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Adhesive small bowel obstruction after appendectomy in children – Laparoscopic versus open approach☆

Cecilia Arana Håkanson [a], Fanny Fredriksson [a,b], Helene Engstrand Lilja [a,b,]*

[a] Department of Women's and Children's Health, Uppsala University, Uppsala, Sweden
[b] Section of Pediatric Surgery, Uppsala University Children's Hospital, Uppsala, Sweden

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ABSTRACT

Background: The aims of this study were to compare the incidence of small bowel obstruction (SBO) requiring laparotomy after laparoscopic appendectomy (LA) and open appendectomy (OA) in children and to identify risk factors for SBO.
Methods: Medical records of patients who underwent appendectomy from 2000 to 2014 at our department of Pediatric Surgery were reviewed. Risk factors were analyzed using Cox proportional hazard regression.
Results: Totally 619 out of 840 patients were included. OA was performed in 474 (76.6%), LA in 130 patients (21%), and 15 (2.4%) were converted from LA to OA. Age, sex and proportion of perforated appendicitis were comparable in the LA and OA groups. Median follow-up time was 11.4 years (2.6–18.4). The incidence of SBO after LA was 1.5%, after OA 1.9% and in the converted group 6.7% ($p = 0.3650$). There were no significant differences in the incidence of postoperative intraabdominal abscess, wound infection or length of stay between LA and OA. Perforation and postoperative intra-abdominal abscess were identified as risk factors with 9.03 ($p < 0.001$) and 6.98 ($p = 0.004$) times higher risk of SBO, respectively.
Conclusions: The risk for SBO after appendectomy in children was significantly related to perforated appendicitis and postoperative intra-abdominal abscess and not to the surgical approach.
Level of Evidence: Level III.

Intra-abdominal adhesion formation occurs as a response to peritoneal trauma caused by abdominal or pelvic surgery. The type and grade of peritoneal trauma seem to play an important role in the pathophysiology of adhesion formation [1]. Adhesions are common and develop in up to 93% of adults following laparotomy [2]. The majority of adhesions are asymptomatic however complications associated with postoperative adhesions are a source of considerable morbidity. The most serious complication is adhesive small bowel obstruction (SBO) with the highest incidence in pediatric surgery [3,4]. Surgery for adhesive SBO is technically more difficult and adds significant time to the surgical procedure [3,5]. Other complications caused by intra-abdominal adhesions are chronic abdominal pain and female infertility. These complications lead to more hospitalization, time off school for the children and off work for the parents, restrictions to normal activities and ultimately cause not only personal suffering but also a significant economic burden [3,6–8].

The estimated risk of appendicitis in children is 2.5% [9]. The overall incidence of adhesive SBO due to intra-abdominal adhesions following appendectomy in children is reported to be relatively low (0.7–3%) [10–19]. Nevertheless, appendectomy is the most common abdominal surgical procedure in childhood with a lifelong risk of developing appendicitis of 7–8% [20,21]. Thus, appendectomy causes the majority of cases with adhesive SBO in the pediatric and adult population [22–24]. Laparoscopic appendectomy (LA) may have the advantage of reducing the formation of intra-abdominal adhesions compared to open appendectomy (OA) as laparoscopic procedures are thought to reduce the degree of trauma to the abdominal wall and intra-abdominal operative site. Available studies on adhesive SBO in children comparing LA and OA are relatively few compared to studies in adults and the results are conflicting [10–19,25].

The aims of this study were to compare the incidence of SBO requiring laparotomy after LA and OA in children and to identify risk factors for adhesive SBO.

1. Patients and methods

This is a retrospective observational study including patients who underwent appendectomy at the Department of Pediatric Surgery at the University Children's Hospital in Uppsala, Sweden from January

Abbreviations: LA, laparoscopic appendectomy; OA, open appendectomy; SBO, small bowel obstruction; PAD, histopathological diagnosis; LOS, length of stay.
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* Corresponding author at: Department of Women's and Children's Health, Uppsala University, Section of Pediatric Surgery, Uppsala University Children's Hospital, SE-751 85 Uppsala, Sweden. Tel.: +46 18 6115901; fax: +46 18 6115905.
E-mail address: helene.lilja@kbh.uu.se (H.E. Lilja).

