 ± 17.28	<0.0001
Postoperative hospital stay, days	2.45 ± 0.86	3.09 ± 1.16	0.008
First out-of-bed activity time, days	0.53 ± 0.21	0.47 ± 0.25	0.254
First postoperative exhaust time, days	1.00 ± 0.58	1.23 ± 0.54	0.063
Preoperative VAS score	2.94 ± 0.35	2.97 ± 0.56	0.741
24-hour postoperative VAS score	0.38 ± 0.79	1.05 ± 0.86	0.0004
Complications			
Incision infection	0	1	
Adhesive intestinal obstruction	0	0	1
Cost of hospitalization, yuan	11957.9 ± 2094.3	12342.4 ± 1849.2	0.361
Abdominal drainage tube	0	8	0.090
Fasting time, days	0.92 ± 0.52	1.26 ± 0.52	0.004
Frequency of antibiotic administration, times	4.25 ± 1.16	6.09 ± 2.22	<0.0001
Follow-up time, months	19.69 ± 6.66	18.48 ± 7.43	0.441

Data are presented as n or mean ± standard deviation.
SLAN, single-port laparoscopic appendectomy using a needle-type forceps; CLA, conventional three-port laparoscopic appendectomy; VAS, visual analogue scale.

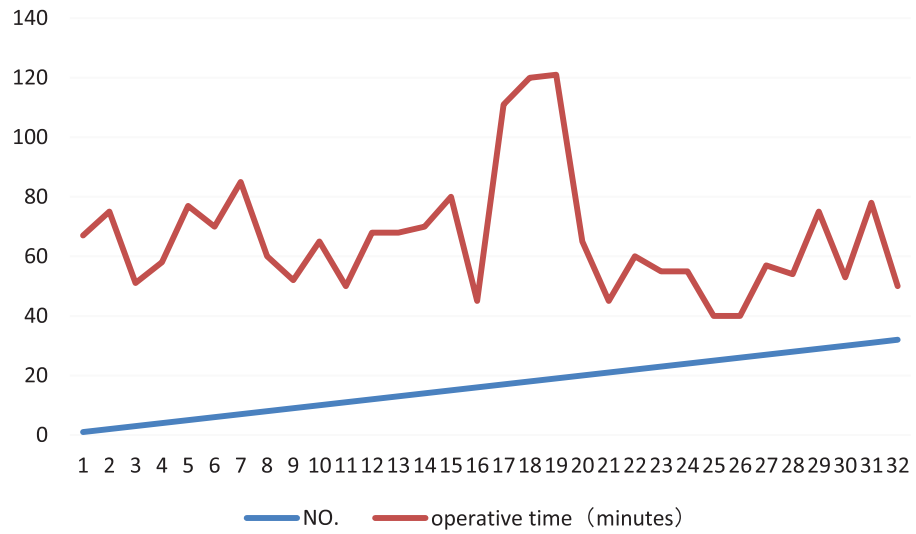

Figure 2. Trends in operative time of SLAN group.
SLAN, single-port laparoscopic appendectomy using a needle-type forceps.

time, postoperative hospital stay, first postoperative exhaust time, 24-hour postoperative VAS scores, complications, cost of hospitalization, fasting time, or frequency of antibiotic administration. We also divided the patients into three groups according to the appendiceal diameter (<0.6, 0.6–1.0, and >1.0 cm). The results showed that

