Original Article

Experiences with LESS-appendectomy in Children

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Abstract

Purpose: To evaluate the outcome of laparoendoscopic single-site (LESS-A) through one transumbilical port vs. 3-port laparoscopic (3TA) appendectomy in children.

Methods: We reviewed the records of 309 children (65 LESS-A, 244 3TA) operated on between 2008 and 2012. One hundered forty-nine patients had acute catarrhalis (CA), 133 phlegmonous (PLA), and 27 perforated appendicitis (PA). We compared the duration of operation (DO), the incidence of abdominal abscesses (AA), and wound infections (WI), as well as the degree of appendiceal inflammation (DI) among surgeons with and without board certification.

Results: For all DI, LESS-A resulted in a shorter DO than 3TA (CA 57.9 ± 22.8 vs. 68.5 ± 23.2, $P = 0.014$; PLA 51.5 ± 16.5 vs. 68.4 ± 33.0, $P = 0.006$; PA 66.0 ± 29.0 vs. 97.3 ± 41.8, $P = 0.039$). LESS-A was not used for less complicated cases when compared to 3TA (CA 50.8% vs. 47.5%; PLA 33.8% vs. 45.5%; PA 15.4% vs. 7.0%; CA vs. PLA, $P = 0.292$; CA vs. PA, $P = 0.142$; PLA vs. PA, $P = 0.031$). Surgeons without board certification were assigned to a similar percentage to perform both techniques for any DI (CA 30.3% vs. 37.1%, $P = 0.541$; PLA 31.8% vs. 40.5%, $P = 0.484$; PA 40% vs. 35.3%, $P = 1.0$). We found no significant differences concerning AA (1.5% vs. 1.2%, $P = 1.0$) and WI (3.1% vs. 1.6%, $P = 0.61$).

Conclusions: LESS-A can be done by surgeons with and without board certification for all DI, with shorter DO and similar complication rates as compared to 3TA.

Keywords: Appendectomy, children, laparoscopic, LESS, perforated

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Introduction

Appendectomy is the most common acute surgical intervention in children,[1,2] and it is often the first abdominal surgical procedure to be taught to surgeons who lack board certification. Single-incision laparoscopic appendectomy represents the most recent attempt to reduce the number of visible scars on the abdominal wall, and many publications have attested to it better cosmetic satisfaction among patients and parents.[3–5] In a recent online survey sent to members of the International Paediatric Endosurgery Group, 71% of pediatric surgeons from 32 countries on six continents stated that they had performed single-incision laparoscopic surgery.[6] However, many randomized controlled trials[5,7–9] and one recent study[10] excluded cases of perforated appendicitis or proposed selection towards uncomplicated appendicitis.[11] In addition, very little information is available regarding whether the method is amenable to being performed by assisted surgical trainees, as many publications limited its use to experienced surgeons only.[8,9,12–19] More information will be required regarding what happens when surgeons with different skill levels perform single-incision appendectomy for all degrees of appendiceal inflammation. The aim of our study was to analyze the outcome of laparoendoscopic single-site (LESS-A) through one transumbilical port vs. 3-port laparoscopic (3TA) appendectomy in children with all degrees of appendiceal inflammation by surgeons with and without board certification.

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Methods

After obtaining institutional review board approval (4599-13), a retrospective chart review identified all children aged ≤ 18 years with intraoperatively and histologically confirmed appendicitis who underwent laparoscopic appendectomy between October 2008 and July 2012 at the Department of Pediatric Surgery of Ruhr-University in Bochum, Germany. Informed consent was obtained from the patients' guardians. Patients were divided into two groups: those who underwent LESS-A through one transumbilical multichannel port and patients who underwent standard 3TA. The degree of appendiceal inflammation was histologically classified as acute (catarrhalis), phlegmonous, and perforated appendicitis. Access to the abdominal cavity was gained using a modification of Hasson's technique, whereby access to the peritoneal cavity is gained through an incision in the umbilical stalk. Three-mm straight instruments and three Endo-Loops® were used for LESS-A and 3TA. To minimize clashing during LESS-A, a 30° endoscope with a working length of 300 mm, integrated camera, and light source (EndoEye®) was used (Figure 1A). LESS-A was performed using the TriPort® device with three gel valves. For easier manipulation during LESS-A, all instruments except the

