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Laparoscopy-Assisted Single-Port Appendectomy in Children

Safe Alternative also for Perforated Appendicitis?

Sergio B. Sesia, MD, Eliane Berger, MD, Stefan Holland-Cunz, MD, Johannes Mayr, MD, and Frank-Martin Häcker, MD

Abstract: Because of its low complication rate, favorable safety, cost-effectiveness, and technical ease, mono-instrumental, laparoscopy-assisted single-port appendectomy (SPA) has been the standard therapy for appendicitis in our department since its introduction 10 years ago. We report our experience with this technique and compare its outcome to open appendectomy (OA).

The records of all children who underwent appendectomy at our institution over a period of 8 years were analyzed retrospectively. Patient baseline data, markers of inflammation, operative time, length of hospital stay, complication rate according to the classification of Clavien-Dindo, and histologic grading were assessed to compare the 2 surgical techniques (SPA and OA). The chi square test, the Student's t test and the Wilcoxon-Mann-Whitney test were used to analyze the data and the comparisons of the mean values. A P value < 0.05 was considered significant.

Overall, 975 patients were included in the study. A total of 555 children had undergone SPA and 420 had been treated by OA. Median operative time of SPA was longer than that of OA (60.8 min vs 57.4 min; $P < 0.05$). Length of hospital stay after SPA was shorter than after OA (4.4 days and 5.9 days, respectively; $P < 0.001$). The overall complication rate was lower for SPA than that for OA (4.0% vs 5.7%), but the difference of complications for SPA and OA was not statistically significant ($P < 0.22$). SPA was successfully performed in 85.9% of children. In 53.8% of patients with perforated appendicitis, no conversion was required. In the group of children with perforated appendicitis, the complication rate of ~20% was independent of the surgical technique applied.

With respect to operative time, length of hospital stay, and post-operative complication rate, SPA is not inferior to OA. SPA is safe and efficient, even in the management of perforated appendicitis.

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Abbreviations: CPR = C-reactive protein, EKNZ = Ethikkommission Nordwest- und Zentralschweiz, ESI = extension of skin incision, LAPA = laparoscopic appendectomy, LOS = length of hospital stay, NOTES = natural orifice transluminal endoscopic surgery, OA = open appendectomy, OR = operation time, SILS = single-incision laparoscopic surgery, SPA = mono-instrumental laparoscopy-assisted single-port appendectomy, TULAA = transumbilical laparoscopically assisted appendectomy, UKBB = University Children's Hospital Basel, VATA = video-assisted transumbilical appendectomy.

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From the Department of Pediatric Surgery, University Children's Hospital of Basel (UKBB), Spitalstrasse 33, 4056 Basel, Switzerland.
Correspondence: Sergio B Sesia, Department of Pediatric Surgery, University Children's Hospital of Basel (UKBB), Spitalstrasse, 33, 4056 Basel, Switzerland (e-mail: sergio.sesia@ukbb.ch).
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INTRODUCTION

Surgical techniques to treat appendicitis in children range from conventional open techniques to procedures without any skin incision. Open appendectomy (OA) allows the surgeon's hand to directly access the organ. The obvious disadvantage of OA is the larger skin incision. In contrast, the wider view of the abdominal cavity, reduced postoperative pain, shortened hospital stay, and optimized esthetic result are well-accepted advantages of laparoscopy.[1] Laparoscopic appendectomy (LAPA) with the need for 3 trocars has become the standard technique in adults,[2] even for perforated appendicitis.[3] To minimize invasiveness, multi-instrumental surgical techniques performed through a single skin incision (SILS, single-incision laparoscopic surgery),[4] or through a natural orifice (NOTES, natural orifice transluminal endoscopic surgery)[5] have been developed.

In 1983, Semm described for the first time the 3-trocar LAPA[6] and in 1992, Pelosi introduced the mono-instrumental, laparoscopy-assisted single-port appendectomy (SPA)[7] that combined the benefits of both OA and LAPA. At the beginning, SPA was recommended only in the case of uncomplicated appendicitis[8,9] but was subsequently used also in perforated appendicitis.[10,11] However, a guideline technique for appendectomy in children such as the laparoscopic approach for cholecystectomy is still missing, especially for perforated appendicitis.

The aim of this study was to compare SPA with OA with respect to operative time, complication rate, and length of hospital stay, and to assess whether SPA is feasible and safe without the need of conversion to OA, even in the presence of perforated appendicitis.