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2000 to December 2014. Patients were identified by their unique 10-digit birth identification number in the hospital discharge database. Deceased patients were excluded but also patients who had undergone previous abdominal surgery, moved from the region or lived with protected personal data. The last two were exclusion criteria due to the possibility of incomplete charts. Data were extracted from the medical records of patients admitted for appendectomy and any subsequent admissions were reviewed by a researcher not involved in the treatment of the patients. The collected parameters were sex, age at surgery, surgical technique, conversion to open surgery, duration of surgery, time at surgery (daytime or night), length of hospital stay, duration from appendectomy to development of SBO requiring laparotomy, confirmation of appendicitis by histopathology, perforated appendicitis, postoperative complications such as wound infection, postoperative intra-abdominal abscess formation and SBO requiring laparotomy. The diagnosis of SBO was based on the surgical report. Duration of follow-up was defined as the date from appendectomy to the date when the medical records were reviewed. Night-time surgery was defined as the hours between 00.00 and 07.59. LA was introduced at our center in 2009. The choice of procedure was made according to the operating surgeon's preference. Patients were retrospectively divided into three groups, OA, LA and conversion from LA to OA. The surgeon's perception of degree of inflammation and the histopathological finding of inflammation were recorded and assigned to one of four categories: no signs of inflammation, catarrhal inflammation, phlegmonous inflammation and gangrenous inflammation. In the case of perforated appendicitis, the histopathological degree of inflammation was not taken into consideration, instead it was decided by the macroscopic finding during appendectomy. If the appendix perforated at the time of surgery due to the instrumental handling of the appendix the diagnosis of perforation was not set.

1.1. Ethics

The study was approved by the Regional Ethical Review Board in Uppsala, Sweden.

(DNR 2016/535; DNR 2016/535/2).

1.2. Statistical analysis

Continuous variables were summarized with median (range) and categorical variables were summarized with frequency (%). Comparisons between occurrence of SBO, postoperative intra-abdominal abscess and wound infection between surgical approaches were performed using Fisher's exact test. Risk factors for SBO were analyzed using univariate Cox proportional hazard regression. Differences in duration of surgery between all surgical approaches were tested using the non-parametric Kruskal-Wallis test and subsequently the Mann–Whitney *U* test was used for pairwise comparison. The relationship between age and perforation was analyzed using univariate logistic regression. Differences between gender were analyzed using a two-sample test of proportions. All analyses were performed using R version 3.6.0.

2. Results

During the study interval of 2000 to 2014, 840 patients who underwent appendectomy for appendicitis were identified (Fig. 1). Out of these, 211 patients were excluded because they had moved from the region, six were excluded due to previous abdominal surgery, one patient was excluded on account of protected identity and three were deceased. In total there were 619 patients included in the study group (75% of eligible 840 patients). Gender and age were comparable between the non-participants and participants. The number of perforated cases was significantly lower, 17% among non-participants compared to 26% among participants ($p = 0.0133$). Most (87%) of the non-participants underwent appendectomy before 2009, and 93% of the non-participants underwent OA.

In our study, OA was performed in all but one case from 2000 to 2008, after that LA was introduced and from 2012 LA was the most commonly used technique. In total, OA was performed in 474 (76.6%), LA in 130 patients (21%) and 15 cases (2.4%) were converted from LA to OA (Table 1). Perforated appendicitis was found in a total of 158 patients (25.5%), in OA 122 (25.7%), in LA 27 (20.7%), and in converted appendectomy nine (60%) patients.

Gender, age and perforation were comparable between the groups. Median follow-up time in all patients was 11.4 years (2.6–18.4). Patients in the OA group had significantly longer follow-up time than LA, 13 (2.6–18.4) and 5.3 years (2.6–11.9), respectively ($p < 0.001$) (Table 1).

Overall, the incidence of first time SBO requiring laparotomy in our study group was 1.9% ($n = 12$). A laparotomy due to SBO was performed once in 12 patients and twice in three patients. After OA the incidence of first time SBO was 1.9%, after LA 1.5% and in the converted group 6.7%. No significant differences were found between the groups ($p = 0.3650$). When we excluded the 10 patients with appendectomy à froid performed with OA, the changes were small. In patients with OA, the incidence of SBO was 1.9%, LA 1.6% and in the converted group 7.1% ($p = 0.3560$). The time to first SBO ($n = 12$) was within 15 days of surgery, except for two individuals with 256 and 2456 days.