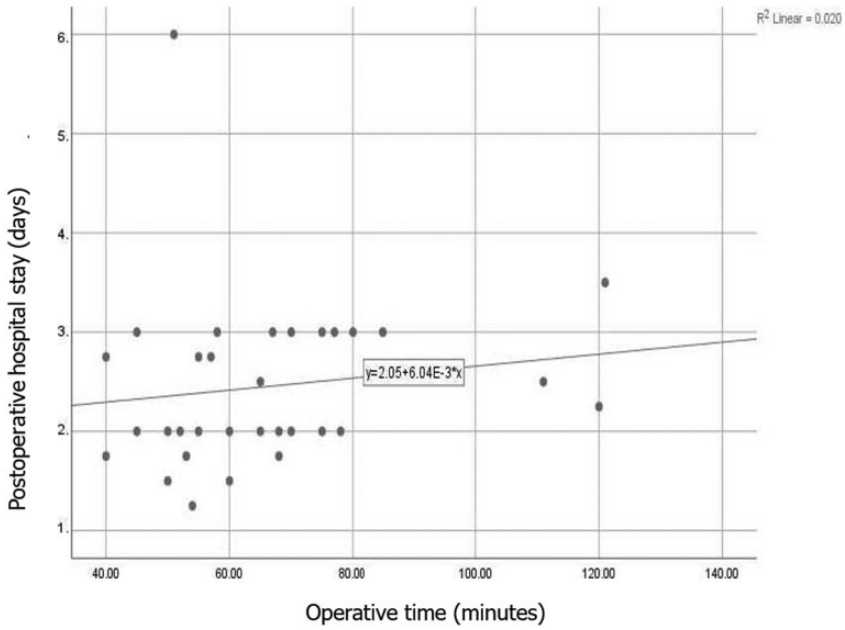

Figure 3. Correlation between operative time and postoperative hospital stay in SLAN group. SLAN, single-port laparoscopic appendectomy using a needle-type forceps.

a thicker appendix was associated with a higher proportion of male patients (male/female: 0/3 vs. 12/9 vs. 6/2, $P = 0.048$). Moreover, patients with an appendiceal diameter of 0.6 to 1.0 cm had a longer postoperative hospital stay than the other two groups (1.92 ± 0.14 vs. 2.73 ± 0.91 vs. 1.94 ± 0.51 days, $P = 0.042$) and higher frequency of antibiotic administration (3.67 ± 0.58 vs. 4.62 ± 1.20 vs. 3.50 ± 0.76 times, $P = 0.040$). There were no significant differences in the operative time, first postoperative exhaust time, 24-hour postoperative VAS scores, complications, cost of hospitalization, or fasting time. In addition, we divided the patients into two groups based on their BMI (≥ 25 and < 25 kg/m^2). There were no significant differences in the operative time, postoperative hospital stay, first postoperative exhaust time, 24-hour postoperative VAS sores, complications, cost of hospitalization, fasting time, or frequency of antibiotic administration. Finally, the patients were divided into three groups according to their disease course (<24, 24–48, and >48 hours). No significant differences were found in any of the above-mentioned factors.

Discussion

Acute appendicitis is one of the most common causes of acute abdomen worldwide, with an annual incidence rate of about 91 to 110 cases per 100,000.[1–3] Optimizing and improving the treatment strategy will benefit thousands of patients with acute appendicitis. Despite the continuous challenges and controversies regarding the diagnosis and treatment of acute appendicitis,[2,12–17] there is still a lack of sufficient evidence on whether antibiotic treatment or surgical intervention is the most appropriate initial treatment for acute uncomplicated appendicitis.[18] Nevertheless, surgery is still considered an effective treatment and

Table 3. Comparison between perioperative outcomes and appendiceal length and diameter in SLAN group.

	Appendiceal length, cm				Appendiceal diameter, cm			
	<6.0	6.0–8.0	>8.0	*P*-value	<0.6	0.6–1.0	>1.0	*P*-value
Diagnosis, purulent/simplex	1/3	12/13	1/2	0.742	0/3	9/12	5/3	0.081
Sex, male/female	3/1	13/12	2/1	0.742	0/3	12/9	6/2	0.048
Age, years	43.50 ± 23.10	19.60 ± 13.67	12.00 ± 3.46	0.010	18.67 ± 13.28	20.57 ± 14.03	26.50 ± 23.53	0.660
Operative time, minutes	60.50 ± 4.93	66.56 ± 19.21	71.33 ± 43.50	0.787	62.67 ± 9.24	69.52 ± 23.42	59.00 ± 12.55	0.455
Postoperative hospital stay, days (days)	2.13 ± 0.63	2.52 ± 0.90	2.33 ± 1.01	0.690	1.92 ± 0.14	2.73 ± 0.91	1.94 ± 0.51	0.042
First postoperative exhaust time, days	0.88 ± 0.25	0.96 ± 0.57	1.50 ± 0.90	0.288	0.5	1.07 ± 0.62	1.00 ± 0.52	0.286
24-hour postoperative VAS score	1.00 ± 1.41	0.32 ± 0.69	0	0.198	0	0.33 ± 0.66	0.63 ± 1.19	0.482
Complications								
Incision infection	0	0	0		0	0	0	
Adhesive intestinal obstruction	0	0	0		0	0	0	
Cost of hospitalization, yuan	12,702.32 ± 1469.31	11,826.96 ± 2135.51	12,056.20 ± 2947.09	0.750	12,570.20 ± 2655.88	11,967.86 ± 2200.11	11,702.04 ± 1828.50	0.840
Fasting time, days	0.75 ± 0.29	0.90 ± 0.53	1.33 ± 0.63	0.319	0.5	1.06 ± 0.56	0.72 ± 0.34	0.095
Frequency of antibiotic administration, times	3.50 ± 0.58	4.44 ± 1.19	3.67 ± 1.15	0.219	3.67 ± 0.58	4.62 ± 1.20	3.50 ± 0.76	0.040

Data are presented as n or mean ± standard deviation.