PATIENTS AND METHODS

Data Collection

After approval of the study by the institutional review board (EKNZ, Ethics Committee Basel 81/11), the records of 1025 children who underwent appendectomy in an emergency setting at the University Children's Hospital Basel (UKBB) were retrospectively analyzed. In total, 50 patients who underwent appendectomy during treatment of another abdominal illness were excluded.

Definition of the Study Groups

The groups compared were: open appendectomy (OA; n = 420) and single-port appendectomy (SPA; n = 555) (Fig. 1).

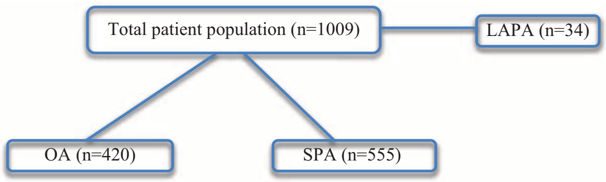


FIGURE 1. Definition of the study groups.

Diagnosis

Diagnosis of appendicitis was based on the patients' medical history, clinical examination with the classical signs of appendicitis,[12–14] white blood cell count, and the level of C-reactive protein (CRP). Preoperatively, all patients underwent ultrasonic examination of the abdomen. All children received a single course of antibiotics prior to surgery (cefuroxime and metronidazole). All appendectomy specimens were subjected to histological examination. The grade of inflammation was classified as inflamed, acute, ulcero-phlegmonous, gangrenous, or perforated.

Definition of SPA

The mesenterium of the appendix was grasped with a 5 mm atraumatic forceps through a single-use balloon trocar introduced at the lower umbilical border into the abdomen, and the appendix exteriorized.[15] Appendectomy was then completed extracorporally.

Definition of OA, Conversion, and Complication

For OA, a McBurney's incision was created in the right lower abdominal quadrant, and open appendectomy was carried out.

Each modification or extension of the initial technique was considered a conversion, for example, introduction of an additional trocar, extension of the skin incision, or any change of the initial procedure. Operative time was defined as the time interval from skin incision to skin closure, and hospital stay from the day of surgery until discharge. The day of surgery was counted as the first day.

Complications were divided into medical and surgical complications. According to the classification by Clavien–Dindo, each deviation from the normal clinical course after appendectomy was considered a complication.[16–17]

Pneumonia, urinary tract infection, drug intolerance or adverse drug effects, and delayed oral feeding due to paralytic ileus were classified as medical complications. Wound infection, intra-abdominal abscess, reoperation because of mechanical ileus, and stump insufficiency were defined as surgical complications.

Postoperative Management

Antibiotics given prior to surgery were continued postoperatively only in the case of perforated appendicitis for at least 3 days and until normalization of the CRP value (<5 mg/dL). Refeeding was started according to the bowel sounds. For discharge, the child had to have a dry scar, tolerate oral feeding, had to be afebrile, and had to be able to walk without assistance.

Statistics

Data were analyzed using the chi squared test and Student's *t* test. For the comparison of the medians the Wilcoxon–Mann–Whitney test was used. A P value < 0.05 was considered significant. Data analysis was performed with Microsoft Excel 2010® (Microsoft Inc, Redmond, Washington). The data are presented as median ± standard deviation (SD).

RESULTS

Baseline Data

Table 1 shows the baseline characteristics of the children by the study group. No significant difference was found between the 2 groups.

Operative Time, Length of Hospital Stay, and Qualification of the Surgeon

Table 2 shows the medians for operation time and length of stay (LOS) at the hospital. LOS was significantly shorter in the SPA group (median of 4.4 days) than in the OA group (median: 5.9 days; $P < 0.001$). Median operative time was longer in the SPA group than in the OA group (median: 60.8 min vs 57.4 min; $P < 0.05$).

As shown in Table 3, ~30% of SPA procedures were performed by residents specializing in pediatric surgery under the supervision of a consultant surgeon. With respect to the conversion rate, no statistically significant difference was noted between the residents and the consultants versus the head physicians. However, the head physicians operate significantly faster than the residents.

Complication Rate

The SPA group displayed the lowest complication rate (surgical and medical; medical complications not shown) (Table 4). The rate of intra-abdominal abscesses and wound infections was similar in the SPA and OA groups. The complication rate in the group of histologically confirmed perforated appendicitis was ~20%, independent of the surgical technique applied (Table 5).