In the group with non-perforated appendicitis 0.6% of the patients developed SBO, 0.6% in the OA, 1.0% in the LA and 0.0% in the converted group, thus no significant differences were found ($p = 0.5557$). In the group with perforated appendicitis 6% developed SBO, 5.7% in OA, 3.7% in LA and 11.1% in converted group, no statistical differences between the groups were found ($p = 0,6308$). When we analyzed conversion from LA to OA based on intention to treat, we found no significant differences between OA and LA. The perforation rate in the converted + LA group was 26% compared to 25% after OA and the incidence of SBO in the converted + LA group was 2.1% compared to 1.9 in OA group.

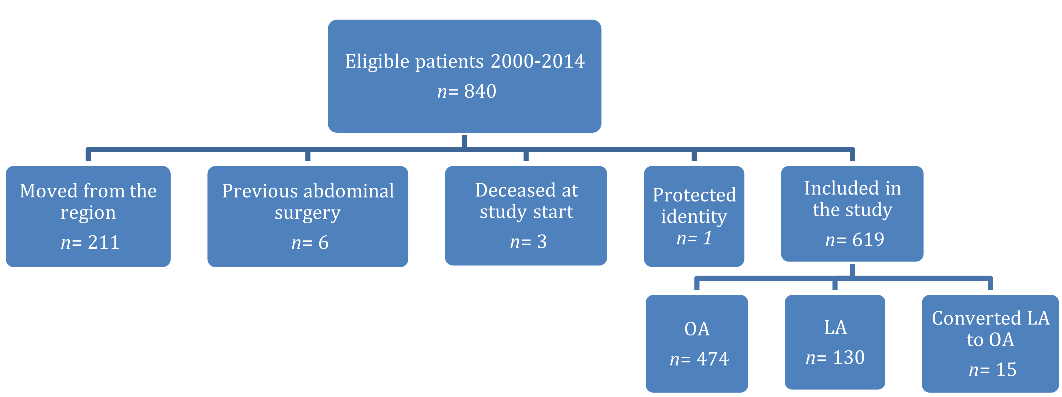

Fig. 1. Flow diagram of the study population.

Table 1
Descriptive statistics by surgical approach, median (range) or n (%).

	Open	Laparoscopic	Converted	p-Value
n	474 (77%)	130 (21%)	15 (2%)	
Age	10 (2–16)	11 (4–15)	12 (2–15)	0.056
Gender				
Male	289 (61%)	79 (61%)	6 (40%)	
Female	185 (39%)	51 (39%)	9 (60%)	0.2742
Perforated				
No	352 (74%)	103 (79%)	6 (40%)	
Yes	122 (26%)	27 (21%)	9 (60%)	0.006
Length of stay (LS)	4 (1–32)	3 (2–19)	6 (3–20)	<0.001
Follow-up (years)	13.0 (2.6–18.4)	5.3 (2.6–11.9)	4.4 (3.3–9.3)	<0.001

p-Value for numerical based on Kruskal Wallis test and for categorical based on Fisher's Exact test. Median (range) combined for follow up: 11.4 (2.6–18.4).

There were not any significant differences between the groups in the presence of postoperative intra-abdominal abscess formation; OA 4.2%, LA 6.2%, converted 6.7%; ($p = 0.3996$) or postoperative wound infection OA; 2.1%, LA 1.5%, converted 0.0%; ($p = 1.0000$).

The converted group had the significantly longest median duration of surgery, 102 min (45–180) followed by LA, 63 min (20–154) and lastly OA 45 min (15–190), ($p < 0.0001$), (Fig. 2). Consequent pairwise comparison between each pair of groups yielded significant results (all $p < 0.0001$).

There was no significant difference when comparing the two time periods 2008–2010 and 2011–2014 regarding duration of surgery, for LA 68 min (40–154) and 60 min (20–120) respectively ($p = 0.0787$) and OA 45 min (20–113) and 53 min (21–115) respectively ($p = 0.2983$). A significantly longer time for surgery in the LA group was seen in both time periods, 2008–2010 ($p < 0.0001$) and 2011–2014 ($p = 0.0203$).

There was an increasing proportion of LA during the study period (Fig. 3).