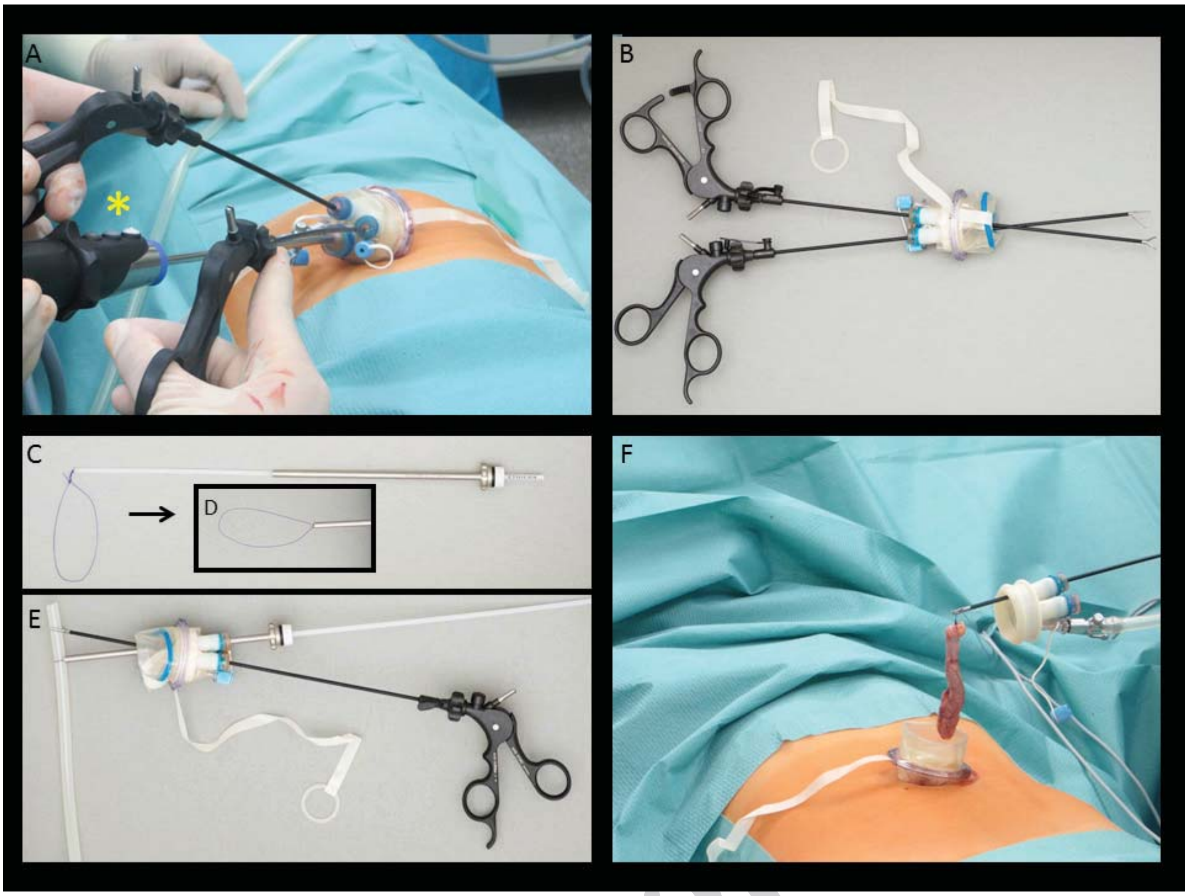

Figure 1. Laparoendoscopic Single-Site Appendectomy instrumentarium; **A)** Minimizing clashing of instruments by integrated endoscope-camera combination (*) with additional working length; **B)** Crossing 3-mm straight instruments inside a TriPort® system with silicone valves; **C)** Single-handed adjustment of the normal EndoLoop® diameter by insertion of the EndoLoop® into a reduction sleeve; **D)** Adjusted diameter of the loop after advancing the reduction sleeve; **E)** Closing loop; **F)** Removal of the appendix by lifting up the cap of the TriPort®.