Conversion Rate

In 85.9% of cases, SPA was performed with success and without any need of conversion (Table 6). The general conversion

TABLE 1. Baseline Data

	SPA	OA	*P* Values
Number of children	555	420	
Median age ± SEM (range), y	11.2 ± 3.0 (2.6–17.5)	10.8 ± 3.1 (0.6–21.0)	n.s.
Male/female	311 (56%)/244 (44%)	237 (56%)/183 (44%)	($chi^2 = 0.009$) $P = 0.99$ n.s.
Median weight ± SEM (range), kg	41.0 ± 14.6 (13.0–94.0)	38.4 ± 14.8 (8.0–95.0)	n.s.

n.s. = nonsignificant, OA = open appendectomy, SEM = standard error of the mean, SPA = single-port appendectomy.

TABLE 2. Median Operation Time (OR) and Median Length of Hospital Stay (LOS)

	SPA	OA	*P* Values
Number of children	555	420	
Median OR time, min	60.8 ± 27.3 (20.0–195.0)	57.4 ± 26.9 (20.0–225.0)	$P < 0.05$
Median LOS, d	4.4 ± 1.7 (2.0–18.0)	5.9 ± 2.5 (3.0–21.0)	$P<0.001$

LOS = length of hospital stay, OA = open appendectomy, OR = operation time, SPA = single-port appendectomy.

TABLE 3. Qualification of the Surgeon in Relation to Conversion Rate and Mean Operation Time

	Residents	Consultants	Head Physicians	*P* Values
SPA	146 (26.3%)	340 (61.3%)	69 (12.4%)	
Conversion from SPA to OA	9 (6.2%)	11 (3.2%)	7 (10.1%)	Residents and consultants versus head physicians $P = 0.22$; n.s.
Mean operation time, min	63.1 (±25.15) (25–165)	61.3 (±29.00) (20–195)	50.9 (±19.53) (25–115)	Residents versus consultants: $t = 0.47$; $P > 0.3$; n.s. Residents versus head physicians: $t = 3.57$; $P<0.001$

n.s. = nonsignificant, OA = open appendectomy, SPA = single-port appendectomy.

rate to OA was 14.1% for the SPA group (n = 78). In children suffering from perforated appendicitis, the conversion rate in the SPA group was 46.2%. Of the ''converted'' patients (n = 78), 51/78 (65.4%) needed an extension of the skin incision or the use of 1 or 2 additional trocars. In 27/78 (34.6%) of patients, the SPA technique was converted to OA. The group of children with perforated appendicitis displayed the highest rate of conversion.

Histological Findings

The categorized histological findings differed significantly between the group of children operated by SPA and OA ($Chi^2 = 34.5$; $P < 0.001$) (Tables 7 and 8).

DISCUSSION

Single-port appendectomy (SPA) and open appendectomy (OA) were comparable with regard to the operative time, LOS, and complication and conversion rates. Especially in the case of perforated appendicitis, the complication rate seemed to be independent of the surgical technique chosen. SPA was performed without the need of conversion in 85.9% of cases. In >65% of patients, extension of the skin incision or the use of 1 or 2 additional trocars were sufficient to ensure the successful removal of the appendix by SPA.

Surgical Technique

For the SPA technique, we used a single-use 10 mm-balloon trocar, a laparoscope with an integrated working channel, and a single laparoscopic instrument. In the literature, different techniques are described as ''single-port'' technique. Transumbilical laparoscopically assisted appendectomy (TULAA) and video-assisted transumbilical appendectomy (VATA) also represent extra-abdominal appendectomy, with the TULAA technique requiring 1 additional trocar in the left lower abdominal quadrant[18] or several ports through a wound retractor[11] or several fascia incisions.[19] The terms ''1-trocar appendectomy,''[20] ''all-in-one appendectomy,''[21] or ''umbilical one-puncture laparoscopically assisted appendectomy''[9] all basically describe a similar SPA technique. In contrast, single-incision laparoscopic surgery (SILS) is a purely intra-abdominal surgical technique.[22]

SPA combines the advantages of laparoscopic surgery with open surgery.[15] Exploration of the abdomen by only 1 instrument, resulting in a parallel rather than angled view, requires some adaptation.