SLAN, single-port laparoscopic appendectomy using a needle-type forceps; VAS, visual analogue scale.

Table 4. Comparison of perioperative outcomes with BMI and disease course in SLAN group.

	BMI, kg/m^2			Disease course, days			
	<25	≥25	*P*-value	<24	24–48	>48	*P*-value
Diagnosis, purulent/simplex	11/14	3/4		8/8	6/6	0/4	0.166
Sex, male/female	14/11	4/3		11/5	5/7	2/2	0.257
Age, years	18.88 ± 14.11	32.57 ± 20.82	0.050	24.19 ± 17.68	22.17 ± 17.01	11.75 ± 3.50	0.414
Operative time, minutes	65.08 ± 19.69	70.43 ± 24.04	0.549	71.69 ± 25.59	60.42 ± 12.41	62.00 ± 12.36	0.329
Postoperative hospital stay, days	2.53 ± 0.92	2.18 ± 0.62	0.350	2.25 ± 0.62	2.81 ± 1.13	2.19 ± 0.55	0.192
First postoperative exhaust time, days	1.01 ± 0.58	0.96 ± 0.64	0.857	1.16 ± 0.68	0.90 ± 0.47	0.69 ± 0.24	0.264
24-hour postoperative VAS score	0.28 ± 0.68	0.71 ± 1.11	0.357	0.44 ± 0.89	0.42 ± 0.79	0	0.614
Complications							
Incision infection	0	0		0	0	0	
Adhesive intestinal obstruction	0	0		0	0	0	
Cost of hospitalization, yuan	11,960.9 ± 2009.5	11,947.0 ± 2551.5	0.988	11,787.08 ± 1906.47	12,426.84 ± 2589.21	11,234.14 ± 914.07	0.568
Fasting time, days	0.98 ± 0.55	0.71 ± 0.37	0.240	0.89 ± 0.46	1.04 ± 0.66	0.69 ± 0.24	0.488
Frequency of antibiotic administration, times	4.36 ± 1.15	3.86 ± 1.22	0.320	4.00 ± 1.03	4.67 ± 1.37	4.00 ± 0.82	0.302

Data are presented as n or mean ± standard deviation.

SLAN, single-port laparoscopic appendectomy using a needle-type forceps; BMI, body mass index; VAS, visual analogue scale.

is widely performed by surgeons worldwide.[3,19] With the application and popularization of minimally invasive surgical techniques, patients with acute appendicitis have gained satisfactory clinical outcomes, such as early discharge and a low incidence of incision infection. Many surgical strategies of laparoscopic appendectomy have been reported, including the conventional three-port, two-port, and single-port surgical approaches. Conventional three-port laparoscopic appendectomy requires three skin incisions with a total length of about 2.5 cm, whereas the incisions of most conventional single-port laparoscopic approaches is about 1.5 to 2.5 cm[20,21]; however, the cost of hospitalization is high and the learning curve is long.[22,23] Thus, there is still room to improve the conventional single-port laparoscopic technique, especially for patients with acute uncomplicated appendicitis. In view of this, our center established the novel technique termed SLAN, which uses a needle-type grasping forceps as an assist. A hidden 1-cm skin incision is performed under the umbilicus, facilitating a perfect cosmetic outcome. The objective of this retrospective study was to evaluate the clinical value of SLAN by comparing its perioperative clinical outcomes with those of CLA.