camera, as well as the Endo-Loops®, were lubricated with Instillagel®. LESS-A was performed by crossing instruments (Figure 1B) through the TriPort® system. Before insertion into the TriPort®, the Endo-Loops® were introduced into a 3-mm reduction sleeve (Figure 1C). This allowed exact single-handed adjustment of the loop size (Figures 1D and 1E). The cap of the TriPort® could be temporarily lifted for removal of the appendix, and replaced to continue with the laparoscopic procedure (Figure 1F). A separate 5-mm 30° endoscope with a working length of 260 mm attached to the camera was used for 3TA. One 5-mm and one 3-mm trocar in the left lower quadrant accompanied by a transumbilical 12-mm trocar were used. The decision of whether to perform LESS-A or 3TA was based on the surgeon's preference. Surgical procedures were performed according to the described standardized algorithm under the supervision of board-certified surgeons with and without board certification. Our antibiotic regimen consisted of daily intravenous administration of cefuroxime (100 mg/kg body weight in three doses/day) and metronidazole (20 mg/kg body weight in two doses/day). For acute appendicitis, cefuroxime alone was administered for 3 days. For phlegmonous appendicitis, cefuroxime was administered for 5 days followed by 3 days of metronidazole. According to our established regimen, cefuroxime was administered for 7 days and metronidazole for 5 days for the treatment of perforated appendicitis. Some patients received an adapted antibiotic therapy regime based on the results of their intraoperative microbiological smear. Patients' medical records were reviewed retrospectively, and the following data were collected: age, sex, surgical procedure(s), duration of operation, incidence of intra-abdominal abscess formation, and wound infection. Patients with less than one-month follow-up period, incomplete documentation, concomitant operations, conversions to other procedures, or those who were referred after appendectomy in other hospitals were excluded. Comparative statistical analyses were undertaken using the Fisher's exact test for categorical data and the Mann-Whitney *U* test for nonparametric continuous data. Categorical and continuous data were presented as bars and stacked bars, illustrating counts, percentages, and means ± standard deviations (SD). Statistical analysis was performed using SPSS® version 21 software. Differences were considered significant at $P < 0.05$.

Results

Demographic data

Appendectomies were completed in 337 children with appendicitis evident upon surgery and confirmed by histopathology. We excluded 25 patients with concomitant surgical procedures, and three LESS-A patients who underwent insertion of additional trocars. The rate of additional trocar insertion was (0.9%). One patient required an additional trocar, and two additional trocars were used in the remaining two cases. Board-certified surgeons performed all three conversions. Two cases of non-perforated appendicitis were converted during the learning curve, and were the 3rd and 5th operations performed by the respective surgeons. The 3rd case was

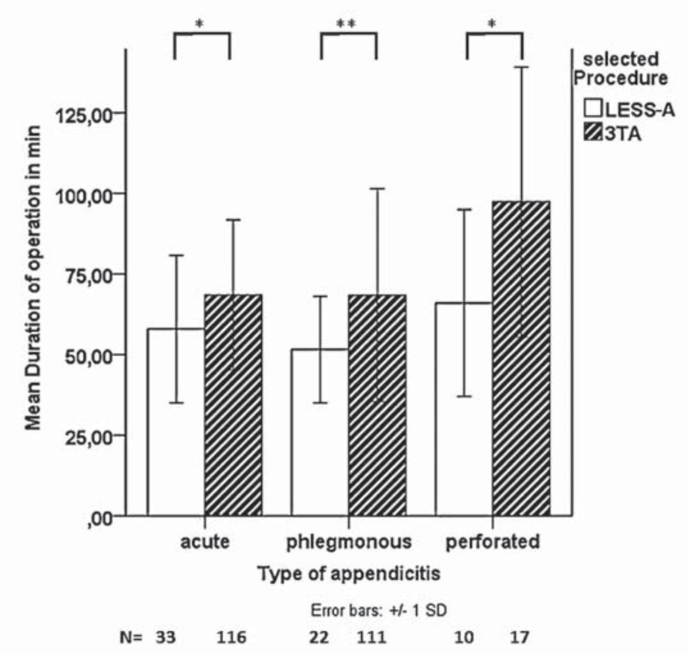

Figure 2. Impact of surgical procedures on duration of operation. The mean duration of operation in minutes was compared across surgical procedures. LESS-A, Laparo-Endoscopic Single-Site appendectomy; 3TA, three-trocar laparoscopic appendectomy. Data are plotted as bars with standard deviations (SDs). *indicates $P < 0.05$, **indicates $P < 0.01$, ***indicates $P < 0.001$. n = absolute counts at 100%.