Length of stay (LOS) during the whole study period was 4 days (1–32) after OA and 3 days (2–19) after LA ($p = 0.0199$). There was no significant difference found when a comparison was made of the two time-periods after LA was introduced to the clinic, 2008 to 2010 and 2011–2014. LOS for OA and LA during 2008–2010 was 4 days (1–18) and 3 days (2–14) respectively ($p = 0.4575$). LOS for OA and

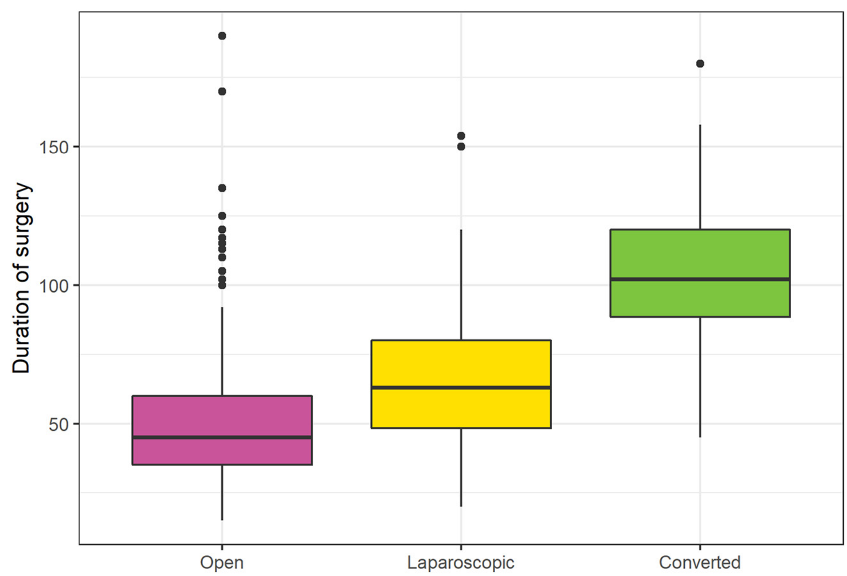

Fig. 2. Boxplot of duration of surgery by surgical approach.

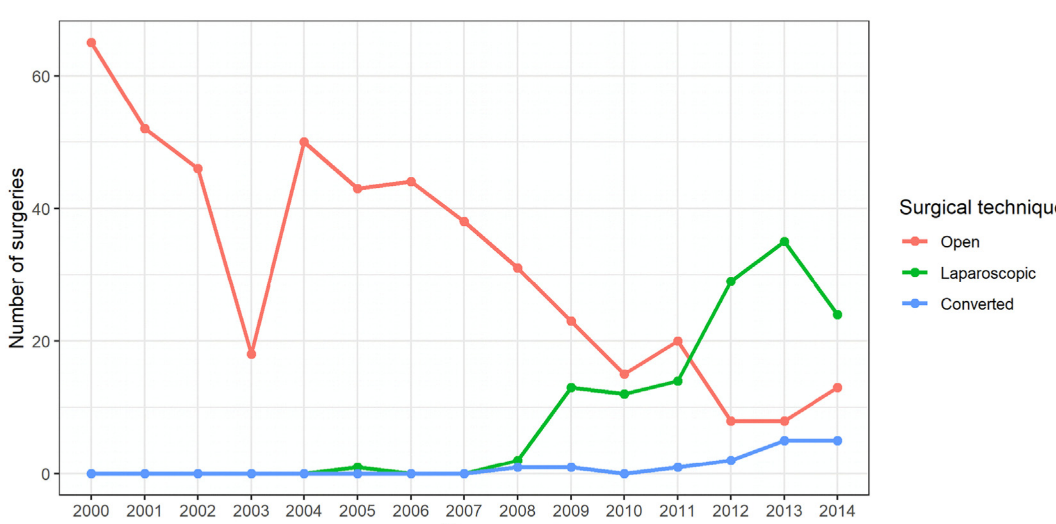

Fig. 3. Number of operations by surgical approach.

Table 2
Two-way table comparing the surgeon's estimation and histopathological diagnosis (PAD) for degree of inflammation in non-perforated appendicitis.

		PAD			
		No signs of inflam.	Catarrhal inflam.	Phlegmonous	Gangrenous
Surgeon	No signs of inflam.	1	0	0	0
	Catarrhal inflam.	4	2	6	0
	Phlegmonous	5	2	126	34
	Gangrenous	0	0	32	76

LA during 2011–2014 was 4 days (2–22) and 3 days (2–19) respectively ($p = 0.0933$).