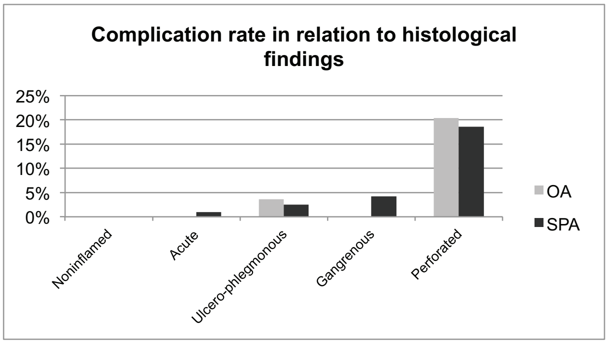
Median operative time was longer in the group of children treated with SPA than in the group treated with OA (60.8 vs 57.4 min; $P < 0.05$). In the literature the shortest operation time reported for SPA is 15 min.[9] Possible explanations for our

TABLE 4. Comparison of Complication Rate (Surgical Complications Only) Between the Group of Patients Treated by Single-Port Appendectomy (SPA) and Open Appendectomy (OA)

	SPA	OA	*P* Values
Number of children	555	420	
With surgical complications	22 (4.0%)	24 (5.7%)	($chi^2 = 1.64$) $P = 0.22$; n.s.

n.s. = nonsignificant, OA = open appendectomy, SPA = single-port appendectomy.

TABLE 5. Complication Rate in Relation to Histological Findings



longer operation time for SPA are the personal learning curve of the surgeon and the fact that by an optimized learning curve more complicated cases, characterized by thicker abdominal wall, cecum difficult to mobilize, appendicitis with massive surrounding adhesions and also perforated appendices were operated using the SPA technique. Another aspect is that in ∼30% of patients, SPA was conducted by a resident surgeon under the direct supervision of a senior surgeon. Modern working time models with reduced hours of presence of residents in the hospital as well as more frequent rotations to different departments are additional possible explanations for the prolonged learning curve.

Postoperative Findings

The LOS of 4.4 days for the SPA group in our study is longer than the values reported in the literature (2–3 days), but Deie et al reported a higher LOS (5.7 days),[11] and Ohno et al recorded even 9 days.[2] Moreover, LOS of the OA group was longer than that of the SPA group (5.9 days and 4.4 days, respectively; $P < 0.001$), mainly because of the inclusion of a higher proportion of children suffering from advanced appendicitis in the OA group.

Comparison of the complication rate reported in the literature to that observed with our patients is challenging because the reporting of postoperative complications is not standardized. The published postoperative complication rates range from 0 to 14.6%.[20,24] The value of 18.6% reported by Ohno et al also included intraoperative complications, mainly consisting of wound infections and intra-abdominal abscesses.[2] Rates of wound infections of up to 13.7%[23] and intra-abdominal abscesses of up to 6.3%[24] were reported in the pediatric literature. Our overall complication rate of 4% (0.9% for wound infection and 2.3% for intra-abdominal abscesses) in the SPA group compares favorably to the data reported in the literature. The rates of wound infections and intra-abdominal abscesses of the OA group (0.6% and 2.1%, respectively) do not exceed the values reported in the meta-analysis published by Aziz et al (LAPA: 1.5% and 3.8%; OA: 5% and 3.4%).[25]

TABLE 7. Histological Findings

	SPA	OA
Number of children	555	420
Noninflamed	18 (3.2%)	14 (3.3%)
Acute/ulcero-phlegmonous/gangrenous	478 (86.1%)	302 (71.9%)
Perforated	59 (10.6%)	104 (24.8%)

OA = open appendectomy, SPA = single-port appendectomy.

In the study of Visnjic et al[24] a nonsignificantly higher rate of wound infections was reported for the TULAA group. In contrast, in the study of Deie et al,[11] the difference between complication rates in favor of the TULAA group was statistically significant.

Our reoperation rate in the SPA group was lower than that in the OA group (0.5% and 2.6%; respectively; n.s.). A lower number of adhesive small bowel obstructions and/or stump insufficiencies in the SPA group may explain this observation. The reoperation rate was only occasionally cited in the literature and ranged from 0 to 2.0%.[8,9]

In nearly 65% of the converted SPA cases, the operation was finalized by extending the skin incision by 1 or 2 cm at the umbilicus or using additional trocars, but without the need for a laparotomy in the right lower abdominal quadrant. Thus, there was no true conversion to an open surgical technique, but only an extension of the SPA procedure.

Our operative success rate for the SPA group of 85.9% is similar to the 83.2% reported by Ohno et al and Codrich et al[2,10] and even higher than the 77.3% reported by D'Alessio et al in a selected group of patients with uncomplicated appendicitis.[8]

Valla et al attributed the 16 conversions (8% of all SPA cases described in their study) to the presence of perforated (n = 7) and retrocecal appendices (n = 9).[9] Codrich et al

TABLE 6. Conversion Rate of SPA in Relation to the Histological Grading: Extension of the Skin Incision (ESI), Introduction of Additional Trocars (+1 or +2 Trocars), and Conversion to OA