converted after the learning curve (20th operation) while treating a perforated appendicitis. No LESS-As or 3TAs had to be converted to an open procedure. A total of 309 patients were included in our study. The incidence of appendicitis did not significantly differ ($P = 0.403$) between boys (n = 162) and girls (n = 147). The median follow-up period was 12 months (range: 1 – 21 months) for LESS-A and 19 months (range: 2 – 46 months) for 3TA. The degree of appendiceal inflammation was acute (catarrhalic) in 149 (48.2%), phlegmonous in 133 (43.0%), and perforated in 27 (8.7%) patients. Sixty-five (21%) children underwent LESS-A and 244 (79.0%) underwent 3TA. There was no difference in age between patients who underwent LESS-A and 3TA (median 135, range: 38 – 198 months vs. median 132 months, range: 22 – 211 months, $P = 0.823$). Twenty-two different surgeons performed the surgical procedures, and the same surgeons operated on patients from different treatment groups. Several surgeons performed operations, both as pediatric surgical trainees and subsequently as board-certified pediatric surgeons. Consequently, 194 patients (62.7%) were operated by seven board-certified pediatric surgeons, and 15 pediatric surgical trainees operated on the remaining 115 patients (37.2%) under the supervision of a board-certified pediatric surgeon.

Impact of surgical procedures on the duration of operation

Information on the duration of operation was available for 244 LESS-As and 65 3TAs. The duration of operation (Figure 2) was shorter for LESS-A compared to 3TA for acute (57.9 ± 22.8 vs. 68.5 ± 23.2 min., $P = 0.014$), phlegmonous (51.5 ± 16.5 vs. 68.4 ± 33.0 min, $P = 0.006$), and perforated (66.0 ± 29.0 vs. 97.3 ± 41.8 min, $P = 0.04$) appendicitis.

The degree of appendiceal inflammation did not represent a limitation for performing LESS-A

The cross-tabulation of acute and phlegmonous appendicitis vs. LESS-A and 3TA (Table 1) did not reveal any differences in the distribution ($P = 0.292$). There was also no difference in the dis-

Table 1. Descriptive and statistical analysis of the distribution of procedures according to the degree of appendiceal inflammation

	LESS	3TA
Acute appendicitis, n (%)	33 (50.8%)	116 (47.5%)
Phlegmonous appendicitis, n (%)	22 (33.8%)	111 (45.5%)
Perforated appendicitis, n (%)	10 (15.4%)	17 (7.0%)
Total	**65 (100%)**	**244 (100%)**
Statistics	***P*-value**	
acute vs. phlegmonous appendicitis	0.292	
acute vs. perforated appendicitis	0.142	
phlegmonous vs. perforated appendicitis	0.031	

LESS-A: Laparo-Endoscopic Single-Site appendectomy; 3TA: three-trocar laparoscopic appendectomy; The absolute and relative (%) counts of all LESS-A and 3TA are represented for acute (catarrhalis), phlegmonous, and perforated appendicitis; Statistical differences in the distribution of LESS-A and 3TA between acute, phlegmonous, and perforated appendicitis were analyzed using Fisher´s exact test and considered significant at $P < 0.05$.