An odds ratio of 0.93 for age showed that a one-year higher age was related to a 0.93 times lower risk of perforation. This decrease in risk was significant ($p = 0.020$).

There were 288 observations comparing the histopathological diagnosis (PAD), and the surgeon's estimated degree of inflammation. The perceptions corresponded in 205 individuals which gives an accuracy of 71%, (95%; CI 65.6–76.3) (Table 2). In the non-perforated cases ($n = 461$) PAD was missing in 165 cases, mainly at the beginning of the study period as PAD not was compulsory at that time. In eight cases an estimation of degree of inflammation by the surgeon were missing.

Two risk factors for SBO requiring laparotomy were identified. Patients with perforation had a 9.03 times higher risk of SBO ($p < 0.001$) and patients with the development of an intra-abdominal abscess had a 6.98 times higher risk of SBO ($p = 0.004$) (Table 3). The surgical technique, age, night-time surgery, duration of surgery >1 h or wound infection were not found to be risk factors.

There were no significant gender differences for the variables SBO, perforation, intra-abdominal abscess or wound infection.

3. Discussion

This single-center cohort study of children who underwent surgery for appendicitis between 2000 and 2014, compared the incidence of SBO requiring laparotomy in patients who had undergone LA or OA and assessed risk factors for adhesive SBO after appendectomy. There was no significant difference between LA and OA in the incidence of SBO requiring laparotomy. Postoperative intra-abdominal abscess and perforated appendicitis were identified as risk factors for SBO requiring laparotomy after appendectomy. The relationship between perforated appendicitis and adhesive SBO may be explained by the more challenging surgery as the appendix may form adhesions to nearby structures and dissection of the inflammatory mass may require more manipulation of the tissue leading to a higher risk of adhesion formation [26]. Also, the inflammatory process in itself in abscesses and perforated appendicitis is considered to be a predisposing factor for formation of adhesions [27].

We found an increased risk of perforation in children of a younger age which also implies that they have a higher risk of SBO. In addition, younger children have a greater lifetime risk of SBO.

The time from appendectomy to SBO in our study was shorter than in a similar study by Tsao et al. [10] who reported an overall mean time from appendectomy to SBO of 46 days (4–285 days), 8 days after LA and 58 days after OA. The follow-up time in our study was longer than other comparable studies [10,12–17] besides Kaselas et al. where the study period was 1 year longer (1992–2007) [11].

The incidences of SBO after LA or OA in the present study were higher than in a meta-analysis from 2012 [25]. There, an incidence of SBO after uncomplicated appendicitis was found in 0.25% and 0.23% in LA and OA, respectively, with no statistical difference. In the case of complicated appendicitis, the incidence was 1.23% and 1.48% with a significantly reduced incidence when using the LA approach [25]. In a meta-analysis by Esposito et al., only one out of eight studies reported a significantly lower incidence of SBO after LA [28]. A meta-analysis by Aziz et al. included nine studies in which none showed a statistically significant reduction in SBO when comparing LA versus OA [29]. Meta-analysis of all studies showed a significantly reduced incidence of 1.3% (26 of 1956) in LA versus 2.8% (48 of 1735) in OA [29]. Yet, there are several limitations of meta-analyses such as variations in inclusion criteria, definitions of complicated appendicitis, study type, treatment protocols and follow-up time.

Tsao et al. reported that SBO was less common after LA compared to OA in children and, similar to this study, that SBO was significantly related to perforated appendicitis [10]. In contrast to our study, their study had a statistically larger proportion of perforated appendicitis in the OA group which could explain the difference in postoperative SBO. Another study of appendectomy in children reported a significantly lower incidence of SBO after LA than after OA irrespective of the severity of the appendicitis [11]. In that study the incidence of SBO was generally higher with an overall incidence of 2.2% and for OA and LA 4.51% and 1.19% respectively, no consideration was given to the conversion rate.

In agreement with a recent Swedish study of 1745 children [30], we found no significant differences in the rate of postoperative intra-abdominal abscess, wound infections or length of stay between LA and OA. In that study, the initial assumption that the patients treated with LA had a shorter postoperative stay was not confirmed by linear regression, which showed that the assumed difference was due only to a trend toward shorter postoperative LOS over time, regardless of the surgical intervention. The same conclusion was made from our study as we did not find any significant difference in LOS after the time period when both techniques were used.