SLAN showed obvious advantages over CLA in terms of perioperative clinical outcomes

SLAN is performed using traditional laparoscopic instruments such as an ultrasonic scalpel and Hem-o-lok clips, which can be easily adapted by experienced laparoscopic surgeons. The method of securing the base of the appendix using Hem-o-lok clips has been proven effective.[24,25] Manual knotting for appendiceal stump closure has also been proven safe and effective.[26] The main steps of resecting the appendix in SLAN are similar to those in CLA, and the needle-type grasping forceps can assist in grasping the appendix at McBurney's point. This is convenient for exposure of the base of the appendix and can reduce the collision caused by lack of the "triangular principle" from the conventional single-port approaches, and it can shorten the learning curve. As shown in Figure 2, most patients in the SLAN group underwent the operation within about 60 minutes, and the latter 12 patients underwent the operation between 40 and 60 minutes; in 2 patients, the procedure was even completed in 40 minutes. Although the median operative time was slightly longer in the SLAN than CLA group (which may have been related to the surgeons' lack of experience, incongruities between the surgeon and assistant, or unstable pneumoperitoneum pressure), the efficacy and safety of the single-port approach was still comparable with those of the conventional three-port approach in the management of uncomplicated appendicitis, as previously reported.[27]

The learning curve showed that the operative time decreased as more SLAN approaches were performed, and there was no increase in the complication rate during the learning stage.[28–31] The present study showed that SLAN effectively relieved the patients' postoperative pain as shown by an average VAS score of only 0.38. The degree of pain was extremely mild, promoting early out-of-bed activities and gastrointestinal function recovery; this is also consistent with previous research results.[32] Our study also indicated that the cost of hospitalization was lower in the SLAN than CLA group, although the difference was not statistically significant; at the very least, there was no increase in the economic burden of patients in the SLAN group. This may have been related to the use of traditional instruments, the shorter postoperative hospital stay, the shorter fasting time, and the lower frequency of antibiotic

administration in the SLAN than CLA group. These advantages can reduce patients' physical and psychological burdens, which is in accordance with concept of enhanced recovery after surgery.[33] In addition, there was no need for insertion of an indwelling abdominal drainage tube in any patients in the SLAN group, thus greatly improving the patients' comfort. More importantly, the 1-cm skin incision under the umbilicus was small and hidden; not only was the total number of incisions reduced, but the length of the incision was also shortened, and no obvious scars were observed during follow-up. Thus, a perfect cosmetic effect was achieved (Figure 4). We noted that a single-port technique with an umbilical incision of only 0.5 to 1.0 cm has been previously reported[34]; nonetheless, SLAN is more feasible and safer and has the advantages of using an ultrasonic scalpel and Hem-o-lok clips, which can effectively manage bleeding and other complications during the operation.

Details of surgical procedures should be emphasized

As a novel minimally invasive technique, the details of SLAN should not be ignored. First, although the auxiliary needle-type grasping forceps induces only minimal trauma, the texture of the appendix is soft and bending of the tissue should thus be avoided. Second, two 5-mm trocars must be simultaneously inserted into the 1-cm umbilical incision, and maintenance of stable pneumoperitoneum pressure can thus become problematic. We introduced sterile gauze into the umbilical incision, effectively improving the smoothness of the operation and shortening the operative time. In addition, cooperation between the surgeon and assistant is particularly important. Based on our experience, the laparoscopic camera lens was first inserted into the right upper abdomen; next, the ultrasonic scalpel was placed in the operative visual field and then transferred to the

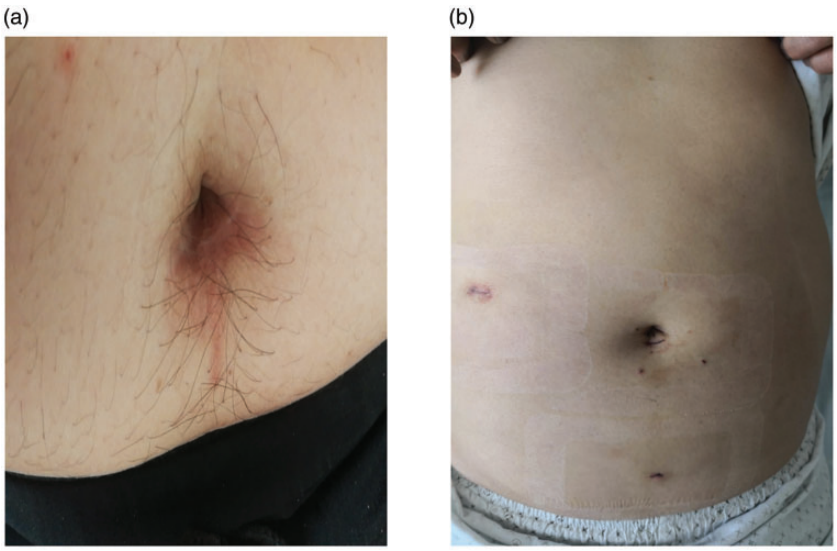

Figure 4. Appearance of surgical incisions on postoperative day 2. (a) Healing status of surgical incisions in SLAN group and (b) Healing status of surgical incisions healing status in CLA group.
SLAN, single-port laparoscopic appendectomy using a needle-type forceps; CLA, conventional three-port laparoscopic appendectomy.