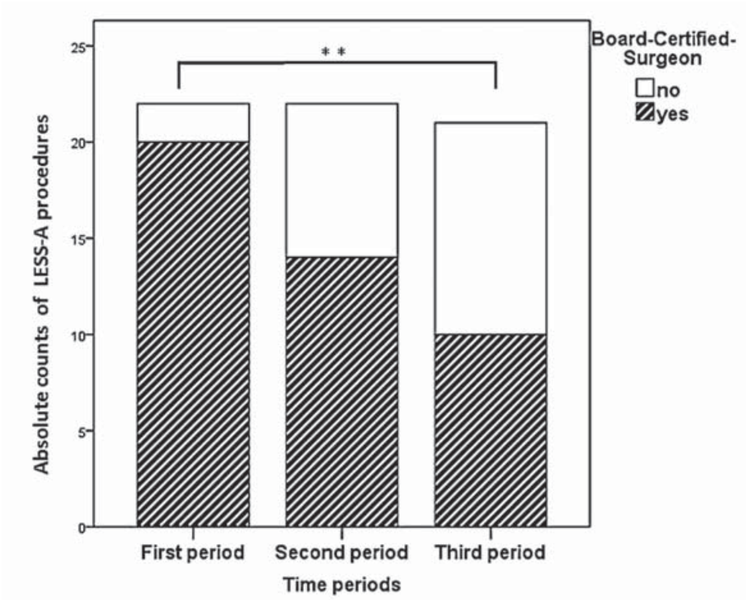

Figure 3. Implementation of LESS-A among surgeons with and without board certification LESS-A, Laparo-Endoscopic Single-Site appendectomy. The stacked bars represent the absolute counts of LESS-A procedures for surgeons that were or were not board-certified during the three consecutive time periods of the study. **indicates $P < 0.01$.

tribution of procedures towards LESS-A and 3TA between acute and perforated appendicitis ($P = 0.142$). In contrast, we found a higher percentage of LESS-A than 3TA when perforated appendicitis was compared with phlegmonous appendicitis ($P = 0.031$).

Implementation of the LESS-A procedure among surgeons with and without board certification

First, LESS-A was performed only by board-certified surgeons. After a delay during which the operative steps were evaluated and standardized, surgeons without board-certification were assisted by board-certified surgeons while performing the procedure. This resulted in three time periods (Figure 3). The first 22 procedures determined the first period. During this period, one board-certified surgeon performed the first four LESS-A procedures and subsequently trained three other board-certified surgeons willing to embrace the new procedure. We felt that the procedure was feasible, and decided to evaluate whether it could be taught to surgeons who were not board-certified. This training was performed by the first board-certified surgeon. Accordingly, 20 procedures were performed by four board-certified and two (9.1%) procedures were performed by surgeons without board certification. The second time period included the next 22 procedures, when surgeons without board-certification were assisted to perform 8/22 operations (36.4%). The remaining 21 procedures determined the third period. Here, the number of surgeons without board-certification significantly increased compared to that in the first period ($P = 0.003$), reaching 11/21 (52.4%) of LESS-A procedures.

The qualification of surgeons (board-certified vs. non board-certified)

The qualification of the surgeon (board-certified vs. non board-certified) did not represent a limitation for performing LESS-A for any degree of appendiceal inflammation. There was no difference between the percentage of procedures performed by board-certified and non-board-certified surgeons (Table 2, Figure 4) when LESS-A and 3TA were compared, neither for acute ($P = 0.541$) nor for phlegmonous ($P = 0.484$), or perforated appendicitis ($P = 1.000$).

Impact of procedures on postoperative complications

LESS-A and 3TA were compared with respect to the incidence of intra-abdominal abscesses and wound infections for acute, phlegmonous, and perforated appendicitis. For all of these parameters, there were no statistically relevant differences (Table 3).

Table 2. Descriptive and statistical analysis of the distribution of procedures according to the qualification of the surgeon

	LESS-A		3TA		*P*-value
	Board certified surgeon	**Not board certified surgeon**	**Board certified surgeon**	**Not board certified surgeon**	
acute appendicitis, n (%)	23 (69.7%)	10 (30.3%)	73 (62.9%)	43 (37.1%)	**0.541**
phlegmonous appendicitis, n (%)	15 (68.2%)	7 (31.8%)	66 (59.5%)	45 (40.5%)	**0.484**
Perforated appendicitis, n (%)	6 (60%)	4 (40%)	11 (64.7%)	6 (35.3%)	**1.00**

LESS-A: Laparo-Endoscopic Single-Site appendectomy; 3TA: three-trocar laparoscopic appendectomy; The absolute and relative (%) counts of all LESS-A and 3TA are represented for board-certified and non-board-certified surgeons for acute (catarrhalis), phlegmonous, and perforated appendicitis; Statistical differences in the distribution of LESS-A and 3TA between board-certified and not board-certified surgeons were compared for each degree of appendiceal inflammation using Fisher´s exact test and considered significant at $P < 0.05$.