	Total Conversion	ESI	Additional +1 Trocar	Additional +2 Trocars	Conversion to OA
Total	78/555 (14.1%)	25 (25.6%)	10 (16.7%)	16 (23.1%)	27 (34.6%)
Noninflamed	1/78 (1.3%)	0	1/10 (10.0%)	0	0
Acute	5/78 (6.4%)	0	1/10 (10.0%)	4/16 (25.0%)	0
Ulcero-phlegmonous	17/78 (21.8%)	2/25 (8.0%)	3/10 (30.0%)	5/16 (31.25%)	7/27(26.0%)
Gangrenous	19/78 (24.3%)	9/25 (36.0%)	1/10 (10.0%)	1/16 (6.25%)	8/27 (29.6%)
Perforated	36/78 (46.2%)	14/25 (56.0%)	4/10 (40.0%)	6/16 (37.5%)	12/27 (44.4%)

ESI = extension of skin incision, OA = open appendectomy, SPA = single-port appendectomy.

TABLE 8. Additional Histopathological Findings Related to Histological Classification

	Total	Noninflamed	Acute	Ulcero-phlegmonous	Gangrenous	Perforated
Patient (n)	975	32 (3.3%)	107 (11.0%)	624 (64.0%)	49 (5.0%)	163 (16.7%)
Neurogenic appendicopathy	91 (9.3%)	14 (43.7%)	48 (44.9%)	25 (4.0%)	0	4 (2.4%)

reported 9 advanced and 3 retrocoecal appendicitis cases.[10] In the study by Kagawa et al, the reason for conversion was the presence of inflamed masses in 60.4% of cases, nonmobilisable appendices in 36.6%, and volvulus in 3%.[26]

In the study by Cobellis et al, the conversions were attributed to problems associated with the difficult mobilization of the appendix.[27] In our cohort, immobile appendices and dense adhesions were the most frequent reasons for incision extension or conversion. In nearly 65% of our complicated cases, an extension of the incision or the introduction of an additional trocar was necessary to avoid conversion to open surgery. In the case of complicated appendicitis, Ohno et al suggested to immediately use additional trocars or to convert to open surgery, in order to guarantee the patient's safety. The higher complication rate after extension of the incision or conversion may be explained by more severe inflammation.[2] Kagawa et al described a conversion rate of 10.9% for uncomplicated appendicitis versus 86.7% for perforated appendicitis.[26]

We performed the SPA successfully without changing the technique in 53.8% of perforated appendices. Similarly, Stanfill et al reported a success rate of 55.5%.[23]

In the group of children with perforated appendicitis, a similar complication rate was reported for both operative techniques. In the study by Kagawa et al, all complications (ie, 4 intra-abdominal abscesses and 1 wound infection) occurred in the group of children suffering from perforated appendicitis (complication rate 22.7%).[26]

Histological distribution of the inflammatory status of the appendices (3.2% noninflamed and 10.6% perforated appendicitis) is comparable to the data reported in the literature. In 78,625 patients in the USA and Canada, Cheong et al reported 4.3% noninflamed and 26.7% perforated appendices.[28] The low rate of perforated appendicitis of 8.5% in the study of von Suchodoletz including 1249 patients was associated with a higher rate of appendectomies for noninflamed appendices (15.5%).[13]

Neurogenic appendicopathy may be the reason for chronic pain in the right lower abdominal quadrant and may justify appendectomy. In the case of a macroscopically noninflamed appendix and after exclusion of other abdominal disorders, we recommend removal of the appendix, in agreement with other authors.[12,29–31]

The choice of surgical technique seems to have no significant influence on the complication rate, especially in the group of histopathologically confirmed perforated appendicitis. Therefore, the SPA technique can be used safely also in perforated appendicitis. To the best of our knowledge, there are no reports in the literature regarding the reliability of the mono-instrumental SPA technique in perforated appendicitis in children.

Study Limitations

We were faced with several limitations concerning this investigation. Children operated by SPA were likely to have had early stage appendicitis, at least in the first months of this study. The choice of surgical technique has changed over the years, most likely associated with the learning curve in SPA. Additionally, we were not confident that all potential confounders within this retrospective study design could be addressed adequately.

Positive study characteristics include the large number of patients as well as the in-depth analysis of surgical complications according to the classification of Clavien und Dindo.[16–17]

Outlook

Randomized, controlled trials are required to confirm our results and to verify the parity of the SPA technique versus the OA procedure.

CONCLUSION

We conclude that SPA is not inferior to the OA procedure with respect to operative time, LOS, and postoperative complication rate. SPA is safe and efficient, even in the management of perforated appendicitis in children.

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