right lower abdomen along with the laparoscopic camera lens. When the diseased appendix was observed and the diagnosis was defined, the laparoscopic camera lens was fixed at the proper visual angles.

Finally, the principle of asepsis should be emphasized. Previous studies have shown that the rate of incision infection is higher in single-port laparoscopic surgery than in conventional laparoscopic surgery. Importantly, acute appendicitis is an infectious disease, and a no-touch technique is the most important principle to avoid incision infection.[23] As previously reported, whether to use the retrieval bag as a protective method remains controversial.[35,36] We have two suggestions. First, when the appendiceal diameter is <1 cm, the appendix can be placed in one finger of the surgical glove for protection or directly extracted through a 10-mm disposable trocar. Second, if the appendiceal diameter is >1 cm, one finger of the surgical glove is necessary to avoid contaminating the umbilical incision. As our follow-up results showed, neither incision infection nor abdominal abscess was observed in all 32 patients in the SLAN group.

Careful selection of surgeons and patients is important

Although single-port laparoscopy is reportedly safe and feasible when performed by surgical residents,[37] we believe that careful selection of surgeons is still important to ensure maximal safety. Experienced senior laparoscopic surgeons should be preferentially selected to deal with possible complications such as bleeding, side injury, and incision hernia. Considering that an indwelling abdominal drainage tube cannot be inserted in patients with gangrene perforation and other complications, SLAN should ideally only be performed in patients with acute uncomplicated appendicitis. Preoperative computed tomography may have advantages in assessment of the abdominal cavity, especially in patients with bowel wall thickening, as shown in a previous study.[38] Moreover, further research is needed to evaluate the feasibility of treating chronic appendicitis without adhesion. Our study showed that the hospital stay was slightly longer and the frequency of antibiotic administration was slightly higher in patients with acute uncomplicated appendicitis whose appendiceal length was 0.6 to 1.0 cm; interestingly, this did not increase the cost of hospitalization or delay the postoperative recovery process. Therefore, SLAN is also safe and feasible for these patients. Moreover, our data showed no significant differences in postoperative outcomes among patients with different BMIs, disease courses, and appendiceal lengths.

Overall, our results showed that SLAN is a safe and feasible surgical approach with obvious advantages. No postoperative complications were observed during hospitalization and follow-up, and the cost of hospitalization did not increase. The incision size was minimal and the cosmetic appearance was perfect. SLAN showed a high benefit-injury ratio. Although the operative time was longer in the SLAN than CLA group, the operative time showed a decreasing trend as surgeons' experience increased. Nonetheless, our study had several limitations. First, the small sample size and retrospective nature of our study may have introduced some bias regarding our outcomes. Second, although all four surgeons in this study were experienced in laparoscopic surgery, the results may have been influenced by differences among the surgeons and the time at which the patients joined the study (patients may have benefitted from joining the study at a later time, which may have affected the comparisons of the operative time, postoperative complications, and

other factors). Finally, the short follow-up period may have influenced the observable results regarding complications. Thus, a long-term, multicenter, large-sample, prospective study should be carried out in the future.

Conclusion

Our study showed that SLAN may be a safe and feasible alternative to CLA for patients with acute uncomplicated appendicitis. Although the operative time was longer, SLAN showed obvious advantages over CLA in terms of clinical outcomes and the cosmetic appearance. A gentle operation and careful selection of surgeons and patients are important. Further long-term, multicenter, large-sample, prospective research is needed.

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Author contributions

YC and SG: Conception and design. YC, YL, and ZF: Study materials provision, data collection and analysis. YC, SG, and JY: Manuscript writing. All authors reviewed and approved the final manuscript.

Data availability statement

The article already contains all relevant data. If necessary, the corresponding author can be contacted for further information.

Declaration of conflicting interests

The authors declare that they have no competing interest.

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