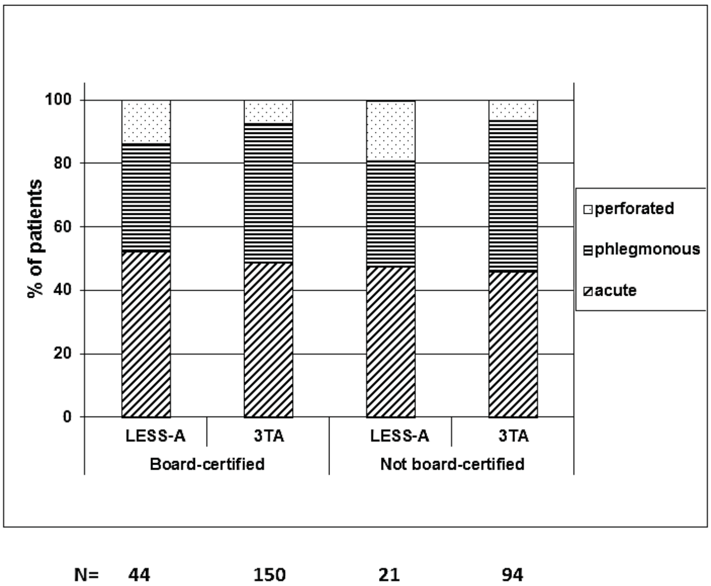

Figure 4. Distribution of procedures according to type of appendicitis and surgeon qualification. LESS-A, Laparo-Endoscopic Single-Site appendectomy; 3TA, three-trocar laparoscopic appendectomy. The stacked bars represent the percentage (%) of patients with acute, phlegmonous, and perforated appendicitis among all patients (n) who underwent the same surgical procedure (LESS-A vs. 3TA) compared to surgeons who were or were not board-certified. n = absolute counts at 100%.

Table 3. Impact of surgical procedures on postoperative complications

Complication parameters	Degree of appendiceal inflammation	LESS-A, n (%)	3TA, n (%)	*P*-Value
Intraabdominal abscesses	acute	0/33 (0%)	2/116 (1.7%)	1.0
	phlegmonous	0/22 (0%)	1/111 (.9%)	1.0
	perforated	1/10 (10%)	0/17 (0%)	0.37
Wound infections	acute	1/33 (3%)	2/116 (1.7%)	0.53
	phlegmonous	0/22 (0%)	2/111 (1.8%)	1.0
	perforated	1/10 (10%)	0/17 (0%)	0.37

LESS-A: Laparo-Endoscopic Single-Site appendectomy; 3TA: three-trocar laparoscopic appendectomy; Patients were evaluated to determine whether they had the following postoperative complications: re-admission, re-operation, intraabdominal abscess, and wound infection; The absolute and relative (%) counts of patients with postoperative complications among all patients who underwent the same surgical procedure and had the same degree of appendiceal inflammation were represented for LESS-A vs. 3TA and for acute (catarrhalis), phlegmonous, and perforated appendicitis; Statistical differences (*P*) in the distribution of LESS-A and 3TA for each degree of appendiceal inflammation were analyzed using Fisher´s exact test and considered significant at $P < 0.05$.

The incidence of intra-abdominal abscesses did not statistically differ for LESS-A when comparing to 3TA (1/65, 1.5% vs. 3/244, 1.2%, $P = 1.0$). There were no differences for acute (0/33, 0% vs. 2/116, 1.7%, $P = 1.0$), phlegmonous (0/22, 0.0% vs. 1/111, .9%, $P = 1.0$), and perforated (1/10, 10.0% vs. 0/17, 0%, $P = 0.37$) appendicitis.

There were no statistical differences regarding the incidence of wound infections between LESS-A and 3TA (2/65, 3.1% vs. 4/244, 1.6%, $P = 0.61$). There were no differences for acute (1/33, 3.0% vs. 2/116, 1.7%, $P = 0.53$), phlegmonous (0/22, 0.0% vs. 2/111, 1.8%, $P = 1.0$), and perforated (1/10, 10.0% vs. 0/17, 0%, $P = 0.37$) appendicitis.