A Swedish registry study from 2014 including 169,896 adults and children who had undergone appendectomy reported a lower rate of wound infections but a higher rate of deep abdominal infections in the LA group compared to the group with OA [31]. Corresponding studies only including children are scarce, but in a registry study including 95,806 children aged 1 to 18 years, the risk of postoperative abscess

Table 3
Univariate Cox regressions for time to SBO requiring laparotomy.

Risk factor	HR	95% CI	P-value
Surgical technique (Reference: Open)			
Laparoscopic	0.87	(0.19–4.07)	0.864
Converted	3.86	(0.49–30.72)	0.201
Night time surgery (Reference: No)			
Yes	1.12	(0.30–4.15)	0.861
Duration of surgery >1 h (Reference: No)			
Yes	1.70	(0.53–5.35)	0.368
Perforation (Reference: No)			
Yes	9.03	(2.44–33.34)	<0.001
Age (numeric)	1.08	(0.89–1.32)	0.439
Postoperative intra-abdominal abscess (reference: No)			
Yes	6.98	(1.89–25.81)	0.004

drainage after LA was reported to be slightly increased compared to OA [14].

In our study we found a significantly longer duration of surgery in LA compared to OA. To reduce the impact of the learning curve associated with LA we compared two time periods but found no significant difference between these two time periods. Longer duration of LA has been observed in other studies [25,28,30]. A longer duration of surgery may have a potentially negative effect on children. Over the last decade there has been a focus on the potential harm of anesthesia on the developing brain. Studies have mainly been conducted into exposure during infancy and early childhood with some adverse outcomes in neurodevelopmental assessments [32,33].

Accurately estimated degree of inflammation between the surgeon and PAD was seen in 71% of cases in our study. The correlation between surgical and histopathological degree of inflammation has previously been investigated with an agreement of 48% when dividing into specific groups of inflammation [34]. In the same study, when assessing the severity of disease as simple or complicated the agreement improved to 82%. In previous studies, greater discrepancy has been shown with descending degree of inflammation, with an overall discrepancy of 12.4%-16.5% [34,35]. In the case of an assumed more severe disease than the PAD suggested there could be the risk of overtreatment and vice versa. However, Fallon et al. concluded that the operative diagnosis at the time of appendectomy appeared to be more predictive of clinical outcome than the PAD [34] suggesting that the intraoperative findings are also important to take into consideration when treating appendicitis.

Since LA was first reported in adult patients in 1983 [36] most of the experiences and papers are from the adult population. The results in adults are not directly transferable to children as there are physiological and anatomical differences. In this study, we found none of the techniques of appendectomy to be favorable compared to the other regarding adhesive SBO requiring laparotomy, postoperative intra-abdominal abscess formation, wound infection or LOS. The national cohort study including 169,896 patients showed small differences of limited clinical importance between LA and OA [31]. The author drew the conclusion that the choice of surgical method therefore depends on the local situation, the surgeon's experience and the patient's preference. The same conclusion was drawn in the study by Jen et al. including 95,806 children [14]. A prospective randomized study by Oka et al. failed to identify any difference between the two techniques in operative time, LOS, or complication rate [16].

Until one of the techniques has proved superior to the other we believe that it is valuable to have both surgical approaches available in the clinic, not least for residents who must be familiar with the OA in cases of conversion of LA. When we analyzed conversion from LA to OA based on intention to treat in the present study, the differences in the incidence of SBO between LA and OA was even smaller.

We agree with Markar et al. that it is important to find the technique that best benefits the individual patient [25]. One benefit of laparoscopy seems to be in the treatment of pubescent females with abdominal pain as it is both diagnostic and therapeutic and it also seems favorable in obese patients. There is a need for large prospective trials with long follow-up time comparing LA to OA in children matched for age, sex, body mass index, severity of appendicitis and the surgeon's experience.

The strengths of this study were the inclusion of 75% of the eligible patients with a long follow-up and the medical records were individually reviewed by a researcher not involved in the treatment of the patients.

A limitation of this study was the retrospective design. Also, a number of PAD were missing, as this was not mandatory in the earlier part of the study period. The follow-up time differed between the groups as LA was introduced during the study period. Even though the LA and OA groups were different in size, they were comparable in terms of patient demographics and the incidence of perforated appendicitis.

4. Conclusion

The risk for SBO after appendectomy in children in the present study was significantly related to perforated appendicitis and postoperative intra-abdominal abscess and not to the surgical approach.

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