Discussion

Numerous studies and meta-analyses[4,20–24] have shown that single-incision and conventional laparoscopic appendectomies do not differ in their rates of complications in both adults and children. This correlates with our observation that there is no significant difference between LESS-A and 3TA with respect to intraabdominal abscesses and wound infections. In our setting, no selection of cases for LESS-A was performed. As a result, LESS-A was used for perforated appendicitis. Only a few other authors[18,25,26] included perforated appendicitis in their studies. Despite including complicated appendicitis for LESS-A, we encountered an abscess rate of 1.5% in LESS-A, which is comparable to the 2.0% reported in a recent meta-analysis on adults and children[22] and to the 3.27% rate in a recent large single-center study on children.[25] Our 3.0% rate of wound infections for LESS-A was comparable to the 3.6% reported for single-incision appendectomy in the same meta-analysis[22] and to the 3.9% in the same single-center study on children.[25] As a consequence, we argue against limiting the use of LESS-A to uncomplicated appendicitis, as proposed by some authors.[5,7–11] As stated in a meta-analysis, like every new technique, LESS-A can be more technically challenging in the beginning.[21] However, the same concerns existed in the past, when laparoscopic appendectomy appeared as an alternative to open appendectomy. At that time, we could demonstrate that laparoscopic appendectomy was superior to open appendectomy for perforated appendicitis.[27] Our current study goes one step further, and demonstrates that the new method of LESS-A is now feasible for more complicated cases.

We demonstrated that a higher percentage of cases with perforated appendicitis could be treated by LESS-A. We encountered no conversions to open appendectomy. We detected a 0.9% rate of conversions to 3TA. This result is situated in the lower limit of the range reported in the literature. Accordingly, conversions were reported in most trials analyzing single-incision appendectomy[21–24] and ranged between 0.7%[25] and 3.8%[23] in single-center studies and between 6.12%[22] and 7%[24] in recent meta analyses. Despite the low number of conversions to 3TA documented in our study, we recommend generous insertion of additional trocars in cases of intraoperative difficulties to maintain patient safety until experience is gained with the new method. Our approach was to implement a standardized way of performing LESS-A first among board-certified surgeons, and then to expand its use gradually to pediatric surgical trainees. This is in accordance with the statement of one study in children, which concluded that at least five cases are necessary for the surgeon to gain mastery of single-incision appendectomy.[26] Using our approach, LESS-A proved to be feasible in the day-to-day clinical situation of a university teaching hospital, as well as being suitable for pediatric surgical trainees to perform when assisted by more experienced surgeons. In fact, during the last time period of our study, more than half of the procedures were performed by pediatric surgical trainees. This observation is supported by other authors,[25,26] who expanded the use of this technique in children to trainees. We found that LESS-A requires less time than 3TA regardless of the degree of appendiceal inflammation. In our study, the mean duration of operation for LESS-A (57.3 min) and 3TA (70.5 min) were within the ranges published in recent meta-analyses[11,21] (33.857– 75.90 min, and 26.3 – 71 min, respectively). However, the multitude of surgeons with different experience levels participating in our study, and the inclusion of the learning curve period constitute a limitation in the interpretation of our data regarding surgery duration. It might be possible that the actual duration of operation might decrease with increasing experience. Chow, et al. found a trend to reduced operative time with increasing experience in single incision appendectomy and cholecystectomy.[28] Farach, et al. documented a decrease in variance in operative time after 100 cases.[25] This might explain why literature analysis of duration of operation revealed much heterogeneity between studies.[11] Accordingly, duration of operation can be a subject of a controversial discussion. While some authors claim that single incision appendectomy takes 5 min longer on average,[11,22] others found a comparable operative time between procedures,[21] especially when perforated appendicitis was analyzed separately.[18,29] Due to the limitations of our study design, we are cautious in interpreting the actual duration of operation and limit our evaluation to reporting our observation that LESS-A did not take longer than 3TA. In conclusion, LESS-A, as described in our series, can be performed for all degrees of inflammation, by surgeons with different qualifications, using conventional straight instruments. LESS-A has a shorter duration of operation than 3TA without presenting an increased complication rate.

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